Process optimization methods
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Introduction

This report is a collection of different process optimization tools and approaches that can be used as a theoretical basis to the FIS-moderators for the implementation of the FIS concept (Factory in a Seminar room) lead by “Learning Factory”.

The Learning Factory will develop a pedagogic-didactic concept for the FiS within the scope of the COSIMA-project. The Learning Factory's FiS is a business simulation programme, in which several improvement tools (look also “Tools – in improvement processes”) are applied.

This report can also be used as material during the train-the- trainer course. This document was produced as contribution to Work Package 2 part b) in the COSIMA project. The partners bfw – Unternehmen für Bildung, HTL Wolfsberg, Junior Achievement, Learning Factory and Campus Varberg have all contributed to the report.

Definition of process optimization

Process optimization is the discipline of adjusting a process so as to optimize some specified set of parameters without violating some constraint. The most common goals are minimizing cost, maximizing throughput, and/or efficiency. This is one of the major quantitative tools in industrial decision making.

General principles

For a long time the process optimization was considered as the task of quality management, but today it is increasingly grown as a part of a comprehensive and integrated process management in organizations. Process orientation and optimization as the basis of an effective type of farming is now an indispensable part of any modern business management in order to survive in the national and international competitive environment.

It is based on a process-oriented approach throughout the business processes. For this purpose it is necessary to define process chains across departments instead of thinking in hierarchical department structures.

First the present working processes have to be recorded and classified within the context of a process analysis using process modeling. To evaluate the quality and performance of such processes to be described, appropriate key figures (Key Performance Indicator) must be implemented. With the aid of these obtained process descriptions a process map can be created, which provides a basis for further optimizations.

This may affect all of the following business sectors: research and development, production, from administration to purchasing to sales and delivery.

Ideally, the entire business processes as well as the human and material resources of such evaluation and classification are examined in the context of an integrated e-business concept. The continuously ongoing process optimization, which is based on such an evaluation, aimed at sustainable improvement of the given processes without interrupting the workflow.

Well-known management concepts in this context are, for example, Business Process Reengineering (BPR) in 1991, Six Sigma (early 90s) or Kaizen (1994), etc.
Process optimization methods - Approaches

When you want to optimize a process you can do this from a variety of approaches. Below there are a list of five common procedures, after these it follows a number of tools you can implement when you have selected an approach that fits your process.

BPR – Business process reengineering

“fundamental and radical approach to reengineer the processes with a ‘top down’ approach”

Business process reengineering is a business management strategy, focusing on the analysis and design of workflows and business processes within an organization. BPR aimed to help organizations fundamentally rethink how they do their work in order to dramatically improve customer service, cut operational costs, and become world-class competitors.

BPR seeks to help companies radically restructure their organizations by focusing on the ground-up design of their business processes. Re-engineering emphasized a holistic focus on business objectives and how processes related to them, encouraging full-scale recreation of processes rather than iterative optimization of sub processes. Business process re-engineering is also known as business process redesign, business transformation, or business process change management.

BPR is different from other approaches to organization development (OD), especially the continuous improvement or TQM movement, by virtue of its aim for fundamental and radical change rather than iterative improvement.

Lean Management

“Remove all forms of waste”

Lean manufacturing, lean enterprise, or lean production, often simply, “lean”, is a production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination. Working from the perspective of the customer who consumes a product or service, "value" is defined as any action or process that a customer would be willing to pay for. With the approach to ideally design the processes and to harmonize them in a way that they perfectly fit together. To do so, all unnecessary items are identified and the process is designed as lean as possible. The targets: maximum efficiency, clearly defined responsibilities, exactly described processes and processes, traceable ways of communication.

Lean-Management is a further development of lean-production the origins of lean management, which is widely found throughout the business world, sprang from a simple concept. The core philosophy behind lean is that customers do not pay for mistakes or waste but value. As such, companies need to increase the value of their products or services in order to maximize profit. Lean management offers an opportunity to drive up value and promote continuous improvement.
**Kaizen (CIP)**

“When things are constantly improved through many small modifications”

For process optimization, kaizen or coined in Japanese is a management concept, which focuses on the gradual improvement of processes and on the development of people so that they are able to solve the problems and the desired results can be achieved.

It’s not a project, it is a comprehensive tool and mindset to develop the business. It is used to remove problems and capitalize opportunities for improvement. This work is driven by employees with management support. The industry was the first to use that tool by Toyota and Sony. But it is now also used in the service sector as medical, health and dental care, municipalities, schools, banks and others.

**Six Sigma**

“Quality improvement strategy focused on removing variability from a process”

Is a methodology for improvement, the goal is to achieve savings by reducing the causes of defects and variability in manufacturing and business processes. The method is used primarily by large manufacturing companies for example in manufacturing or automotive industry in order to become even more cost effective.

Six Sigma is a statistical method within the area of quality management with the approach – define – measure – analyze – improve - monitor. Is frequently used in manufacturing processes to increase the quality level. The ‘Six Sigma’ methodology requires a special training for the company staff, it means talking about the different roles that staff can fill depending on their level of education.

Six Sigma is a quality improvement strategy focused on removing variability from a process. Although originally developed for manufacturing processes, the Six Sigma methodology has been successfully applied to a wide range of processes. As a tool for process improvement and reduction of defects, Six Sigma compliments Lean and is a component of many Lean programs.

**TQM – total quality management**

“Awareness of quality throughout the organizational process”

For corporate management TQM is a comprehensive and structured approach to organizational management that seeks to improve the quality of products and services through ongoing refinements in response to continuous feedback. TQM requirements may be defines separately for a particular organization or may be in adherence to established standards, such as the international organization for standardization ISO 9000 series. TQM can be applied to any type of organization; it originated in the manufacturing sector and has since been adapted for TQM is based on quality management from the customer’s point of view.
Tools - in improvement processes

Process optimization methods provide you with the tools and techniques you will need to successfully optimize your current processes. The programs will provide you with the knowledge, techniques and methods that is used to optimize processes. Today you can find many different tools. In this report we are focussing of some basic tools.

Mind maps

"A diagram used to visually out like information"

**A mind map** is a diagram used to visually outline information. A mind map is often created around a single word or text, placed in the centre, to which associated ideas, words and concepts are added. Major categories radiate from a central node, and lesser categories are sub-branches of larger branches. Categories can represent words, ideas, tasks, or other items related to a central key word or idea. Mind maps offer great flexibility and can present complex systems in a very easy to understand format. The strategy of mind mapping are to help persons to quickly relate a central word or concept. The mind forms associations almost instantaneously and 'mapping' allows you to write your ideas quicker, using only words or phrases. Mind Maps help organise information. This can allow people to develop a strategy for note-taking, creative writing, report writing, studying the easy way, studying as a group, meetings, think tanks and can alleviate writer's block.

**Example**
The following guidelines for creating mind maps:

1. Start in the centre with an image of the topic, using at least 3 colours.
2. Use images, symbols, codes, and dimensions throughout your mind map.
3. Select key words and print using upper or lower case letters.
4. Each word/image is best alone and sitting on its own line.
5. The lines should be connected, starting from the central image. The central lines are thicker, organic and thinner as they radiate out from the centre.
6. Make the lines the same length as the word/image they support.
7. Use multiple colours throughout the mind map, for visual stimulation and also to encode or group.
8. Develop your own personal style of mind mapping.
9. Use emphasis and show associations in your mind map.
10. Keep the mind map clear by using radial hierarchy, numerical order or outlines to embrace your branches.

This list is itself more concise than a prose version of the same information and the mind map of these guidelines is itself intended to be more memorable and quicker to scan than either the prose or the list.

**Use**
Mind maps can be used for:

1. problem-solving
2. outline/framework design
3. structure/relationship representations
4. anonymous collaboration
5. marriage of words and visuals
6. individual expression of creativity
7. condensing material into a concise and memorable format
8. team-building or synergy creating activity
9. enhancing work morale

Types

Reference mind maps - for keeping track of information
A reference mind map is a map that contains information organized so that you can find it again easily. Many types of subject can be broken down and represented this way. You can start by collecting ideas and facts, then reorganizing them into sections and subsections, so that you get a complete overview.

Use this mind map type for

- **Assembling documents or reports**: the topic texts will become the section headings when you export the mind map to a word processor
- **Collecting resources**: capture and organize resources such as web pages, companies and information about people
- **Learning about a subject**: build a mind map of information and facts to help you learn and revise
- **Keeping lists**: keep track of detailed information in categories in different parts of your mind map

Presentation mind maps - for presenting or training
Use a presentation mind map when you need to tell a story or make a point with a call to action. In contrast to the Reference mind map, the Presentation mind map is designed to be used only to support a talk, to keep the audience focused on your message. Keep the mind map as small as you can. You can add supporting information or materials under the main topics, but only use them to support the messages. When presenting from the mind map, start at the top right, and work clockwise.

Use the Presentation mind maps for

- Presentations where a decision or action is needed
- Training sessions
- Presentation hand-outs

Planning mind maps - for creating plans
When planning something, focus on the outcome and put that at the centre of your mind map. Think about everything in the mind map as leading towards the outcome in some way, like arrows aimed at a target. The actions you take will build up to achieve the overall goal, so things to do later in the project will be near the centre, and things to do at the start of the project will be near the outside of the mind map.

Use the Planning mind map for

- Agreeing draft project plans
- Working out the order in which things need to be done
- Analysing the root causes of a problem or issue
Fish Bone

“Cause and effect diagram”

Fishbone, a Cause and Effect Diagram displays graphically the factors and underlying causes of a defect or problem. A fishbone diagram, also called Ishikawa diagram, is a visualization tool for categorizing the potential causes of a problem in order to identify its root causes. When you have a serious problem, it's important to explore all of the things that could cause it, before you start to think about a solution. That way you can solve the problem completely, first time round, rather than just addressing part of it and having the problem run on and on, in this case you can use a fishbone diagram.

The factors are drawn on lines radiating out from a central line. The completed diagram resembles a fish skeleton hence the nickname. Cause and Effect Analysis is a mix of brainstorming and mind mapping and it was originally developed as a quality control tool, but you can use the technique just as well in other ways. For instance, you can use it to:

- Discover the root cause of a problem.
- Uncover bottlenecks in your processes.
- Identify where and why a process isn't working.

A fishbone diagram is useful in brainstorming sessions to focus conversation. After the group has brainstormed all the possible causes for a problem, the facilitator helps the group to rate the potential causes according to their level of importance and diagram a hierarchy. The design of the diagram looks much like a skeleton of a fish. Fishbone diagrams are typically worked right to left, with each large "bone" of the fish branching out to include smaller bones containing more detail.

Fishbone diagrams are used in the "analyse" phase of Six Sigma's DMAIC (define, measure, analyse, improve, control) approach to problem solving.

Factors of the process

Common uses of the Ishikawa diagram are product design and quality defect prevention, to identify potential factors causing an overall effect. Each cause or reason for imperfection is a source of variation. Causes are usually grouped into major categories to identify these sources of variation. The categories typically include:

- **People**: Anyone involved with the process
- **Methods**: How the process is performed and the specific requirements for doing it, such as policies, procedures, rules, regulations and laws
- **Machines**: Any equipment, computers, tools, etc. required to accomplish the job
- **Materials**: Raw materials, parts, pens, paper, etc. used to produce the final product
- **Measurements**: Data generated from the process that are used to evaluate its quality
- **Environment**: The conditions, such as location, time, temperature, and culture in which the process operates

Causes in the diagram are often categorized. Cause-and-effect diagrams can reveal key relationships among various variables, and the possible causes provide additional insight into process behaviour.

Causes can be derived from brainstorming sessions. These groups can then be labelled as categories of the fishbone. They will typically be one of the traditional categories mentioned above but may be something unique to the application in a specific case.
Procedure
- Create a head, which lists the problem or issue to be studied.
- Create a backbone for the fish (straight line which leads to the head).
- Identify at least four “causes” that contribute to the problem. Connect these four causes with arrows to the spine. These will create the first bones of the fish.
- Brainstorm around each “cause” to document those things that contributed to the cause. Use the 5 Whys or another questioning process such as the 4P’s (Policies, Procedures, People and Plant) to keep the conversation focused.
- Continue breaking down each cause until the root causes have been identified.

This example illustrates how a group might begin a fish diagram to identify all the possible reasons a web site went down in order to discover the root cause.

There are 4 Main Reasons to use a Fishbone Diagram:
- **Display relationships** - The fishbone diagram captures the associations and relationships among the potential causes and effects displayed in the diagram. These relationships can be easily understood.
- **Show all causes simultaneously** - Any cause or causal chain featured on the fishbone diagram could be contributing to the problem. The fishbone diagram illustrates each and every possible cause in an easily comprehendible way; this makes it a great tool for presenting the problem to stakeholders.
- **Facilitate brainstorming** - The fishbone diagram is a great way to stimulate and structure brainstorming about the causes of the problem because it captures all the causes. Seeing the fishbone diagram may stimulate your team to explore possible solutions to the problems.
- **Help maintain team focus** - The fishbone framework can keep your team focused as you discuss what data needs to be gathered. It helps ensure that everyone is collecting information in the most efficient and useful way, and that nobody is wasting energy chasing non-existent problems.

![Figure 1. Fishbone diagram.](image_url)
DMAIC – Define, Measure, Analyse, Improve and Control

**DMAIC** refers to a data-driven improvement cycle used for improving, optimizing and stabilizing business processes and designs. The DMAIC improvement cycle is the core tool used to drive Six Sigma projects. However, DMAIC is not exclusive to Six Sigma and can be used as the framework for other improvement applications.

**Define**
The purpose of this step is to clearly articulate the business problem, goal, potential resources, project scope and high-level project timeline. This information is typically captured within project charter document. Write down what you currently know. Seek to clarify facts, set objectives and form the project team. Define the following:

- A problem
- The customer(s)
- Voice of the customer (VOC) and Critical to Quality (CTQs) — what are the critical process outputs?
- The target process subject to DMAIC and other related business processes
- Project targets or goal
- Project boundaries or scope
- A project charter is often created and agreed upon during the Define step.

**Measure**
The purpose of this step is to objectively establish current baselines as the basis for improvement. This is a data collection step, the purpose of which is to establish process performance baselines. The performance metric baseline(s) from the Measure phase will be compared to the performance metric at the conclusion of the project to determine objectively whether significant improvement has been made. The team decides on what should be measured and how to measure it. It is usual for teams to invest a lot of effort into assessing the suitability of the proposed measurement systems. Good data is at the heart of the DMAIC process:

- Identify the gap between current and required performance.
- Collect data to create a process performance capability baseline for the project metric, that is, the process Y(s) (there may be more than one output).
- Assess the measurement system (for example, a gauge study) for adequate accuracy and precision.
- Establish a high level process flow baseline. Additional detail can be filled in later.

**Analyse**
The purpose of this step is to identify, validate and select root cause for elimination. A large number of potential root causes (process inputs, X) of the project problem are identified via root cause analysis (for example a fishbone diagram). The top 3-4 potential root causes are selected using multi-voting or other consensus tool for further validation. A data collection plan is created and data are collected to establish the relative contribution of each root causes to the project metric, Y. This process is repeated until "valid" root causes can be identified. Within Six Sigma, often complex analysis tools are used. However, it is acceptable to use basic tools if these are appropriate. Of the "validated" root causes, all or some can be

- List and prioritize potential causes of the problem
- Prioritize the root causes (key process inputs) to pursue in the Improve step
- Identify how the process inputs (Xs) affect the process outputs (Ys). Data is analysed to understand the magnitude of contribution of each root cause, X, to the project metric, Y. Statistical tests using p-values accompanied by Histograms, Pareto charts, and line plots are often used to do this.
- Detailed process maps can be created to help pin-point where in the process the root causes reside, and what might be contributing to the occurrence.

**Improve**

The purpose of this step is to identify, test and implement a solution to the problem; in part or in whole. Identify creative solutions to eliminate the key root causes in order to fix and prevent process problems. Use brainstorming or techniques like Six Thinking Hats and Random Word. Some projects can utilize complex analysis tools like DOE (Design of Experiments), but try to focus on obvious solutions if these are apparent.

- Create innovative solutions
- Focus on the simplest and easiest solutions
- Test solutions using Plan-Do-Check-Act (PDCA) cycle
- Based on PDCA results, attempt to anticipate any avoidable risks associated with the "improvement" using FMEA (failure mode effect analysis)
- Create a detailed implementation plan
- Deploy improvements

**Control**

The purpose of this step is to sustain the gains. Monitor the improvements to ensure continued and sustainable success. Create a control plan. Update documents, business process and training records as required.

A Control chart can be useful during the Control stage to assess the stability of the improvements over time by serving as

- A guide to continue monitoring the process and
- Provide a response plan for each of the measures being monitored in case the process becomes unstable.

**7 Wastes**

Toyota developed its production system, striving for Excellence, with a keen sensitivity to waste. Toyota executive Taiicho Ohno (1912-1990) defined The 7 Deadly Wastes (muda).

The seven types of waste are:

1. Waste from overproduction
2. Waste from waiting times
3. Waste from transportation and handling
4. Waste related to useless and excess inventories
5. Waste in production process

6. Useless motions

7. Waste from scrap and defects

1. Waste from overproduction

Many companies are producing more than necessary because they lose parts, products, material! Without order, care and discipline in storage, inventories will fill all available space. Temporary storing a batch in a non defined / dedicated area is risky, as someone could move the batch without care nor notice. In such a case, it is likely to lose its track, all ending in a waste of raw material, energy and man power. It may lead to a double waste if the lost batch requires to produce a new one be delivered!

**How to handle overproduction**

- Eliminating the wasted space and valuable surface by excess inventories and overproduction is a potential improvement.
- 5S can be used to setup rules for storing, define space and places. These rules have to be widely communicated so that everyone knows where is what, why and for how long. While continuously improving the situation, the rules have to be updated and stick to the newest state.

2. Waste from waiting times

Waiting is a consequence of poor synchronization between process stages or bad preparation. Waiting for parts, material, tools, instructions, etc... can be caused by a lack of rules about storage places, when people have to search everywhere.

Are the items you are waiting for really necessary? If they’re not, if they do not add value to the job or the product, it is wise to try to eliminate them or at least reduce the waiting time and storage distances.

Computers with plenty and poorly ordered data on hard disk drives slow down.
Did you consider directories and files as candidates for 5S?

All search is reduced if the searcher knows where to search.

3. Waste from transportation and handling

The necessity to move and transport can be caused by the previously mentioned wastes. All transportations may not be eliminated, but they have to be kept to the very minimum.

Looking for a pallet truck to move crates or pallets is a common occupation in the workshops. People most often claim for more trucks, but a proper set of rules, parking areas and discipline to bring them back after use is enough to solve availability problems.
4. Waste related to useless and excess inventories

"Useless"! The name itself gives the solution.

In the 5S way, anything that is useless is to be eliminated. In case of inventories, the gain is the value of the goods stored and the regained spaces, which must be dedicated preferably to value creating activities.

Paper documents and their numerous copies, catalogues and calendars of previous years, files and data, dry and worn out pens and pencils... all excess inventories!

5. Waste in production process

Procedures and work guides which are not constantly updated are likely to let useless operations be performed in the process. Sorting and ordering applies also in the sequences of the process and the related documents.

This type of waste is also common in administration processes and office work. Old rules still remain even if the causes of their creation disapeared a while ago. As long as nobody will update the set of rules, everyone will carry on, sticking to the olds with application and discipline(!!).

6. Useless motions

Ergonomics of the work place is certainly the most popular and "visible" application of the 5S. The layout and display of the area will follow the 5S logic, favoring availability of necessary items, distance of reach, ease for tending...

Among useless motions, do not forget the walks to search for missing items, data, instructions, complementary information...

7. Waste from scrap and defects

Number of defects and quality problems can be directly linked to the work place state:

- Assembly mistakes (parts mismatch) due to jammed work table with parts from different models / series
- Forgotten parts in assembly, the parts could not be seen in the mess on the table
- Scratches on parts by scrap form the work table (burrs, dirt, parts...)
- Spoiled parts, useless because dirty, scratched...
- Assembly mistake by not following the right sequence

A few more types of waste can be added and analysed:

8. Waste from confusion — Any missing or misinformation. Any goals or metrics that cause uncertainty about the right thing to do.
9. **Waste from unsafe or unergonomic work** conditions - Office work conditions that cause carpel tunnel, eye fatigue, chronic back pain, or that compromise the health and productivity of workers in any way.

10. **Waste from underutilized human potential** — skills, talents, and creativity. Restricting employee's authority and responsibility to make routine decisions. Having highly paid staff do routine tasks that don't require their unique expertise. Not providing the business tools needed to perform and continuously improve each employee's assigned work. Not trusting your people to stop production to stop and fix a problem (jidoka). Not trusting your people to be responsible for the cleanliness, maintenance, and organization of their own work area. Not trusting people with a flat organization structure of largely self-directed teams. Not expecting (and measuring) every person to contribute to continuous improvement.

**How to eliminate the 7 forms of waste**

- Lean Objectives and Ideals
- The PDCA scientific method
- The Lean Management
- Kaizen

**Principle of 5 S**

The **5S philosophy** is a way of thinking, focusing on effective work place organization, simplified work environment, strives waste reduction while improving quality and safety.

The five **$** stand for the five first letters of these Japanese action words:

<table>
<thead>
<tr>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seiri</td>
</tr>
<tr>
<td>Seiton</td>
</tr>
<tr>
<td>Seiso</td>
</tr>
<tr>
<td>Seiketsu</td>
</tr>
<tr>
<td>Shitsuke</td>
</tr>
</tbody>
</table>

**Figure 2. Principle of 5 S.**

Calling these principles the "5S" is a good way to remember their meaning and content.

Developed in Japan, this method assume no effective and quality job can be done without clean and safe environment and without behavioral rules.

The 5S allow to set up a well -adapted and functional work environment, ruled by simple yet effective rules.

5S deployment is to be done in a logical and progressive way. The 3 first $ are shop floor actions, while the 2 lasts are sustaining and progress actions.
It is recommended to start implementing 5S in a well-chosen pilot workshop or pilot process, and spread to the others step by step

**What is 5S?**

1. **Seiri - Sort**

   Sorting, keep the necessary in work area, dispose or keep in a distant storage area less frequently used items, unneeded items are discarded.

   Seiri fights the habit to keep things because they may be useful someday. Seiri helps to keep work area tidy, improves searching and fetching efficiency, and generally clears much space. Seiri is also excellent way to gain valuable floor space and eliminate old broken tools, obsolete jigs and fixtures, scrap and excess raw material.

2. **Seiton – Set in order**

   Systematic arrangement for the most efficient and effective retrieval. A good example of Seiton is the tool panel. Effective Seiton can be achieved by painting floors to visualize the dirt, outlining work areas and locations, shadow tool boards. An example of Seiton are "broom carts". As cleaning is a major part of 5S we custom made carts to hold brooms, mops and buckets. Several carts have specific locations and all employees can find them.

   Seiton saying would be: "A place for everything and everything on its place."

3. **Seiso - Shine**

   Cleaning. After the first thorough cleaning when implementing 5S, daily follow-up cleaning is necessary in order to sustain this improvement. Cleanliness is also helpful to notice damages on equipment such as leaks, breakage and misalignment. These minor damages, if left unattended, could lead to equipment failure and loss of production. Regular cleaning is a type of inspection. Seiso is an important part of basic TPM; **Total Productive Maintenance** and Safety matter through cleanliness is obvious.

4. **Seiketsu - Standardize**

   Standardizing. Once the first three S have been implemented, it should be set as a standard so to keep these good practice work area. Without it, the situation will deteriorate right back to old habits. Have an easy-to-follow standards and develop a structure to support it. Allow employees to join the development of such standards.

   The 3 first S are often executed by order. Seiketsu helps to turn it into natural, standard behavior.
5. Shitsuke - Systematize

Finally, to keep first 4 $ alive, it is necessary to keep educating people maintaining standards. By setting up a formal system; with display of results, follow-up, the now complete 5S get insured to live, and be expanded beyond their initial limits, in an ongoing improvement way; the Kaizen way.

The effect of continuous improvement leads to less waste, better quality and faster lead times.

What types of businesses benefit from a 5S program?

Everyone and all types of business benefit from having a 5S program. Manufacturing and industrial plants come to mind first, as those are the business that can realize the greatest benefits. However, any type of business, from a retail store to a power plant — from hospitals to television stations — all types of businesses, and all areas within a business, will realize benefits from implementing a 5S program.

PDCA (Plan-Do-Check-Act/Adjust)

Definition
PDCA (Plan–Do–Check–Act or Plan–Do–Check–Adjust) is an iterative four-step management method used in business for the control and continuous improvement of processes and products.

Example

![Figure 3. PDCA.](http://upload.wikimedia.org/wikipedia/commons/a/a8/PDCA_Process.png)
Use

**PDCA cycle consists of the following steps:**

- **PLAN:** Establish the objectives and processes necessary to deliver results in accordance with the expected output (the target or goals). By establishing output expectations, the completeness and accuracy of the spec is also a part of the targeted improvement. When possible start on a small scale to test possible effects.

- **DO:** Implement the plan, execute the process, make the product. Collect data for charting and analysis in the following "CHECK" and "ACT" steps.

- **CHECK:** Study the actual results (measured and collected in "DO" above) and compare against the expected results (targets or goals from the "PLAN") to ascertain any differences. Look for deviation in implementation from the plan and also look for the appropriateness and completeness of the plan to enable the execution, i.e., "Do". Charting data can make this much easier to see trends over several PDCA cycles and in order to convert the collected data into information. Information is what you need for the next step "ACT".

- **ACT/ADJUST:** Request corrective actions on significant differences between actual and planned results. Analyze the differences to determine their root causes. Determine where to apply changes that will include improvement of the process or product. When a pass through these four steps does not result in the need to improve, the scope to which PDCA is applied may be refined to plan and improve with more detail in the next iteration of the cycle, or attention needs to be placed in a different stage of the process.

---

**One piece flow (or continuous flow manufacturing)**

**Definition**

One piece flow is a way of production to reduce cycle time and optimize production flow by creating (semi-autonomous) cells in the production line for manufacturing components of a product.

The main principle of the one-piece flow is the design of cells in the production process: Parts of the production process and the according job tasks are arranged in sections in the so-called "cells". In the design of cell production factory floor labor are arranged into semi-autonomous and multi-skilled teams, or work cells, who manufacture complete products or complex components. Properly trained and implemented cells are more flexible and responsive than the traditional mass-production line, and can manage processes, defects, scheduling, equipment maintenance, and other manufacturing issues more efficiently. The cells help to prevent that the task sizes for individual workers are too big and they lose routine and exercise and so on working speed and quality. The employee starts on the first working system of the cell and moves on with the product work system to work system of the cell. The first and the last work station in a cell should be as close together as possible, so that the employee can start the process anew. This is why assembly lines in cells are mostly U- or Omega-shaped.

---

Advantages of the one piece flow are:

- High transparency of the work processes (cell system)
- Easy control of processes / Early error detection
- Short lead times
- Reduction of circulating stocks
- No lengthy queue times
- No unplanned interruptions in the cell
- No batches of WIP (work/goods in process)
- High morale of employees

One-piece flow vs. batch-and-queue manufacturing

In a typical batch-and-queue manufacturing environment parts move from functional area to functional area in batches, and each processing step or set of processing steps is controlled independently by a schedule.
upstream or downstream. This results in:
- Large amounts of scrap when a defect is found because of large batches of WIP (work/goods in process)
- Long manufacturing lead time
- Poor on-time delivery and/or lots of finished goods inventory to compensate,
- Large amounts of WIP

Use
For implementing one-piece flow the following steps should be considered:

1.) Decide which products or product families will go into the one-piece flow cells, and determine the type of cell: Product-focused or mixed model. For product focused cells to work correctly, demand needs to be high enough for an individual product. For mixed model cells to work, changeover times must be kept short; a general rule of thumb is that changeover time must be less than one tact time.

2.) The next step is to calculate tact time for the set of products that will go into the cell. Tact time is a measure of customer demand expressed in units of time and is calculated as follows:
   
   \[ \text{Tact time} = \frac{\text{Available work-time per shift}}{\text{Customer demand per shift}} \]

3.) Next, determine the work elements and time required for making one piece. In much detail, list each step and its associated time. Time each step separately several times and use the lowest repeatable time. Then, determine if the equipment to be used within the cell can meet tact time. Considerations here include changeover times, load and unload times, and downtime. The next step is to create a lean layout. Using the principles of 5-S (eliminating those items that are not needed and locating all items/equipment/materials that are needed at their points of use in the proper sequence), design a layout. Space between processes within a one-piece flow cell must be limited to eliminate motion waste and to prevent unwanted WIP accumulation. U-shaped cells are generally best; however, if this is impossible due to factory floor limitations, other shapes will do. For example, I have implemented S-shaped cells in areas where a large U-shape is physically impossible.

4.) Finally, balance the cell and create standardized work for each operator within the cell. Determine how many operators are needed to meet tact time and then split the work between operators. Use the following equation: Number of operators = Total work content / Tact time

Pareto chart
Definition
A Pareto chart is a bar chart, which contains both bars and a line graph, where individual values are represented in descending order by bars and the cumulative total is represented by the line. It is named after the Italian economist Vilfredo Pareto and finds use inter alia in statistics.
The purpose of the Pareto chart is to highlight the most important among a (typically large) set of factors. In quality control, it often represents the most common sources of defects, the highest occurring type of defect, or the most frequent reasons for customer complaints, and so on.

The left vertical axis is the frequency of occurrence, but it can alternatively represent cost or another important unit of measure. The right vertical axis is the cumulative percentage of the total number of occurrences, total cost, or total of the particular unit of measure. Because the reasons are in decreasing order, the cumulative function is a concave function.

Example

![Pareto Chart of Late Arrivals by Reported Cause](http://upload.wikimedia.org/wikipedia/commons/8/8a/Pareto.PNG)

**Use**

For using a Pareto chart the following steps should be considered:

1.) First, the topic to be processed should be determined.

2.) Then categories are formed, e.g. for types of error or causes or for products, customers, products, suppliers.

3.) In addition, a quantity type must be determined by which one can clarify the effects of a problem. The most common quantity types are the frequency of occurrence, or the cost incidence (number multiplied by expense ratio), or the likelihood and impact.

4.) To create the Pareto diagram the percentage of each error category is determined from the absolute frequency: Subset / Total * 100 = % Frequency

5.) Afterwards the error categories are sorted in descending order according to their importance and then plotted on the horizontal axis from left to right. For each error category a column is drawn, whose height corresponds to the frequency of occurrence. The columns are stacked on one another from left to right, the result is the Pareto curve, which reflects the accumulated percentage value.
Ratios

What gets measured gets done!

Ratios and their importance

A ratio represents the relationship between two quantities (aggregated figures) and makes comparisons possible using different periods of time, operations and categories. In addition to ratios which are established in annual balance sheets, it also possible to use "optional measurands" to determine internal ratios for the purpose of constantly improving a company (within the framework of continual improvement processes, Kaizen, etc).

The proper use of ratios is a key factor for successfully increasing performance. They offer the following possibilities:

1. Confirmation of the achieved state and timely recognition of undesirable developments
2. A guarantee of continual improvement
3. Ratios help to detect areas of potential in production
4. Implementation of business strategies (i.e. zero defect strategy) in production

Possibilities 1 and 2: Confirmation of the achieved state and timely recognition of undesirable developments - A guarantee of continual improvement

Processes can be controlled and measured using the PDCA circle (plan-do-check-act).

Figure 7. PDCA-circle.
Every corrective action taken must be **testable and thus measurable. You can only make meaningful changes to what you can measure.**

Ratios replace assumptions with facts and make informed decisions possible in the first place.

**Possibility 3: Ratios help to detect areas of potential in production**
Areas of potential in production may, as an example, be displayed using the project management triangle with "time, quality, cost".

![Figure 8. The project management triangle.](image)

**Possibility 4: Implementation of business strategies (i.e. zero defect strategy) in production**
The ratios should make it possible to implement and measure company strategies/goals and should therefore be chosen so that progress towards those goals or actions can be measured efficiently.
Ratios for FIS ("Factory in a Seminar Room")

Ratios help to analyse a current state and to review the effectiveness of the corrective actions taken which then makes it possible to establish a new standard. All actions taken should be in tune with the company goals (for example: attaining the highest possible ROI/return on investment, making corresponding profits, etc). As depicted in the project management triangle, the factors cost – quality – time are interrelated which means it is necessary to define goals and priorities.

When conducting FIS, ratios should predominantly be chosen that are suitable for measuring the methods used (for example CIP, Kaizen, Value Stream, etc). Consideration should be given as to what kind of information will be available in FIS and the ratios should be able to be calculated and analysed both easily and quickly.

The methods applied in FIS (see above) mainly address process potential. As can be seen in the following image, the focus is on measuring and reducing the non-value adding time (90% - 95%).

**Management of costs** can be covered using the ROI ratios from the DuPont method, as an example.

![Diagram showing Cost potential and Process potential](image)

**Figure 9. Management of costs.**
Ratios – TIME / PROCESS POTENTIAL

These ratios focus above all on the measurement/reduction of time (queue time, idle time, on time delivery) and on measuring and increasing efficiency.

**Figure 10. Time/process potential.**

**Lead time**

Lead time is the period of time between the placing of an order until the item is shipped. It includes production time, transport time and queue time.

**Process Cycle Efficiency (PCE)**

Process cycle efficiency (PCE) shows how "lean" the process in question is. It is calculated by dividing all of the value adding time by the lead time.
Allocation rate
The allocation rate shows the degree of process density and therefore the amount of WIP (work in progress) and queue and idle times. The time that needs to be allocated is the standard time for equipment (machines). It includes processing time, changeover time and downtime.

\[
\text{Allocation rate} = \frac{\text{allocated time}}{\text{lead time}}
\]

On time delivery (OTD)
This ratio measures the amount of articles delivered on time versus the total quantity shipped.

\[
\text{On time delivery} = \frac{\text{quantity of articles delivered on time}}{\text{total quantity}}
\]

Throughput
Throughput specifies the performance/efficiency of a process.

\[
\text{Throughput} = \frac{\text{production output}}{\text{lead time}}
\]

Employee productivity
This ratio measures the relation of productive time to attendance time in %.

\[
\text{Employee productivity} = \frac{\text{productive working}}{\text{attendance time}}
\]

Unit productivity
This ratio provides information based on the units produced relative to one employee hour.

\[
\text{Unit productivity} = \frac{\text{units produced}}{\text{direct labour hour}}
\]
Ratios - QUALITY

Quality rate
This ratio gives information about the losses that arise due to a noncompliance with specifications that apply to the produced units.

\[
\text{Quality rate} = \frac{\text{good parts}}{\text{total quantity}}
\]

Scrap rate
This ratio gives information about the extent of the loss made due to scrap (number of scrapped units in %).

\[
\text{Scrap rate} = \frac{\text{scrap parts}}{\text{total quantity}}
\]

Rework rate
This ratio calculates the extent of losses made due to rework (amount of products in need of reworking in %).

\[
\text{Rework rate} = \frac{\text{rework parts}}{\text{total quantity}}
\]

Ratios - COSTS

Return on Investment
A possible company objective may be to achieve the highest possible return on total capital. The DuPont ROI tree helps to show which influences affect the ROI, including both income statements and balance sheets.
In FIS, the contribution margin is calculated using the **net sales** and the **variable costs**.

For the fixed costs, the FIS director makes an estimation. The fixed costs are deducted from the contribution margin to determine the net profit.

Net sales are divided by the net profit to determine the net profit margin.

To compare this to the capital invested in FIS, the FIS director has to again make estimations for the total assets. This makes it possible to determine the asset turnover (net sales/total assets).

ROI is calculated using asset turnover * net profit margin.

The ROI can be increased by

- Increasing sales
- Reducing costs (variable and fixed costs)
- Reducing the invested assets.

**Spaghetti Diagram**

*Source: [http://www.lean-production-expert.de/lean-production/spaghetti-diagramm.html](http://www.lean-production-expert.de/lean-production/spaghetti-diagramm.html) [Only available in German online]*

A spaghetti diagram makes it possible to visualise workflows and material flows.

The primary goal when creating a spaghetti diagram is to detect waste in work processes.
A spaghetti diagram makes it possible to clearly depict types of waste, in particular the waste types "transportation" and "motion".

In a layout of the production area, the trips made during the production process are tracked with lines. The less productive a process flow is, the more cluttered the organisation of the lines on the layout will be. The name spaghetti diagram comes from the fact that such plots often look like a plate of spaghetti noodles.

**Goals:**

- Visualise trips made during a work process
- Detect the waste types "transportation" and "motion"
- Provide a basis for optimising the production layout in order to reduce waste and therefore increase productivity

**Ways to create a diagram:**

There are two different approaches to creating a spaghetti diagram:

1. **Sketch the trips made by an employee:**
   The trips in this approach are analysed from the viewpoint of an employee. Too much movement indicates a deficient layout and/or a lack or workplace organisation (tool arrangement, etc).

2. **Sketch the trips made by a part:**
   This approach provides information about the flow of material with a focus on the waste
type "transportation". However it should be taken into account that transport is often associated with unnecessary movement.

Examples for practical use:

- To optimise the layout of production cells
- As a tool for 5S actions --> which tools and equipment should be located directly next to the workplace?
- As a resource for reducing changeover times (SMED workshops)
- To determine the trips made by a product during the production process

Advantages:

Learning to use this tool is simple and it is easy to apply. A spaghetti diagram provides a simple yet powerful depiction of waste in a production process.

Procedure:

1. **Sketch the layout:**
   When creating a layout, care should be taken to draw it to scale so that subsequent analysis of the trips made can be determined by measuring the sketch.

2. **Determine the period of observation:**
   How long does the process need to be observed in order to gather reliable information about waste in the process? For example, if an assembly process is being examined which takes a total of 2 minutes, an observation period amounting to an hour is sufficient for determining the average amount of waste. The observation period is thus determined based on the duration of the process being examined.

3. **Draw lines for every trip taken:**
   During the observation period, draw a line on the layout for every single trip made. While observing the process, it already becomes apparent which trips are unnecessary and how they might be avoided by optimising the layout or workplace organisation.

4. **Analyse the spaghetti diagram:**
   a) Qualitative analysis:
   Just looking at a completed spaghetti diagram suffices for a qualitative analysis. If the diagram is quite cluttered, then it can be assumed that there is a high potential for improvement. Long lines and particularly thick jumbles become immediately obvious to the observer.

   b) Quantitative analysis:
   For quantitative analysis, the length of each line is measured and the total distance travelled is then calculated. A simple table can be of help:
Observation period: 1 hour  Date: 20 June 2010

<table>
<thead>
<tr>
<th>From</th>
<th>Location 1 description</th>
<th>To</th>
<th>Location 2 description</th>
<th>Comments</th>
<th>Distance [m]</th>
<th>Number of trips</th>
<th>Total distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Housing stock - cage pallet</td>
<td>B</td>
<td>Assembly table</td>
<td></td>
<td>1.5</td>
<td>7</td>
<td>10.5</td>
</tr>
<tr>
<td>B</td>
<td>Assembly table</td>
<td>C</td>
<td>Depositing table</td>
<td></td>
<td>1.5</td>
<td>7</td>
<td>10.5</td>
</tr>
<tr>
<td>C</td>
<td>Depositing table</td>
<td>D</td>
<td>Test apparatus</td>
<td></td>
<td>1.8</td>
<td>7</td>
<td>12.6</td>
</tr>
<tr>
<td>D</td>
<td>Test apparatus</td>
<td>E</td>
<td>Carton for finished products</td>
<td></td>
<td>1.0</td>
<td>7</td>
<td>7.0</td>
</tr>
<tr>
<td>D</td>
<td>Test apparatus</td>
<td>F</td>
<td>Cabinet for devices</td>
<td>Changeover</td>
<td>3.2</td>
<td>3</td>
<td>9.6</td>
</tr>
<tr>
<td>E</td>
<td>Carton for finished products</td>
<td>H</td>
<td>Hand lift</td>
<td>Hand lift retrieved</td>
<td>8.0</td>
<td>2</td>
<td>16.0</td>
</tr>
<tr>
<td>E</td>
<td>Carton for finished products</td>
<td>Internal</td>
<td>Cartons taken</td>
<td></td>
<td>10.0</td>
<td>2</td>
<td>20.0</td>
</tr>
<tr>
<td>B</td>
<td>Assembly table</td>
<td>F</td>
<td>Cabinet for tools</td>
<td>Tools retrieved</td>
<td>5.1</td>
<td>2</td>
<td>10.2</td>
</tr>
<tr>
<td>B</td>
<td>Assembly table</td>
<td>G</td>
<td>Stock shelf - small parts</td>
<td>Small parts supplied</td>
<td>5.2</td>
<td>3</td>
<td>15.6</td>
</tr>
<tr>
<td>B</td>
<td>Assembly table</td>
<td>I</td>
<td>Dustbin</td>
<td></td>
<td>5.4</td>
<td>2</td>
<td>10.8</td>
</tr>
</tbody>
</table>

Total distance per hour: 122.8

Figure 13. Spaghetti diagram for housing assembly.

Value Stream Mapping

Value stream mapping is a method which makes it possible to visually depict the current state of production and/or assembly and to detect wastes.

The goal is to first reduce waste and to subsequently shorten the lead time or the efficiency of a process. Value stream mapping is a tool which helps to identify the root causes of waste.

When a value stream is mapped out, material and information flows are illustrated in a clear and transparent manner. In order to holistically improve a process, it is necessary to understand how both flows are interrelated!

Steps / Sequence of a value stream project
1. Choose a product
2. Create a CURRENT state map (value stream mapping)
3. Analysis phase
4. Create a FUTURE state map
5. Implement corrective actions
Step 1 – Choose a product

The first step is to choose a product to be analysed using value stream mapping. 
*An example follows for a loader crane.*

Step 2 – Value stream mapping of the CURRENT state

The current state of the production and/or assembly of the product is mapped using simple, predefined symbols.

**Figure 14. Value stream mapping of the current state.**

Predefined symbols (Source: Rother, Shook 2006)

**KEY German-English**

<table>
<thead>
<tr>
<th>German</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symbole für Materialfluss</td>
<td>Symbols for material flow</td>
</tr>
<tr>
<td>Montage</td>
<td>Assembly</td>
</tr>
<tr>
<td>Fertigungsprozess</td>
<td>Production process</td>
</tr>
<tr>
<td>XYZ Unternehmen</td>
<td>XYZ company</td>
</tr>
<tr>
<td>Externe Quellen</td>
<td>External sources (suppliers, customers)</td>
</tr>
<tr>
<td>Sek</td>
<td>sec.</td>
</tr>
<tr>
<td>Min</td>
<td>min.</td>
</tr>
<tr>
<td>3 Schichten</td>
<td>3 shifts</td>
</tr>
<tr>
<td>Datenkasten</td>
<td>data box icon</td>
</tr>
<tr>
<td>Mon + Mittw</td>
<td>Mon + Wed</td>
</tr>
<tr>
<td>Lieferung per LKW</td>
<td>Delivered by truck</td>
</tr>
<tr>
<td>PUSH Pfeil</td>
<td>PUSH arrow</td>
</tr>
<tr>
<td>Fertigwaren an den Kunden</td>
<td>Finished product sent to customer</td>
</tr>
</tbody>
</table>

The material flow is mapped "backwards", i.e. from shipping back to the receipt of goods. This makes it possible to view the flow from the customer's perspective. This method for recording the current situation is called value stream mapping.
Value stream maps can be sketched on paper or created digitally. Digital versions offer the following advantages:

- easier to present
- easy to duplicate
- can be sent by email and forwarded
- calculated data can be immediately updated using formula links
- different conditions can be simulated virtually
Step-by-step mapping of the current state (Source: www.ipe-gmbh.de) [Only available in German online]

3. Erfassung IST-Zustand

2. Schweißer Durchgang zur Identifikation der Reihenfolge der hauptmächtigen Prozesse

Dieser Schritt soll lediglich einen groben Überblick über die Produktion geben. Ein rascher Durchgang hilft die Hauptprozesse zu identifizieren (Helicopter Perspektive)

Kunde = customer
20,000 units/mo.
Container = 20 units
2 shifts

Stanzen = Stamping
Fräsen = Milling
Schweißen = Welding
Montage = Assembly
Versand = Shipping
KEY German-English

4) Add supply information
Name and location of supplier
Quantity delivered / Transport unit
Delivery cycle (Delivery frequency)
Delivery type

Lieferant = Supplier
Di + Do = Tues + Thurs
5 Tage = 5 days

(For names of different steps, i.e. Stanzen, see key above)
MA = NE (number of employees)
ZZ = CT (cycle time)
RZ = ST (setup time)
Verfüg. = Avail. (availability)
Schichten = Shifts

Versand = Shipping

Step 3 – Analysis phase

The next step is to ask yourself certain key questions about where you want to be in the future and to plot an image of an optimised, future value stream. This is called value stream design.

The map made of the current status of each assembly process serves as the basis for the analysis phase.
Due to the amount of time it takes to collect data, we have added data from our ERP System (SAP) to complement the classic methods for recording time and determining each buffer stock.

The problem areas and potential in the current situation include:

- Utilisation and takt times
- Missing parts
- High inventory levels
- Information flow
An explanation of each area of potential follows:

Utilisation and takt times:

Made to order production at PALFINGER makes it possible for every customer to order a crane (size & model) which suits their individual needs. While this provides quite a considerable advantage when it comes to customer satisfaction, it also leads to problems in production and assembly.

The range of models offered by PALFINGER ranges from standard to high end products. This leads to substantial differences in the takt times between each workplace.

Missing parts:

Due to delivery problems with some subsuppliers, a large amount of cranes could not be completed and had to be put into interim storage. This led to high storage costs for semi-finished products.

High inventory levels:

High inventory levels were caused by the previously mentioned missing parts and also by an outdated push system which was used in assembly. This led to unnecessarily high buffer stock inventories between each work cell.

Information flow:

In assembly at the moment, every assembly work place is equipped with a preview chart which gives employees an overview of the cranes to be assembled.

Creating a future state map

Based on the problems and potential which become apparent during the analysis phase, it is then possible to develop solutions to counteract and eliminate waste.

Key questions must then be asked, such as:

- What takt time is given by our customer?
- Where can a continuous production flow be applied?
- Where should pull systems be employed?
- Which individual processes require improvement?
- ...

The graphic below helps to illustrate where we are now and where we would like to be in the future.
The ideal state is depicted at the very top as the "one piece flow" which is called the "North star" here (the North star represents a distant goal that we would like to reach in the future).

In one piece flow, every operation is given the same takt time to complete a work step and all work cells are arranged like an assembly line which provides the following advantages:

- buffers are no longer necessary
- additional storage areas become unnecessary
- transport and manipulation of material becomes unnecessary

In the second and third position of the graphic there are two types of pull systems. Pull means that every workplace (work cell) sets the takt time for the next workplace. As a result, only what is truly needed is actually produced/assembled.

Our starting point is the widespread push system. Push means that every work cell produces using all of the raw material available to that cell, regardless of what the following work cell needs. This inevitably leads to an unnecessary accumulation of buffer stock, to unnecessary transport and to unnecessary manipulation of material.

**Implementing corrective actions**

Based on the future state map, actions are developed which are necessary to reach the newly defined future state. These actions are documented, allocated and prioritised in an action plan. A small selection of our corrective actions follow, some of which have already been implemented and others which are to be implemented in the future.
The problem with workplace different takt times as a result of offering different crane models can be solved using supermarket pull systems. These supermarket pull systems help to harmonise the different takt times as well as the daily capacity requirements over a broad range of work cells. This is achieved by preassembling time-consuming assemblies (e.g. electronic assemblies, support cylinders) on days with a lighter workload which can then be taken out of the system on days with a heavier workload. Modular construction of crane equipment helps us to keep the variety of components low in the supermarket systems. The effect that this has on takt time is displayed in the diagram on the right.

Initially, 4 or 8 hours were necessary to complete a work step. With the supermarket pull system, this difference is harmonised which means that the workplace now needs 6 hours to complete every crane, regardless of which model.

The following images demonstrate how these modifications look digitally in a value stream map.
Reducing high buffer stock inventory
The starting point here involved fork lifts that delivered all of the daily required materials to each workplace.

The consequences included:
- a high number of fork lift trips per shop
- unnecessary parking spaces
- unnecessary manipulation of material and searching for material

It was possible to drastically reduce the high amount of fork lift transport, parking spots and unnecessary manipulation of set-up material by using a tugger train (see photo). The development and implementation of this transport train was carried out by the head of Cost Centers Logistik, Mr Reitsamer Robert. The detailed implementation in assembly (delivery places, size of buffer places, delivery frequency, etc.) was organised by our team.
Stop 1 Arrival and departure times

This system can be compared to a common train with stops and timetables. The train is pulled by a truck without a fork which can tow up to four trailers and each trailer can carry three euro pallets.

Because the train is able to tow twelvefold the load volume of a forklift, just one delivery replaces eleven forklift runs and therefore reduces the high number of empty runs.

The resulting advantages for the company include:

- Forklift runs reduced by 60%
- Parking spaces reduced by 70%
- Elimination of unnecessary empty runs
- Elimination of individual pallet transportation
- Reduced load on coordinators

Resource: Example for mapping the current state (Rother/Shook 2006)
Step by step mapping of the current state
(Source: [www.ipe-gmbh.de](http://www.ipe-gmbh.de))

**3. Mapping the CURRENT state**
1. Record customer information

Data box includes:
- Customer information
- Requested products
- Requested quantity
- Container volume
- Order and shipping intervals

**NOTE:** For all repeated symbols, please refer to the translations on page 34 and 35

Figure 26. Mapping the current state. Record customer information.

**KEY German-English**

3. Mapping the CURRENT state
1. Record customer information

Figure 27. Mapping the current state. Quick walk through to identify the sequence of the major processes.

**KEY German-English**

Please refer to the translation on page 34
3. Second walk through for to collect detailed data / create a CURRENT state map

Add the data boxes and inventories

Record all process steps and relevant parameters:

- Number of employees
- Cycle time / process time
- Setup time / Batch size
- Number of product variations
- Shifts
- Container volume
- Availability
- Scrap / rework rate

Inventories are recorded between each process

Figure 28. Mapping the current state. Second walk through for to collect detailed data.

KEY German-English

3. Zweiter Bundgang zur detaillierten Datenaufnahme / Erstellung IST-Map

Aufnahme aller Prozessschritte und relevanter Kenngrößen:
Anzahl Mitarbeiter
Zykluszeit bzw. Prozesszeit
Rüstzeit / Losgröße
Anzahl Produktvarianten
Schichten
Behältergröße
Verfügbarkeit
Ausschuss- / Nacharbeitsrate

Bestände werden zwischen den einzelnen Prozessschritten aufgenommen.

Figure 29. Mapping the current state. Add supply information.

KEY German-English

See page 35 for translations except for Täglich = daily:
Figure 30. Mapping the current state. Add information flow.

**KEY German-English**

5. Add information flow

If production is managed by a planning department, this is placed at a central position (red).

All processes that are managed by planning are mapped with an arrow.

Information (orders) that include plans from customers and/or suppliers is also shown accordingly.

Electronic data exchange is shown with an arrow that resembles lightning.

Wochenplanung = Weekly planning

Figure 31. Mapping the current state. Calculating the lead times.

**KEY German-English**

6. Calculating the lead times
Determine Customer takt time = available operating time per unit of time / customer demand per unit of time
Determine Process lead time = (inventory before the process) x Customer takt time
Determine Overall lead time = Sum of all process lead times

Figure 32. Mapping the current state. Example calculation.

**KEY German-English**

Example calculation (Lead time for welding)
Process lead time = 1700 units x 1 unit/min. = 1700 min. = 28.3 hours = 1.8 days (using 2 shifts)
Overall lead time = 5 days + 7.6 days + 1.8 days + 2.6 days + 2 days + 4.5 days = 23.5 days
**Figure 33. Mapping the current state. Determining lead times.**

**KEY German-English**

**Determining lead times**

Lead time is the time that elapses start-to-finish during the production of a product. The lead time thus comprises the sum of all process times, idle times and queue times.

The customer takt time simultaneously defines the minimum output takt time; an output takt time under customer takt time would entail waste in the form of overproduction. In value stream mapping, lead time is calculated in relation to customer takt time:

\[
\text{Lead time} = \sum \text{Buffer (intermediate stock levels) x customer takt time}
\]

Lead time is therefore calculated independently from the cycle times of each process.

**Determining process time (value adding time)**

The time needed to complete a process step. Process time includes the necessary transport and handover times. The total process time is thus the sum of all of the individual process times.

Lead time is a key ratio!!!