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List of abbreviation

5S	Seiri, Seiton, Seiso, Seiketsu and Shitsuke – sort, set in order, shine standardize, sustain
CT	Combined Transport
DMAIC	Define, Measure, Analyse, Improve and Control
EC	European Commision
EU	European Union
EUR	Euro
EUSALP	EU-Strategy for the Alpine Region
ILU	Intermodal Loading unit
ITU	Intermodal transport unit
JIT	Just in Time
JIS	Just-in-Sequence
KM	Kilometer
KPI	Key Performance Indicators
MIN	Minute
MUDA	7 Wastes
OD	Organization Development
O/D	Origin Destination
PDCA	Plan-Do-Check-Act
SMED	Single Minute Exchange of Die
TEN-T	The Trans-European Transport Networks
TEU	Twenty-foot equivalent unit
TQM	Total Quality Management
TPM	Total Productive Maintenance
UIR	Union of Italian freight villages
UTI	Units for intermodal transports - Unité de transport intermodale

Summary

Production overview

Production is a process of combining various material inputs and immaterial inputs (plans, know-how) in order to make something for consumption (the output). It is the act of creating output, a good or service which has value and contributes to the utility of individuals (Kotler et.,2006).

In industry the production represents the a process of planning, organisation, management and control of a product including the selection of the measures and solutions for reaching production goals.

The most common goal of production optimization is to minimize costs, maximize throughput and/or efficiency. Production optimisation techniques allow the product to be delivered in less time, with lower costs, with improved quality and flexibility. In modern industry several fields and topics are overlaped: operations research, systems engineering, manufacturing engineering, production engineering, management science, management engineering, financial engineering, ergonomics or human factors engineering, safety engineering, or others, depending on the viewpoint or motives of the user.

The most developed trend in modern industry to optimise production with improving efficency is the so called »lean production«, which suggests decision makers to decentralize, outsource, define hierarchy and compress the existing production process.

Production optimisation methods

The goal of lean manufacturing is reducing "waste". According to Russell and Taylor (Russel and Taylor, 2011) »waste« is "anything other than the minimum amount of equipment, materials, parts, space, and time that are essential to add value to the product."

Five principles are basic pillars in the lean philosophy: Identifying customer value, Managing the value stream, Developing a flow production, Using pull techniques and striving to perfection.

The methods for optimising production processes can be structured to:

- Process Optimisation tools (reduction of waste)
- Process Trigger Tools (reduction of inventory)
- Quality Improvement Tools (Reduction of defects, improvement of quality)
- Strategic Tools (continuous improving of organisation and operation)
- Visualisation tools (Identification of bottlenecks, weaknesses, visualising potentials for optimisation)
- Lead Time improvement tools (shorten lead time, reduction of inventory/work preparation and searching)

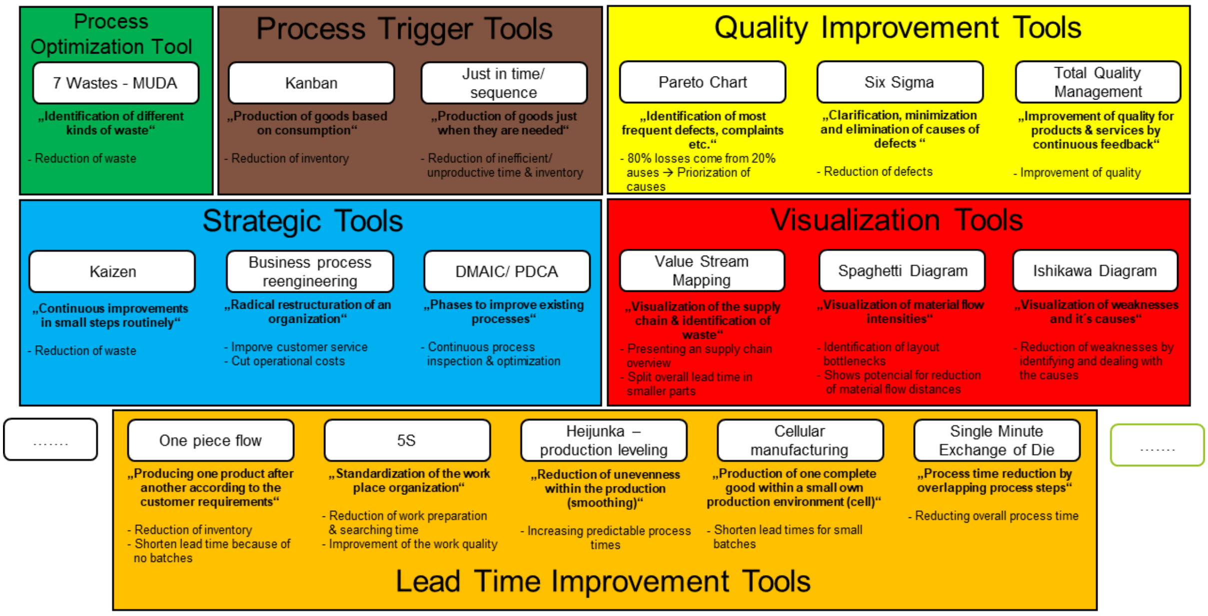

Figure 1: *Clustering of production methods/tools (SGKV, 2018)*

KPI Template

The following table presents the KPI template for CT corridor user, which covers main aspects:

- Financial performance (Finance)
- Operational performance (Time)
- Customer satisfaction (Quality of service)
- Environmental performance
- Other (Security, Damage)

Table 1: *Key Performance Indicators*

Category	Sub category	Indicator	Unit
Financial performance	Terminal operations	Terminal fee	€/TEU
		Transhipment fee	€/TEU
		Administration costs (quality inspection, customs procedures, documents, informatics …)	€/TEU
		Warehousing, parking	€/TEU
		Transport at terminal etc …	€/TEU
		Other (e.g. Costs for damage of loading unit/cargo, VOT etc.)	
	Transport	Total origin – destination transport cost on a CT corridor	€/TEU or €/km
		First mile costs	€/TEU or €/km
		Long haul cost (including shunting)	€/TEU or €/km
		Last mile costs	€/TEU or €/km
		Other	

Operational performance (time)	Terminal operations	Total terminal time	min/TEU or min/block train
		Transhipment (cargo handling)	min/TEU or min/block train
		Marshalling (Shunting)	min/TEU or min/block train
		Waiting time of cargo at terminal (Queueing)	min/TEU or min/block train
		Administration procedures (e.g. cargo inspection, weight and gauge checking) (min/operation	min/TEU or min/block train
		Transport at terminal	min/TEU or min/block train
		Terminal capacity	Trains handled / day
	Transport	First mile	min/km
		Long haul (O/D total corridor), between individual terminals),	min/km
		Long haul (between individual terminals)	min/km
		Last mile,	min/km
		Total	min/km
		Other	
Customer Satisfaction (Quality of service)	Reliability of service	On - time delivery	% of consignments delivered within a pre-defined acceptable time window;
	Frequency of service	Trains per day, Number annualy trains / working days	number of services per day/ week/moth/year); Numbers couples train for railroad track dedicated in one day
	Availability	Rolling stock	% of fleet
		Off terminal transhipment technologies	
		Required transport capacity	Max. TEU/rail link
		number of craneable railroad tracks	
	Other	Time rail plant opening / Efficiency	Number of hours between the arrival and departure of freight train after processing
Environmental performance	CO_2 (SOx) emissions	Population affected with CO_2 (SOx) emissions	g/tonne-km
	Noise	Population affected with noise	
Other	Security	Number of thefts	Number of thefts
	Damage	Damages/losses/ per TEU	Damages/losses/ per TEU

In order to provide clearer monitoring, a unified unit of ILU (Intermodal Loading Unit) can be applied instead of TEU in order to analyse containers, swap bodies or semitrailers.

Identification and depiction of production optimization methods & tools

The identification of production optimization methods and tools is based on reviewed literature of methods and their functional solutions in industry processes. The following presents the possible implementation of solutions in industry process to Combined Transprot processes. The table presents the main category of KPI for which the selected method is most relevant.

For more flexible and innovative CT process, the process should meet the end user requirements, set measurable and achievable targets and implement proposed optimisation method.

Table 2: Possible applicability of Industry process solutions to Combined transport

CT Process main KPI Category	Method	Industry Process Solution
Quality of service	JIT, KANBAN	Few suppliers with long term open relationship
Operational performance	JIS and JIT	Perfect sequence
Quality of service	KANBAN	Kanban cards to identify critical inventories
Quality of service	KAIZEN	Continuous change of small level improvements by workers
All Categories/ Quality of service	BPR (Business Process Reeingineering)	Fundamental change of processes
Quality of Service (including damage loss)	6 Sigma	Reduction of defects - statistically (according to different roles of staff and their level of education)
Quality of Service	TQM (Total Quality Management)	Autonomous maintenance
Quality of Service	TQM (Total Quality Management)	Establish standards
Quality of Service	TPM (Total Productive maintenance)	Clear hierarchy of maintenance management
Operational performance	5S	Organize workplace
Operational performance	Cellular manufacturing	Defects repaired in a cell, not in usual company batch
Operational performance	Value stream mapping	Detect waste
Operational performance	MUDA – 7 wastes	Disposal of defective goods
Operational perfomance	MUDA – 7 wastes	Disposal of overproduction or early production

Operational performance	SMED (Single Minute Exchange of Die)	Splitting the external and internal setup of production in time of machinery changeover
Quality of Service	Fishbone Diagram	Identifiying the root cause of a problem
Operational performance	Heijunka	Leveling – constant speed of production
Operational performance	One piece flow	One product at a time, next product with different requirements
Operational performance/ Quality of Service	Pareto chart	Prioritize the causes of defects and complaints
Operational performance/Quality of Service	Spaghetti Diagram	Change of layout, due to minimized walking/motions/transportation
Quality of Services (continuous improvement)	DMAIC (Define, measure, Analyse, Improve and Control)	Clearly defined sequences for improving the existing process and its »nonquality« parts
Quality of Services (continuous improvement)	PDCA (Plan Do Check Act)	Clearly defined sequences for improving the existing process and its »nonquality« parts

The CT process is to be improved with measures for digitailisation (also blockchain), automatisations and new technologies (transhipment, driving, handling), outsourcing, asset sharing, production (industry 4.o, 3D printing) and harmonised push and pull measures (driving bans, subsidies, investments in Infrastructure, rolling stock and terminals, taxing) in Alpine region.

In general the CT processes can be improved from 2 approaches:

- Bottom up approach – smaller changes based on experience/new technologies (e.g. integration of e-freight documents with KAIZEN, Integration of Nikrasa with MUDA)
- Top down approach – bigger changes based on new technologies (ERTMS on TEN-T Corridors with BPR)

To achieve lean principles in combined transport in Alpine Space, several production methods and tools are needed to be implemented. This approaches are to be used on macro level (for whole CT process or for individual CT process steps) or on micro level (for optimizing single process step – e.g. handling). All relevant stakeholders in the CT process are to be included.

After improvement and starting eliminating wastes (process time, material, tools, space) with concepts and tools like JIT, KANBAN, MUDA or Fishbone Diagramme, additional lean manufacturing methods for leveling and standardisation should be used (Heijnuka, 5S, One piece flow, TQM). To continuously improve the CT process tools like PDCA or DMAIC are to be used. For successul improvement of KPI, several measures and lean concepts are to be implemented in parallel.

Additionally the holistic view is important to be considered in improved CT Service, as also minor changes in process can effect other processes (e.g. elimination of paper wagon control may not be efficient, if not all wagon controls on the corridor are not improved with new technologies and/or skilled stuff).

1. Introduction

Basic idea of the project AlpinnoCT is to analyse the basic principles of the manufacturing industry and use the efficient and successful proved management concepts for the development of the »European transport system«.

The main challenge of AlpinnoCT is to raise efficiency, competitiveness and productivity of Combined Transport (CT). Holistic & transnational optimization between all involved transport chain actors with improved efficiency & competitiveness of CT will lead to easier access to & increase the utilization of this low-carbon transport method with positive effects for environment & inhabitants of the Alpine Space (AS).

In general the output of the project contributes to:

- EC: Europe 2020 (reduction of greenhouse gas emission & EU aim to promote modal shift as part of the greening transport policy),
- European Strategy for low-emission mobility 2016 (Outputs (O) 1,2,5).
- EUSALP, Action 4: promote intermodality in freight transport (O 4,5).
- Alpine Convention: increasing efficiency of transport systems & promoting modes of transport which are more environmentally friendly. WG Transport: Report 2016 Innovative Logistics Solutions (O 1-5).
- Zurich Process: support new technologies & innovations in CT, strengthen cooperation on int. level. (O 1,3,4).
- White Paper 2011,Goal 3: 30% of road freight over 300km should shift to other modes (water, rail) by 2030 and more than 50% by 2050 (O 1,3,5).
- TEN-T: efficient intermodal freight corridors (O 1,2)
- EUSALP goal for improving transnational cooperation to provide easier & more sustainable access to the Alpine Region. Only with cost-effective & attractive goods rail transport, the whole railway system (passenger&goods) can be used efficiently and contribute to EUSALP goals.
- "Better overall transport system in terms of sustainability & quality"/sustainable accessibility to the Alps by raising railway attractiveness & utilization.

Main goal of the project is to organise CT processes more efficiently, productive (benchmark are industrial processes) and coordinated on international level in order to raise the awareness, access and use of CT, especially for small and medium-sized entities.

In work package Task 1 (T1.1 and T1.2) a review of policies, strategies, responsible bodies for CT, CT measures, CT-technologies and funding systems per Alpine space region/Country will be presented. Together with detailed CT process analyzes (T2) and review on production optimization methods (T1.3), the overview will serve as an input for model identification (T3) and pilot implementation (T4).

The analysis of technologies & concepts for fostering modal shift will lead to a guideline showing how to integrate these technologies, concepts and approaches in practical CT processes (Guidelines for CT production – T5). The guidelines will serve Politicians, who may benefit from alpine wide dialogue results to be better prepared to set the future legal & regulatory framework.

Main stakeholders, that need to be considered in the model and in the pilot are :

Shippers, forwarders, transport companies, associations, railway companies, terminals, infrastructure providers, Wagon & semitrailer producers.

1.1. Objective

The main aim of the Deliverable Report of industry (production) development trends relevant for CT in the Alpine Space is to present current methods, tools and approaches in modern industry, that could be applied in Combined Transport processes.

Analysis of development trends in industrial processes will raise awareness and create a common understanding/basis to develop innovative (more flexible & market-oriented…) CT services in the Alpine Space.

T1 provides (working) basis for other WPTs with understanding state of the art & future CT trends.

Purpose of the report is to present and propose main tools and methods for optimisation of production for CT. Selected methods are planned to be analyzed and implemented in a model (T3) and implemented on a transport corridor (e.g. Bettembourg-Trieste & Rostock-Verona) (T4) using an elaborated template for Key Performance Indicators (KPI) as a basis for comparative analysis of CT processes. Purpose of the KPI template is to present main categories for performance monitoring of Combined Transport on a corridor.

1.2. Methodology

A review of industry production principles, methods and tools will be elaborated. Review of production optimisation methods represents theoretical background for charachteristics of lean principles. Based on defined (industry) production methods a review of their general applicability will be defined (e.g. quality assesment methods, process optimization methods).

Each review of method/tool contains:

- Description of the method/tool (basic characteristics)
- Advantages and disadvantages
- Input/output data (variables and parameters), Optimisation technique used (linear programmig,...)
- Applicability
- Resources.

Identification and depiction of production optimization methods & tools is performed on support from practitionaires, due to their CT processes knowhow.

The tools (e.g. Value stream mapping) should enable the analysis of all material and information flow of CT process and with lean principles help to eliminate waste procedures (e.g. waiting at terminal, bottlenecks in the network, unnacessary storage, additional transshipment).

Tools and methods are planned to be in line with KPI template, identified specific objective and possible measures to be implemented.

Based on identified barriers, problems and threats of CT and CT identified processes, a list of combining Industry principles and CT solutions is elaborated at and will serve as a basis for the further work.

2. Production processes and lean principles

The basic idea of the project AlpinnoCT is to transfer the knowledge of pruduction processes in modern industry to Combined transport processes.

Production is a process of combining various material inputs and immaterial inputs (plans, know-how) in order to make something for consumption (the output). It is the act of creating output, a good or service which has value and contributes to the utility of individuals (Kotler et.,2006).

In industry the production represents a process of planning, organisation, management and control of a product including the selection of the measures and solutions for reaching production goals.

The most common goal of production optimization is to minimize costs, maximize throughput and/or efficiency. Production optimisation techniques allow the product to be delivered in less time, with lower costs, with improved quality and flexibility. In modern industry several fields and topics are overlaped: operations research, systems engineering, manufacturing engineering, production engineering, management science, management engineering, financial engineering, ergonomics or human factors engineering, safety engineering, or others, depending on the viewpoint or motives of the user.

In order to reach production goals modern industry implemented operational innovations like digitalisation and automatisation to optimise material and information flow. The experts in this field are called industrial engineers (also production engineers or manufactural engineers), which main role is to eliminate waste of time, materials, person-hours, machine time, energy and other resources. They often also use computer simulations and matemathical tools like queueing theory, data science and machine learning for optimisation of processes. The industrial engineer is responsible for analyzing and optimizing conveyance, material handling, and warehouse flow, layouts, and processes related to production.

The most developed trend in modern industry to optimise production with improving efficency is the so called »lean production«, which suggest decision makers to decentralize, outsource, define hierarchy and compress the existing production process.

2.1. Description of lean principles

Ideally, the entire business processes as well as the human and material resources of evaluation and classification should be examined in the context of an integrated concept.

Lean manufacturing concept uses a number of simple concepts and tools to eliminate »waste« (all kind of excess inventory) in all manufacturing activities[1]. On this way also »hazardous rocks« are removed.

[1] *Lean manufacturing* was introduced and implemented in the manufacturing area in the book *The Machine That Changed the World* by Womack et al. [1] in 1990. In this book, the models the Japanese

The goal of lean manufacturing is reducing "waste". According to Russell and Taylor (Russel & Taylor, 2011), »waste« is "anything other than the minimum amount of equipment, materials, parts, space, and time that are essential to add value to the product."

Lean methods target at the following types of "waste":

1. Defects: money and time wasted for finding and fixing mistakes and defects
2. Over-production: manufacturing products faster, sooner, and more than needed
3. Waiting: time lost because of people, material, or machines waiting
4. Not using the talent of manpower: not using experiences and skills of those who know the processes very well
5. Transportation: not necessary movement of people, materials, products, and information
6. Inventory: raw materials, works in process (WIP), and finished goods more than the one piece required for production
7. Motion: Any people and machines movements that add no value to the product or service.
8. Over-processing: Tightening tolerances or using better materials than what are necessary.

"Waste" can be **anything that adds no value** to a product or service.

Similar principle to follow is used by Toyota , where within the tool **MUDA - 7 wastes** are identified as:

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

Lean Principles

Five principles are basic pillars in the lean philosophy:

- Identifying customer value
- Managing the value stream
- Developing a flow production
- Using pull techniques
- Striving to perfection

were using in their car industry was conceptualized by a group of MIT researchers. Since then, lean concepts and tools have been adjusted and used in other areas such as transportation and warehousing.

Identifying Customer Value

Value is an important and meaningful term in the lean context, meaning something that is worth paying for in a customer's point of view. Therefore, the first step in specifying this value is demonstrating a product's capabilities and its offered price.

Managing the Value Stream

Once value is identified, all required steps that create this value must be specified. Wherever possible, steps that do not add value must be eliminated.

Making Value-Adding Steps Flow

Making steps flow means specifying steps so that there is no waiting time, downtime, or other general waste within or between the steps.

Using Pull Techniques

Fulfilling customer needs means supplying a product or service only when the customer wants it. The following types of waste are eliminated by using pull techniques: Designs that are out of date before the product is completed, finished goods, inventories, and leftovers that no one wants.

Striving to Perfection

By repeatedly implementing these four steps, perfect value is ultimately created and there is no waste.

Using these principles is the key in making an activity lean. These principles are also called *lean thinking*. With this thinking, any tiny change may lead to waste. A good example is changing the placement of a waste bin in a plant. After a while workers get used to the placement of the bin and blindly throw their wastes in it without searching for it. When the bin's place is changed, however, workers have to find the bin first, which is time consuming, even if it is just a few seconds. In lean thinking, these seconds are waste.

Push versus pull strategy

Main processes in Combined Transport are generally divided in pull and push strategies of measures, where:

- "Pull type" starts to supply operations triggered by actual demand
- "Push type" corresponds to a model for trains, lorries, ships etc. for which supply (push) is based on demand forecast by time period and route.

According to the conventional *push system*, manufacturing process functions according to adopted manufacturing plans, available resources and manufacturing capacities **regardless of whether or not the next step needs them at the time.**

3. Tools and methods in optimisation of production processes

3.1. Proccess optimisation tools and methods

There are several management approaches, methods and tools for reducing unwanted processes. Main concepts are:

- Just in time (JIT) / Just in sequence (JIS)
- Kanban
- Kaizen
- Six Sigma
- Total Quality Management (TQM)

Additionally various tools are developed for process optimisation in production. Most important are:

- 5S
- Cellular Manufacturing
- Value Stream Mapping
- 7 Wastes (MUDA)
- Single Minute Exchange of Die (SMED)
- Fishbone Diagram
- Heijunka – Production leveling
- One Piece Flow
- Pareto Chart
- Spaghetti Diagram
- DMAIC / PDCA

3.1.1. Just-in-Time (JIT) / Just-in-Sequence (JIS)

The main goals of JIT in lean manufacturing are: inventory reduction, product quality increase, customer-service improvement and production-efficiency maximization. Furthermore the minimization of process time and stocks are striven (Grundig, 2015). JIT focuses on integration of purchasing (inbound), lean manufacturing using Kanban and out bound logistics processes. In JIT system is aiming at continuous improvement of the processes and the quality of the product and service. This is achieved by reducing inefficient and unproductive time in the production and logistics process.

JIT often changes many conceptual principles of a firm. For example, instead of concentrating on cost, quality is considered more. 'Many suppliers' thinking is replaced by 'few suppliers with long-term open relationship' thinking. In fact, in JIT thinking, higher-quality customer service is more important than cost, which is the main issue in conventional systems.

Another approach to optimize the production process is JIS which is similar to JIT, but instead of perfect timing the perfect sequence is considered. A combination of both methods is common so that JIS tops JIT by adding the right sequence for supplied parts and components (Werner, 2003). JIT and JIS require high discipline and great communication of supplier and manufacturer.

3.1.2. Kanban

The basic philosophy of Kanban is that raw materials, semi products, parts etc. should be supplied right at the moment when they are needed in the production process. Kanban is a *pull system*, which means that input needed for production must only be pulled through the chain in response to the end customer demand. The word "Kanban" is a Japanese word meaning signboard or visible record (*Ukil et al., 2015*). The Kanban system basically uses cards and containers to identify critical inventories and to control the production (*Bauer, 2016*).

In the Kanban system, the aim is to meet demands right at the time they are ordered and not before.

The aim of Kanban is to reduce inventory to its minimal amount at every stage to achieve a balanced supply chain.

3.1.3. Kaizen

"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. The message of kaizen is that there must not be a day without an advancement (Kach, 2015).

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.

Kaizen means continuous change for the better in Japanese (Bauer, 2016). The kaizen rapid-improvement process is the foundation of lean manufacturing. It holds that by applying small but incremental changes routinely over a long period of time, a firm can realize considerable improvements. Kaizen involves workers from all levels of an organization in addressing a specific process and identifying waste in this process. After finding possible »wastes«, the team tries to find solutions to eliminate them and then quickly apply chosen solutions, often within three days. After implementing improvements, periodic events ensure that this improvement is sustained over time.

3.1.4. 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 is used when a company is not competitive anymore caused by changes in the economic environment or changes in the strategic orientation (Koch, 2011).

BPR seeks to help companies radically restructure their organizations by focusing on the ground-up design of their business processes. Unlike Kaizen, BRP does not believe in small improvements but rather aims a total reinvention (Muthu, 1999). Reengineering 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.

3.1.5. Six Sigma

"Quality improvement strategy focused on removing variability from a process"

Developed by Motorola in the 1990s, Six Sigma uses statistical quality-control techniques and data-analysis methods. Six Sigma uses a set of methods that analyse processes systematically and reduce their variations, ultimately leading to continuous improvement. The goal of Six Sigma is that there are only 3.4 defects per one million to satisfy almost every customer (Andersson, 2006). At the Six Sigma quality level, there will be about 3.4 defects per million, which signifies high quality and low variability of process . Six Sigma is used for clarification, minimization and elimination of causes of defects in processes and thereby reducing the variability in manufacturing (Koch, 2015).

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 – analyse – 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.

3.1.6. 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 is an integrated concept which is designed for the long run (Rothlauf, 2014). 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 qualitymanagement from the customer's point of view.

TPM reaches effective equipment operation by involving all workers in all departments. For security and improvement of quality of products it is necessary that workers and managers of all hierarchy levels fell responsible for the quality management (Koch, 2015). The most important concept of TPM is autonomous maintenance, which trains workers to be in charge of and take care of their own equipment and machines. TPM tries to eliminate breakdowns, the time spent on equipment setup or adjustment, and lost time in equipment stoppages and to minimize defects, reworks, and yield losses.

3.1.7. 5S

Standing for *sort*, *set in order*, *shine, standardize*, and *sustain*, 5S represents a set of different practices for an improved workplace organization as well as improved productivity (Kanamori et al., 2015). In a more detailed way 5S is maintaining and creating a high effective, high quality and well organized workplace, supports the reduction of work environment, the improvement of safety and quality of work as well as the elimination of losses resulting from breaks and failures (Filip & Marascu-Klein, 2015). *Sort* means to organize tools in a specific order to prepare an easy storing and retrieval. *Set or Set in order* means to clearly label and designate where things like tools should be stored and that everything should be stored at this exact place to reduce the searching effort to zero. *Shine* means to keep all needed things clean and neat. The S for *Standardize* represents the documentation of the work methods and the implementation of these methods into the organizational culture. The last S - *sustain* means keeping 5S operating over time. (Omogbai & Salonitis, 2007).

The 5S philosophy encourages workers to maintain their workplace in good condition and ultimately leads reduced waste, downtime, and in-process inventory.

3.1.8. Cellular manufacturing

Cellular manufacturing is the actual practice of the pull system. The ideal cell is basically a pull system in which one piece is pulled by each machine as it needs the piece for manufacturing. All of the machines needed for a process are gathered as a group into one cell. Resources within cells are arranged to easily facilitate all operations (Abdulmalek 2006). Using cellular manufacturing offers different advantages such as improving quality while decreasing material handling cost, work in process (WIP), setup time, lead time and throughput time (Ariafar 2009). In a cell, when a defect occurs, only one product is defective, and it can be immediately caught. As soon as a defective part is seen, the operator starts repairing it, which leads to reduced scrap. In addition, using cells can shorten lead times. For example, if a customer's order is less than the usual company batch, the order can be delivered the moment it has been completed. In conventional manufacturing, however, the customer must wait until the company batch is completed before the order is shipped.

3.1.9. Value stream Mapping

Value stream mapping is a method to collect all actions that are required to bring a product through the main flows, starting with raw material and ending with the customer (Abdulmalek 2006). This offers the possibility 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 (*Lasa 2008*):

(1) selection of a product family;

(2) current state mapping (value stream mapping);

(3) future state mapping;

(4) defining a working plan; and

(5) achieving the working plan.

3.1.10. MUDA – 7 Wastes

Muda is the Japanese term for waste and the elimination of these waste is essential in order to become lean (Palmer, 2001). The main categories of waste were already determined in 1988 by Taiichi Ohno and consists out of the seven categories (1) waste of handling, (2) waste of processing, (3) waste of inventory, (4) waste of waiting, (5) waste of manufacturing too much or too early, (6) waste of defective goods and (7) waste of action (Cai et al., 2017). Examples of waste in these categories, which should be eliminated, are for example defective goods because these defective components require disposal or recycling, so waste. Another example is within the category „waste of manufacturing too much or too early“. Here the extra products may become obsolete because they are not needed yet, what leads to the requirement of disposal (Fercoq et al., 2016).

3.1.11 Single Minute Exchange of Die (SMED)

SMED stands for Single-Minute Exchange of Die and it’s a tool for time reduction (McIntosh et al., 2000). The SMED concept has its origin at the Toyo Kogyo´s Mazda plant in Hiroshima, Japan in 1950, in the course of a production efficiency improvement study conducted by Shigeo Shingo (Augustin & Santigo, 1996). This method is focused on changeover time reduction of machinery by splitting the external and the internal setups, followed by converting the internal to external setup and finally streamlining all operations within both kinds of setups (Filla, 2016).

3.1.12 Fishbone Diagram

The fishbone diagram is a nonstatistical tool for identifying the root cause of a problem (*Gupta, 2006)*. Because of the function of the fishbone diagram, it may be referred to as a cause-and-effect diagram (Arvanitoyannis, 2007). 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.

3.1.13 Heijunka – production leveling

The levelling of production, also known as smoothing - according to the Japanese "heijunka" is a technique to reduce the Mur (unevenness), which in turn reduces the Muda (waste). For the development of production efficiency according to the lean manufacturing philosophy. The aim is to produce semi-finished parts and assemblies at a constant speed so that further processing can be carried out at a constant and predictable speed (Matzka et al. 2012).

3.1.14 One Piece Flow

In order to meet the trend of mass customization, established production concepts have to be reconsidered and adapted. The variety of products increases and the available production time decreases. As a component of JIT, the one-piece-flow manages to meet the requirements. The aim is to manufacture only one product at a time, so that the next manufactured product can be produced according to different requirements. In practice, a one-piece-flow may be implemented as the smallest possible batch production (Koch 2015; Scholz et al. 2016).

3.1.15 Pareto Chart

Pareto chart is a basic quality tool that helps identifying the most frequent defects, complaints, or any other factor you can count and categorize. The chart based on the 80/20 rule, which says e.g. 80% the losses come from 20% of the causes. In the production environment, Pareto is used to identify A and B parts, assemblies or products. In this way, measures can be prioritized according to necessity and highest impact (Kulkarni et al. 2017).

3.1.16 Spaghetti Diagram

A spaghetti diagram is a visual representation using a continious flow line tracing the path of an activity through a process (Raikar 2015). The continuous flow line enables to detect redundancies in the work flow and opportunities to expedite process flow.

A spaghetti diagram makes it possible to identify how to change the layout of an area to minimize walking and other non-value activities (Labach 2010). The diagram 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 liik like a plate of spaghetti noodles.

<u>Goals:</u>

- 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.

3.1.17 DMAIC / PDCA

Define, Measure, Analyse, Improve and Control (DMAIC) is the core approach of the quality management method Six Sigma. It has its similarities to the PDCA-cycle method of lean management.

DMAIC improves existing processes, which do not meet the critical quality criteria to the desired extent. It is considered one of the most proven and recognised methods, as it are associated with a systematic and formalised approach. In addition, this method is carried out in a project form with defined milestones and roles in a clearly defined sequence (Koch 2015). DMAIC also meets the requirements of ISO 9001 (Marques et al 2013).

Define Phase: Identifying and selecting those processes that have a high level of revenue for the company and a low sigma level.

Measure phase: Involves the determination of the actual state by measuring the error rate (FpMM) and the dispersion for the critical quality characteristics.

Analysis phase: Statistical tools and methods are used to identify the causes of errors and deviations that have the greatest influence on the quality characteristics for assessing process performance.

Improve phase: Improvement opportunities that have the highest impact on customer satisfaction and economic results are identified. At the end of the phase, the improvement projects are implemented.

Control: The measures implemented are checked to see whether the desired success has been achieved. Deviations from the planned project goal can be calculated by means of final costing.

Plan-Do-Check-Act (PDCA) results from Lean Management and is used for continuous improvement. The procedure is similar to DMAIC. These phases are to be considered as a continuous process and are constantly undergoing (Koch 2015):

1. Plan: Analysis of the actual situation by means of data collection and evaluation using the defined quality tools. Based on these data, an improvement plan is drawn and realistic targets are defined.
2. Do: The affected employees are familiarized with the plan, and the planned improvements are implemented.
3. Check: Data collection as a basis for verifying the achievement of objectives. Determine whether the objectives of the planning phase have been achieved.
4. Act: Check whether there is an overriding of target and actual. Either the results or go through the "Planning" and "Implementation" phases for as long as necessary, until there is agreement. As soon as an improvement is implemented, new goals must be based on the latest improvement (Bandow et al. 2007).

3.2. Practical examples

In Cosima Project (Cosima Project 2015 - Process Optimisation methods) tools are presented with a practical example, where the example for Spaghetti diagramme and Value Stream Mapping could be applied also to Combined transport.

Example for Spaghetti diagramme represents visualization of workflows and material flows. The primary goal is to detect waste in work processes, especialy for transportation/motion processes. This can be done from the viewpoint of the employee or from the viewpoint of a produced part (material). The procedure consist of Sketching a Layout, determine the period of observation, draw lines for every trip taken and analyse the Spaghetti diagramme. A table providing an overview of all trips with data on total distance and number of trips quidkly identifies long unnecessary movements, which can be identified also with a sketch (Thick and long lines represent waste)

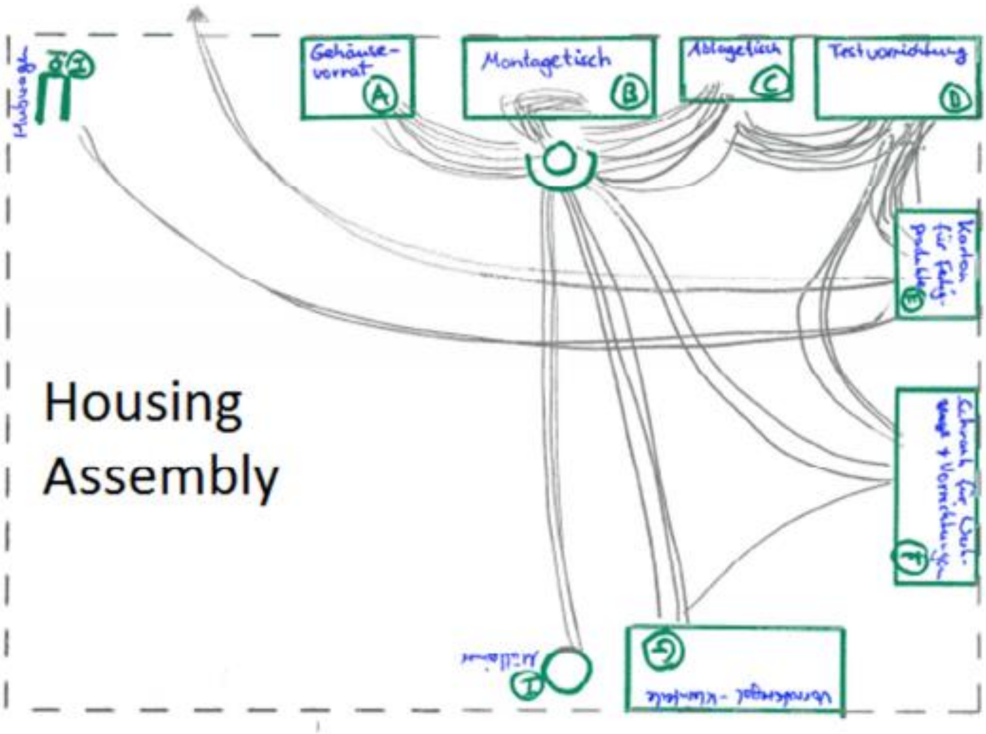

Figure 2: Spaghetti diagramme example

Example for Value stream mapping represents a optimization tool to reduce waste and shorten lead time or improvement of efficiency. Steps / Sequence of a value stream project include:

1. Choose a product (e.g loader crane)

2. Create a CURRENT state map (value stream mapping) – The material flow is made “backwards”, from shipping back to receipts of goods (this allows the custumer perspective view). Processes can be sketched on paper or digitilised according to the level of intervention or individual process step /substep.

3. Analysis phase (plot an optimized image of ideal process, this includes also identified problem areas and potential in the current situation:

- Utilisation and takt times (according to costumer wishes (size and model of wanted crane) the production differences in takt times between each workplace

- Missing parts (delivery problems with subsupplieres)

- High inventory levels (due to outdated push system)

- Information flow (overview of crane assemblies for each employee)

4. Create a FUTURE state map with answering on questions: 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?

5. Implement corrective actions - for example:

a) **with balancing takt times** for production of standard cranes and high sophisticated cranes, 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. 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.

b) **with introduction of tugger train** to drastically reduce the high amount of fork lift transport, parking spots and unnecessary manipulation. (see photo). 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

Figure 3: *Photo of a "train system"*

3.3. Optimisation methods – overview

The methods for optimising production processes can be structured to:

- Process Optimisation tools (reduction of waste)
- Process Triger Tools (reduction of inventory)
- Quality Improvement Tools (Reduction of defects, improvement of quality)
- Strategic Tools (continuous improving of organisation and operation)
- Visualisation tools (Identification of bottlenecks, weaknesses, visualising potentials for optimisation)
- Lead Time improvement tools (shorten lead time, reduction of inventory/work preparation and searching)

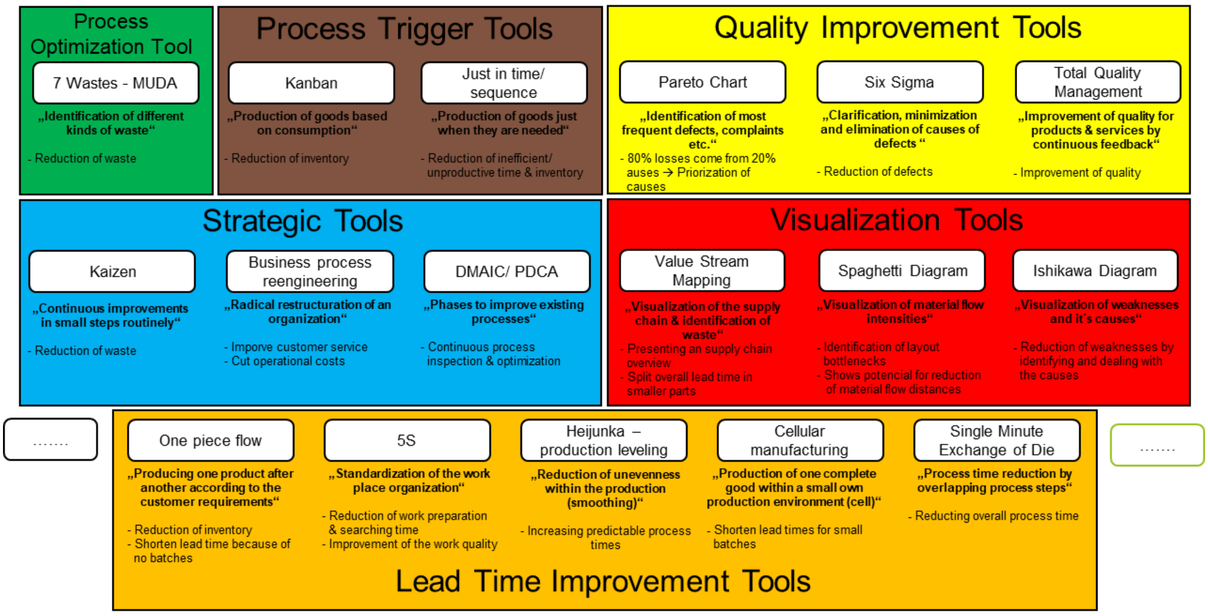

Figure 4: Clustering of production methods/tools (SGKV, 2018)

4. Monitoring of Combined Transport processes on a corridor

To analyse future trends in Combined Transport monitoring an analysis of individual functions in terms of cost and time is needed. The functions are focused on transshipment processes, administration e.g. customs, information system and procedures, interoperability – operations, problems, solutions, organization (e.g. shunting) - and terminal as a whole (organization, capacity, technology, possible improvements…).

Main scope represents the identification of performance indicators (in terms of cost and time) in the entire Combined Transport process, which is seperated to:

- Transport processes and
- Terminal operations

Transport process consist of:

- First mile (operated on road)
- Long haul (operated on rail)
- Last mile (operated on road)

Terminal operations can be:

- Handling
- Shunting
- Storage, parking
- Administration procedures (documentation, booking, weight/gauge inspection, clearance)
- Transport at terminal
- Road traffic from/to terminal (access gate)
- Etc.

Terminal operations differ according to the type of transport and terminal (eg. Port Terminal, RoRo Terminal, Manufacturer Terminal, end costumer Terminal, Logistic center, Shunting Terminal/Marshalling yard, border terminal, etc.).

The monitoring of a CT process in general should cover all relevant stakeholders contributing to transport chain and affecting costs and time in CT corridor.

The main material and information processes of relevant stakeholders are presented in Figure 5.

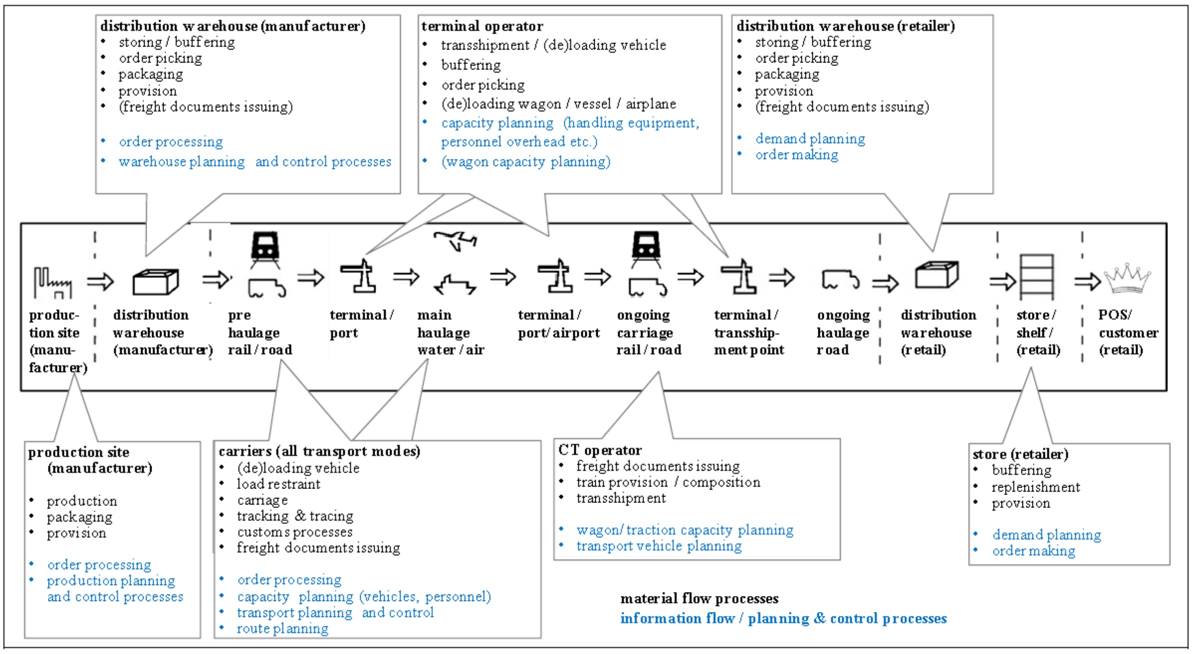

Figure 5: Relevant information and material processes in CT chain (Bendul, 2015)

The Monitoring concept follows the before-after approach, where the monitoring will be performed in two stages:

1. Analysis of existing CT activities and processes on chosen corridors
2. New - improved picture of CT activities and process on chosen corridors (after adoption of measures for improvement)

Combined transport processes can be monitored according to different parameters. Cost and time represent two crucial parameters to be measured for performance analysis. This chapter presents general relationships between costs, distance and time for a CT process. Costs/distance and time/distance relationship in CT Process are presented below. A detailed analyses of CT processes on the corrdors will be made in WPT2.

The basis for implementation of Production optimisation methods represents the cost distance and time distance diagrammes on CT Process with KPI template.

The loading units used for the combined transport are called UTI (Units for intermodal transports - Unité de transport intermodale) or ITU (Intermodal transport unit) or ILU (Intermodal Loading unit). They are characterized by a high transferability, which is the essential element of intermodality. The main elements of the definition of ILU are container, swap body and the semitrailer. The selection of an ILU is depending on the kind of transport (maritime, continental or RoRo). The conversion from ILU in TEU could be done using e.g. the means of the coefficient set at: 1.79 ILU/TEU (e.g. fixed by union of italian freight villages – UIR).

4.3. Costs in CT Process

The costs for Combined Transport process in a corridor consist of costs for transport between nodes and costs in nodes. Figure 6 presents transport cost for main processes in CT consisting of nodes and links between nodes, where monitoring of performance process of CT is presented (costs/distance diagram).

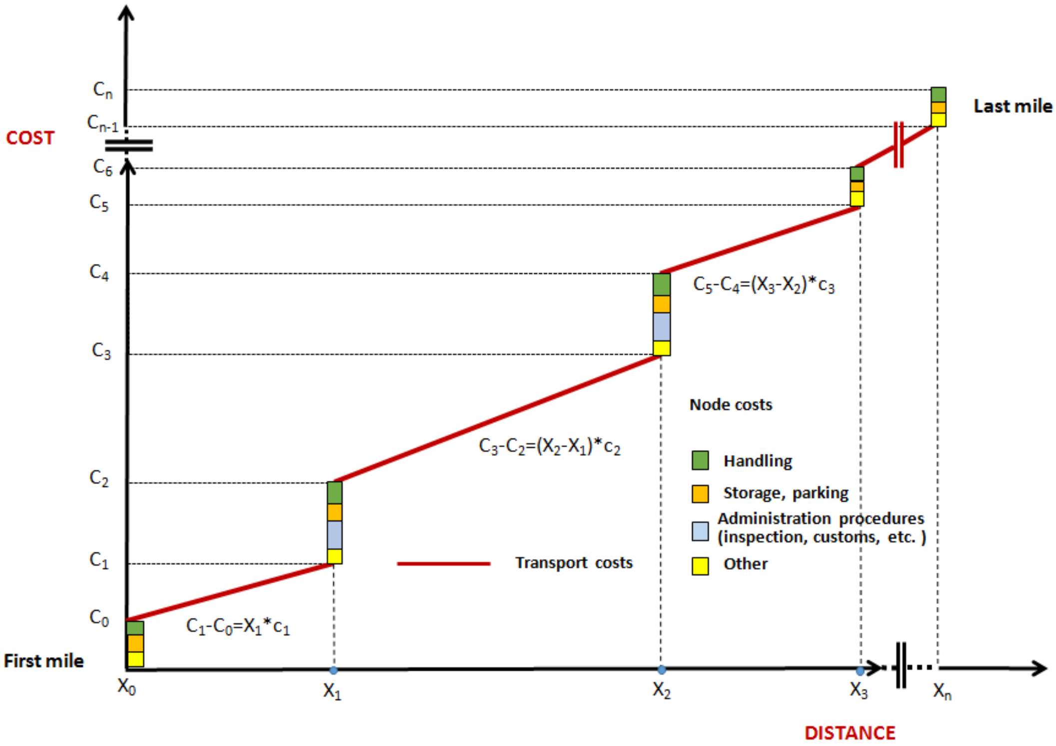

Figure 6: Transport cost for a transport chain

The costs of Combined Transport in the Corridors can be divided into several cost groups referring to transport and nodes. Number of transport links and nodes is to be applied according to individual situation. In the graphs above following index meanings are used:

$x_0, x_1, \ldots x_n$ – represents nodes

x_0-x_1; x_i-x_{i+1}; – represents transport between nodes (terminals)

C_i-C_{i-1} – represents costs in node x_i

C_{i+1}-C_i = c_i - represents costs of transport in the transport link between nodes x_i and x_{i+1}

Costs can be measured in €/tonnekm resp. €/ UTI or TEU or ILU or train and also in €/transhipment (liftings).

Main cost categories can be analysed from the point of view of a user or operator. For the model the unit of measure should be defined as the intermodal transport provides for the adoption of the ITU as standard and not TEU.

Main Terminal operator costs are:

- fix costs (depreciation, labour, ...),
- variable costs (energy, ...):

The aim is to asses costs of terminal per TEU/ILU volume and to compare efficiency of different terminals on the corridor (EUR/TEU). Figure 7 and 8 present the concept of terminal efficiency on a chosen corridor.

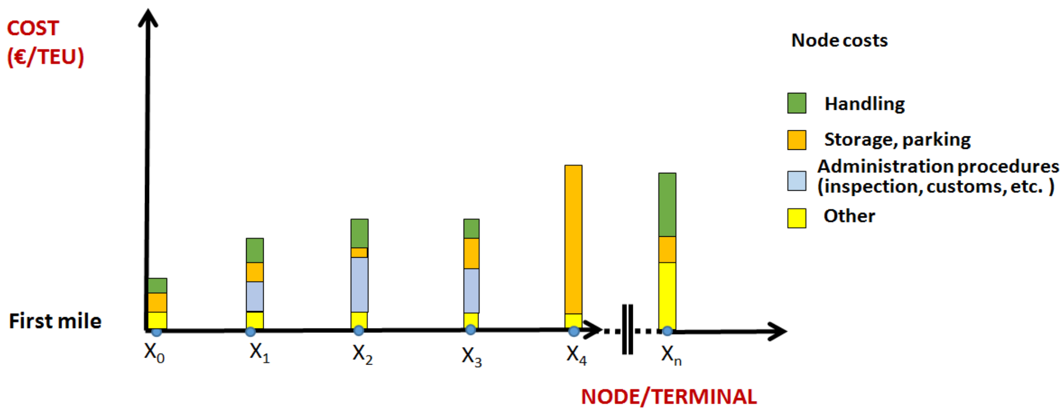

Figure 7: Terminal cost efficency on a chosen corridor

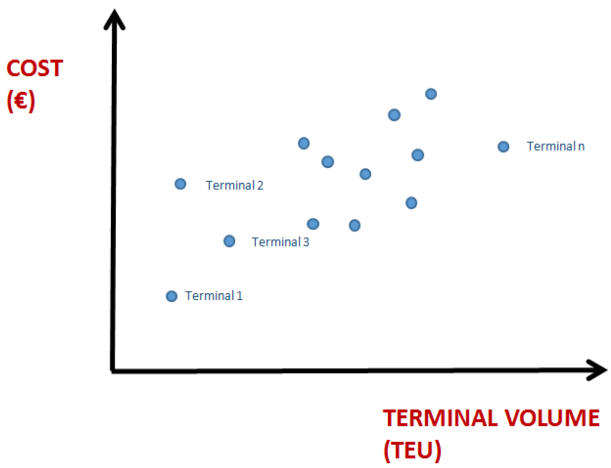

Figure 8: Comparison between terminals (Costs/TEU)

Main User costs at terminals are:

- terminal fee, transhipment fee, administration costs (quality inspection, customs procedures, documents, informatics ...)
- warehousing, parking,
- transport at terminal etc. ...

Main User costs of transport are:

- first mile,
- long haul and
- last mile
- Total

Aim is to assess **Structure and total volume of all transport and terminal costs** (EUR/TEU or EUR/KM) on the entire corridor for:

- existing situation (also comparing with road transport corridor) and
- after implementation of AlpinnoCT project identified measures for improvement of CT processes and procedures.

4.4. Time in CT Process

The time for Combined Transport process in a corridor consists of transport time between nodes and for CT processes in nodes.

Figure 9 presents transport time for a transport chain consisting of nodes and links, where monitoring of performance process of CT is presented (time/distance diagram).

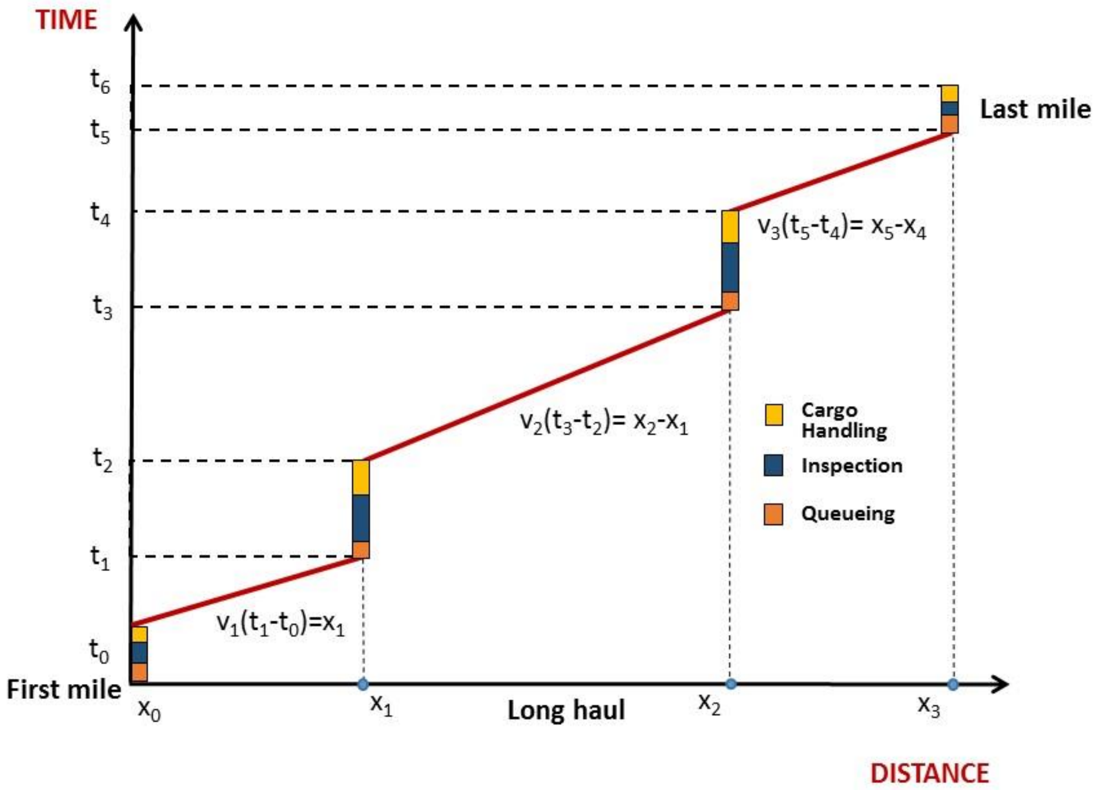

Figure 9: Node/transport time performance monitoring

Main time categories are listed for time at terminals/nodes and transport time between nodes. Transport time can be measured in hours, min/TEU, min/km (or average speed, measured in km/h). The unit depends on the application (e.g. for 1 TEU or 1 block train etc.).

Time needed for individual operations at terminal:

- transhipment (cargo handling),
- marshalling (Shunting),
- waiting time of cargo at terminal (Queueing) and
- administration procedures (e.g. cargo inspection, weight and gauge checking) (min/operation),
- transport at terminal
- damage, checks, repair
- Other

Transport time for combined transport on corridor (distance between x1 and x2-e.g.:t3-t2):

- first mile,
- long haul (O/D total corridor, between individual terminals),
- last mile,
- total (min/km).

Aim is to assess **Structure and total volume of time needed for individual operations at terminal and needed transport time on the corridor** (in hours/minutes) according to:

- existing situation (also comparing with road transport corridor) and
- after implementation of AlpinnoCT project identified measures for improvement of CT processes and procedures.

4.5. Other indicators in Combined transport process

Other key performance indicators can be measured for:

- **Reliability of service** (in terms of timely deliveries), measured in percentage of consignments delivered within a pre-defined acceptable time window);
- **Frequency of service** (measured in number of services per day/ week/month/year);
- **Availability** (rolling stock, off terminal transhipment technologies, required transport capacity)
- **CO_2 (SOx) emissions,(**measured in g/tonne-km); and
- **Capacity (e.g.higher allowance in CT – 44t)**
- **Other.**

4.6. KPI template structure

Relevant KPIs could be selected by the involved stakeholders on the basis of the objectives being pursued – (evaluation possible also within the time framework e.g. today after 5, 10, 20 years…provided the policy & other measures are implemented). The following table presents the KPI template for CT corridor user, which covers main category aspects:

- Financial performance (Finance)
- Operational performance (Time)
- Customer satisfaction (Quality of service)
- Environemntal performance
- Other (Security, Damage)

Table 3: KPI template for CT Corridor

Category	Sub category	Indicator	Unit
Financial performance	Terminal operations	Terminal fee	€/TEU
		Transhipment fee	€/TEU
		Administration costs (quality inspection, customs procedures, documents, informatics …)	€/TEU
		Warehousing, parking	€/TEU
		Transport at terminal etc …	€/TEU
		Other (e.g. Costs for damage of loading unit/cargo, VOT etc.)	
	Transport	Total origin – destination transport cost on a CT corridor	€/TEU or €/km
		First mile costs	€/TEU or €/km
		Long haul cost (including shunting)	€/TEU or €/km
		Last mile costs	€/TEU or €/km
		Other	
Operational performance (time)	Terminal operations	Total terminal time	min/TEU or min/block train
		Transhipment (cargo handling)	min/TEU or min/block train
		Marshalling (Shunting)	min/TEU or min/block train
		Waiting time of cargo at terminal (Queueing)	min/TEU or min/block train
		Administration procedures (e.g. cargo inspection, weight and gauge checking) (min/operation	min/TEU or min/block train
		Transport at terminal	min/TEU or min/block train
		Terminal capacity	Trains handled / day

	Transport	First mile	min/km
		Long haul (O/D total corridor), between individual terminals),	min/km
		Long haul (between individual terminals)	min/km
		Last mile,	min/km
		Total	min/km
		Other	
Customer Satisfaction (Quality of service)	Reliability of service	On - time delivery	% of consignments delivered within a pre-defined acceptable time window;
	Frequency of service	Trains per day, Number annualy trains / working days	number of services per day/ week/moth/year); Numbers couples train for railroad track dedicated in one day
	Availability	Rolling stock	% of fleet
		Off terminal transhipment technologies	
		Required transport capacity	Max. TEU/rail link
		number of craneable railroad tracks	
	Other	Time rail plant opening / Efficiency	Number of hours between the arrival and departure of freight train after processing
Environmental performance	CO2 (SOx) emissions	Population affected with CO2 (SOx) emissions	g/tonne-km
	Noise	Population affected with noise	
Other	Security	Number of thefts	Number of thefts
	Damage	Damages/losses/ per TEU	Damages/losses/ per TEU

5. Applicability of Lean principles in CT - identification and depiction of production optimization methods & tools

The identification of production optimization methods and tools is based on reviewed literature of methods and their functional solutions in industry processes. The Table 4 presents the possible implementation of solutions in industry process to Combined Transport processes. The table presents the main category of KPI for which the selected method is most relevant.

For a more flexible and innovative CT process, the process should meet the end user requirements, set measurable and achievable targets and implement proposed optimisation methods.

Table 4: Possible applicability of Industry process solutions to Combined transport

CT Process main KPI Category	Method	Industry Process Solution
Quality of service	JIT, KANBAN	Few suppliers with long term open relationship
Operational performance	JIS and JIT	Perfect sequence
Quality of service	KANBAN	Kanban cards to identify critical inventories
Quality of service	KAIZEN	Continuous change of small level improvements by workers
All Categories/ Quality of service	BPR (Business Process Reengineering)	Fundamental change of processes
Quality of Service (including damage loss)	6 Sigma	Reduction of defects - statistically (according to different roles of staff and their level of education)
Quality of Service	TQM (Total Quality Management)	Autonomous maintenance
Quality of Service	TQM (Total Quality Management)	Establish standards
Quality of Service	TPM (Total Productive maintenance)	Clear hierarchy of maintenance management
Operational performance	5S	Organize workplace
Operational performance	Cellular manufacturing	Defects repaired in a cell, not in usual company batch
Operational performance	Value stream mapping	Detect waste
Operational performance	MUDA – 7 wastes	Disposal of defective goods
Operational perfomance	MUDA – 7 wastes	Disposal of overproduction or early production
Operational performance	SMED (Single Minute Exchange of Die)	Splitting the external and internal setup of production in time of machinery changeover

Quality of Service	Fishbone Diagram	Identifiying the root cause of a problem
Operational performance	Heijunka	Leveling – constant speed of production
Operational performance	One piece flow	One product at a time, next product with different requirements
Operational performance/ Quality of Service	Pareto chart	Prioritize the causes of defects and complaints
Operational performance/Quality of Service	Spaghetti Diagram	Change of layout, due to minimized walking/motions/transportation
Quality of Services (continuous improvement)	DMAIC (Define, measure, Analyse, Improve and Control)	Clearly defined sequences for improving the existing process and its »nonquality« parts
Quality of Services (continuous improvement)	PDCA (Plan Do Check Act)	Clearly defined sequences for improving the existing process and its »nonquality« parts

The table helps decision makers to select the method according to identified problems. In AlpInnoCT WP1 problems were identified as:

- Barrires of CT implementation (based on questionaire – Deliverable T1.1.1 – WP1)
- Weaknesses of CT (based on analysis of policies, strategies and funding schemes – Deliverable T1.1.1 – WP1)
- Bottlenecks of Transhipment technologies and CT processes (Deliverable T1.2.1)

According to results of the questionnaires most important identified barriers:

- Lack of incentives in some Alpine countries
- Insufficient standards
- Lack of cooperation between actors and transport modes

Weaknesses of CT were identified from Infrastructure, Management and Service point of view:

Infrastructure (differences in energy and signalling systems in EU, insufficient train capacity, interoperability deficit of rail infrastructure (train lenght, maximum weight), lack of maintenance of infrastructure, low average commercial speed, low density of CT terminals, uncoordinated infrastructural works).

Management (lack of open access, lack of service guarantees (no cooperation between main actors).

Services (Costly last mile, deficit in cost-efficiency (e.g. handling costs, costs for short shipping), insufficient ICT capabilities, lack of operational service quality (waiting times at gates, lack of storage areas), lack of standardisation about technical and administrative procedures, non harmonized terms and conditions for rail access).

Bottlenecks of transhipment technologies and CT processes:

- Different loading times (per train, per wagon)
- Different infrastructure and rolling stock requirements (e.g. transhipment vertical-horizontal, loading platform, pocket wagon, slot availability)
- Terminal investments needed (only some technologies relevant for all TEN-T corridors in the Alps)
- Different requirements for selected Intermodal Loading Unit (container, swap body, semitrailer –noncraneable-craneable)

The selection of the method for testing and tools should be in line with the clear identification of objectives and targets to solve according to identified problem/bottleneck.

Table 5: Main problems in CT in Alpine space and suggested lean method

Main Problems of CT in Alpine Space	**Possible Optimisation Method**
Insufficient standards	TQM
Lack of cooperation between actors	KAIZEN
Differences in energy and signalling systems in EU	BPR, SMED
Insufficient train capacity	BPR, SMED
Interoperability deficit of rail infrastructure (train lenght, maximum weight)	TQM,TPM, Heijnuka
Lack of maintenance of infrastructure and rolling stock	TQM, TPM
Low average commercial speed	TQM, TPM
Low density of CT terminals	Value Stream mapping, Spaghetti diagram
Uncoordinated infrastructural works	6SIGMA
Loading/unloading time	MUDA
Resting and transport	MUDA
Needed personal for transhipment	6SIGMA
Operational cost on storing and sorting	Spaghetti Diagram
Terminal space used for transhipment	Value Stream mapping
Train headway (through faster loading)	One piece flow, Cellular manufacturing
Waiting time at terminal (queueing time)	JIT, MUDA
Lack of Storage at Terminal	Value Stream mapping
Noneffective communication between actors	TPM
Deliver on Time	Kanban, 5S
Identification of causes of damages	Pareto chart, 6SIGMA

6. Conclusions - Towards innovative flexible CT processes in the Alpine Space

The scope of the report is to present an overview of production methods and make an analysis of basic characteristics & development trends in modern industry to be considered in future CT services.

Main findings from our analyses show a relative broad field of applicability of industry optimisation methods and tools in Combined Transport processes.

The CT process is to be improved with measures for digitalisation (also blockchain), automatisations and new technologies (transhipment, driving, handling), outsourcing, asset sharing, production (industry 4.o, 3D printing, robotics) and harmonised push and pull measures (driving bans, subsidies, investments in Infrastructure, rolling stock and terminals, taxing) in Alpine region.

In general the CT processes can be improved from 2 approaches:

- Bottom up approach – smaller changes based on experience/new technologies (e.g. integration of e-freight documents with KAIZEN, Integration of Nikrasa with MUDA)
- Top down approach – bigger changes based on new technologies (e.g. ERTMS on TEN-T Corridors with BPR)

After improvement and starting eliminating wastes (process time, material, tools, space) with concepts and tools like JIT, KANBAN, MUDA, Fishbone Diagramme, additional lean manufacturing methods for leveling and standardisation could be used (Heijnuka, 5S, One piece flow, TQM). To continuously improve the CT process, tools like PDCA or DMAIC are to be used. For successul improvement of KPI several measures and lean concepts are to be implemented in parallel.

This approaches are to be used on macro level (for the whole CT process or for individual CT process steps) or on micro level (for optimizing single process steps – e.g. handling).

Additionally the holistic view is important to be considered in improved CT Service, as also minor changes in process can effect other processes (e.g. elimination of paper wagon control may not be efficient, if not all wagon controls on the corridor are not improved with new technologies and/or skilled stuff).

Main criticalities during the future data collection represent lack of statistical data on CT operation (e.g. most ILU on rail are not traced) and non harmonised organisation structure of bodies relevant for CT in individual countries in Alpine space. A main added value of this Deliverable represents a table combining and matching CT processes and industrial process solutions, it represents an entry point for the definition of a measures within the pilotcorridors (as task of WP3 and WP4).

The Deliverable provides the compendium of identified barriers and weaknesses in Deliverable DT1.1.1, bottlenecks of Transhipment Technologies in Deliverable DT1.2.1 in order to find solutions on problems of CT from modern industry. The table also provides a review of possible methods and tools to be further analyzed (WP3) and applicable for the pilot (WP4).

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