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Value stream management (VSM)

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 154, *Processes, data elements and documents in commerce, industry and administration*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The value stream management (VSM) method is an effective tool for the collection, evaluation and continuous improvement of product and information flows within organizations. The VSM methodology includes the analysis, design and planning of value streams. In consideration of an ideal state, the current state of the value stream is mapped according to the gathered data and subsequently analyzed to design a future state with less waste and a reduced lead time. Based on a variety of different VSM approaches, which have been developed in the framework of Lean Production primarily since the 1990s, there are communication and collaboration issues during the application of VSM in practice due to different value stream visualizations and associated calculation procedures. In particular, these challenges occur at the interfaces of departments, corporate groups or entire supply chains (see Figure 1). Therefore, the adherence of rules and guidelines in regard to VSM is required to ensure a common and standardized method for the collection, evaluation and continuous improvement of value streams within cross-enterprise value networks.

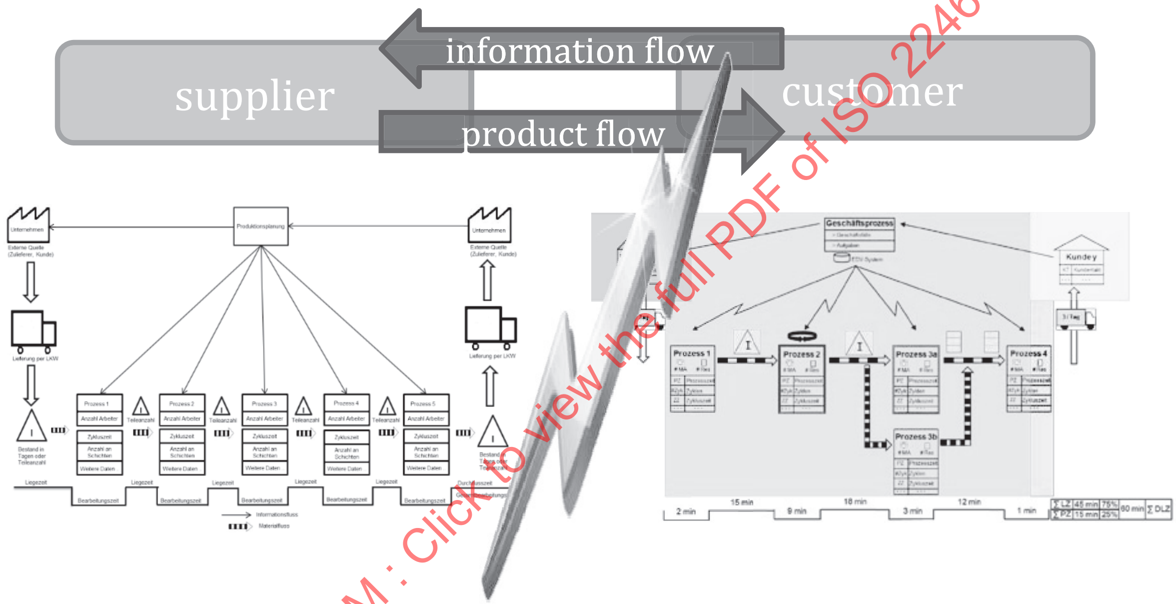


Figure 1 — Communication issues at supply chain interface

This common and goal-oriented application of VSM leads to a reduction or elimination of waste, e.g. unnecessary discussions or the multiple and thus redundant preparation of value stream data targeted to each contact person or auditor are omitted.

With the help of a defined procedure in terms of a unique VSM method, value streams of different sectors and process types are holistically improved. In addition, consistent product and information flows based on a unified VSM method enable a coordinated process planning (see Figure 2).

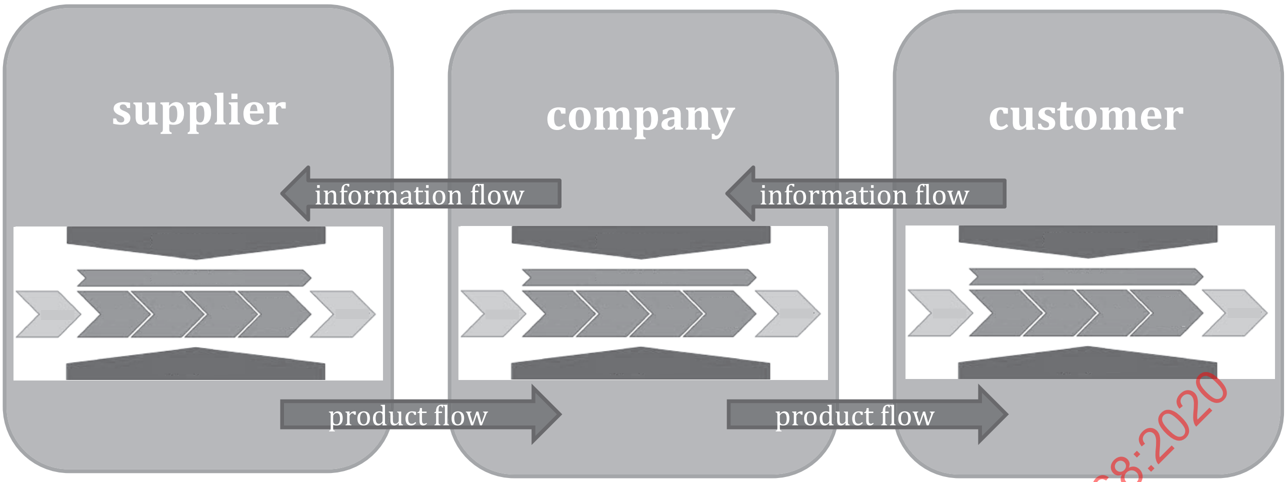


Figure 2 — Integrated supply chain

A common understanding of value streams enables organizations to streamline their internal and external processes. In this regard, the standardized VSM method ensures a unified collection, visualization and calculation of value streams, first within companies or corporations and consequentially along supply chains.

All information or requirements within this document can be transferred to any process type. Figure 3 shows a suitable scheme for the structuring of different process types[2].

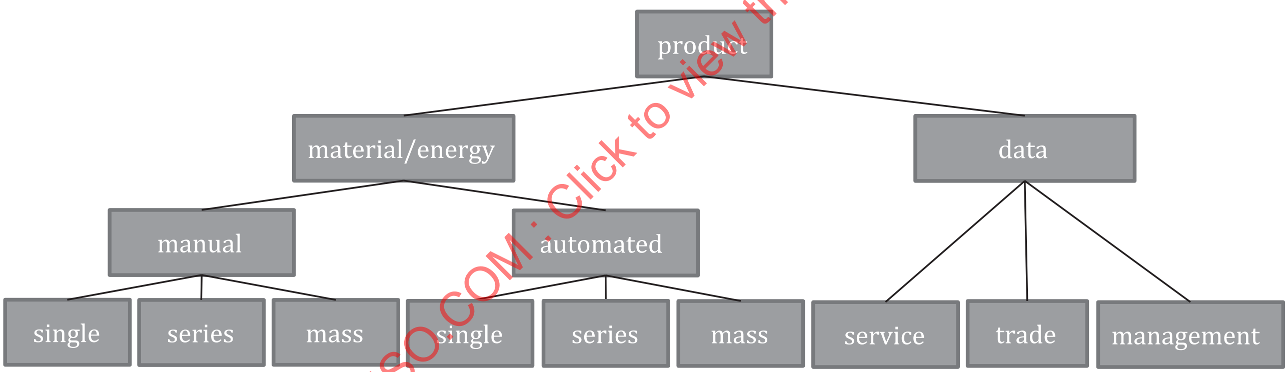


Figure 3 — Main process types

The downstream-oriented product flow in Figure 2 can be generated by material-, energy- or data-related processes. The material- or energy-related processes can be further separated in manual or automated processes of either single, series or mass production. The data-related processes comprise service, trade or management processes.

Value stream management (VSM)

1 Scope

This document provides guidelines for the application of VSM with regard to the collection, evaluation and continuous improvement of value stream relevant data. In addition, it describes the assessment of value streams based on defined key performance indicators.

The VSM method described in this document is generally applicable to material-, energy- or data-related process types. In practice, there are often hybrid forms of these main process types.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
batch size
number of jointly processed (semi-finished) products

3.2
bottleneck
most heavily loaded process (step) in terms of capacity, which is dynamically changing

3.3
continuous improvement
identification of improvement potentials in the sense of a continuous improvement process (CIP) in small steps

3.4
control-ticket
internal purchase requisition, which is used for product flow control (e.g. card, box or electronic)

3.5
customer takt
time interval, which corresponds to the operating time in relation to the (expected) customer demand per period under review

Note 1 to entry: Customer takt is expressed in time unit per piece.

3.6
lead time
time period from the date of order receipt to the transfer of the product to the end customer

3.7
pacemaker process
process step, which sets the pace for the overall process flow

3.8
product family
group of product variants, which require identical or similar process steps

Note 1 to entry: Within this document the term "product" can be understood as material-, energy- or data-related.

3.9
push system
control of product flow based on upstream processes

3.10
pull system
control of product flow based on downstream processes

3.11
range of inventory
time period, which corresponds to the current inventory levels in stock and warehouse

3.12
relative value stream performance indicator
comparative key performance indicator for the assessment of the future state in consideration of the current state of the *value stream* (3.14), in contrast to absolute value stream performance indicators

3.13
supermarket
central instrument with regard to *pull systems* (3.10), which enables a demand-oriented withdrawal

3.14
value stream
all processes oriented at customer demand, that is in particular product and information flows

3.15
value stream mapping
method to develop the current state map of product and information flows within organizations

Note 1 to entry: Value stream mapping is one step of the overall procedure VSM.

3.16
work in process
WIP
total stock level or total range of released starting products and (semi-finished) products within considered *value stream* (3.14), which are either in process or waiting for further processing

4 Value stream management

4.1 Basic VSM procedure

Figure 4 shows the basic procedure of VSM.

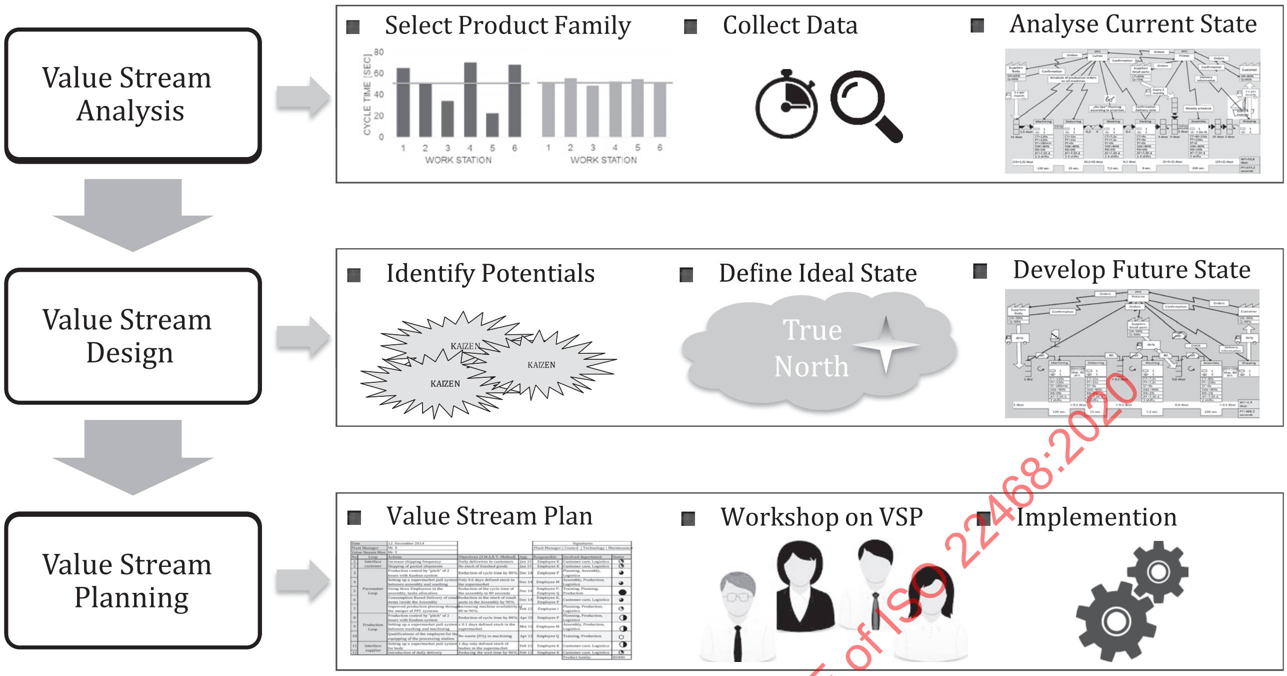


Figure 4 — Basic VSM procedure

The basic VSM procedure can be divided into three main phases: value stream analysis, value stream design and value stream planning. After the selection of a representative product family, relevant data is collected in regard to the current state of the value stream. Based on this current state, concepts for the identification of improvement potentials such as continuous improvement are applied, which lead under consideration of an ideal state as guidance to the desired future state. The individual suggestions for improvement are documented in a catalogue of measures for improvement. Subsequently, this value stream plan is discussed with the responsible employees and implemented within the organization.

These three phases are part of the PDCA (plan-do-check-act) cycle, as they cover “plan” and “do”. Referring to ISO 9001, the first eight steps cover “plan” and the last step, the implementation itself covers “do”. The two missing phases, “check” and “act” are only possible at a later time, since they require a monitoring and an adjustment of the implemented changes. Therefore, they are not included within the basic VSM procedure, but carried out later. In order to conclude the PDCA cycle, an assessment of the value stream is carried out (check), which compares the previous with the target state. The last part covers individual adjustments (act) of the operating value stream to guarantee a stable proceeding. Following this procedure, continuous improvement is ensured by using the PDCA cycle as a frame of reference.

In 4.2 to 4.4, the different phases will be elaborated in detail.

4.2 Value stream analysis

4.2.1 General

The value stream analysis phase is divided into three fundamental steps, which are specified in 4.2.2 to 4.2.4.

4.2.2 Selection of a product family

First, a product family needs to be selected to reduce the complexity of the subsequent steps to collect data as well as to analyze the current state. This product family shall have the following characteristics:

— identical or similar process steps and associated product variants;

— representative product of the organization, with strategic or economic importance;

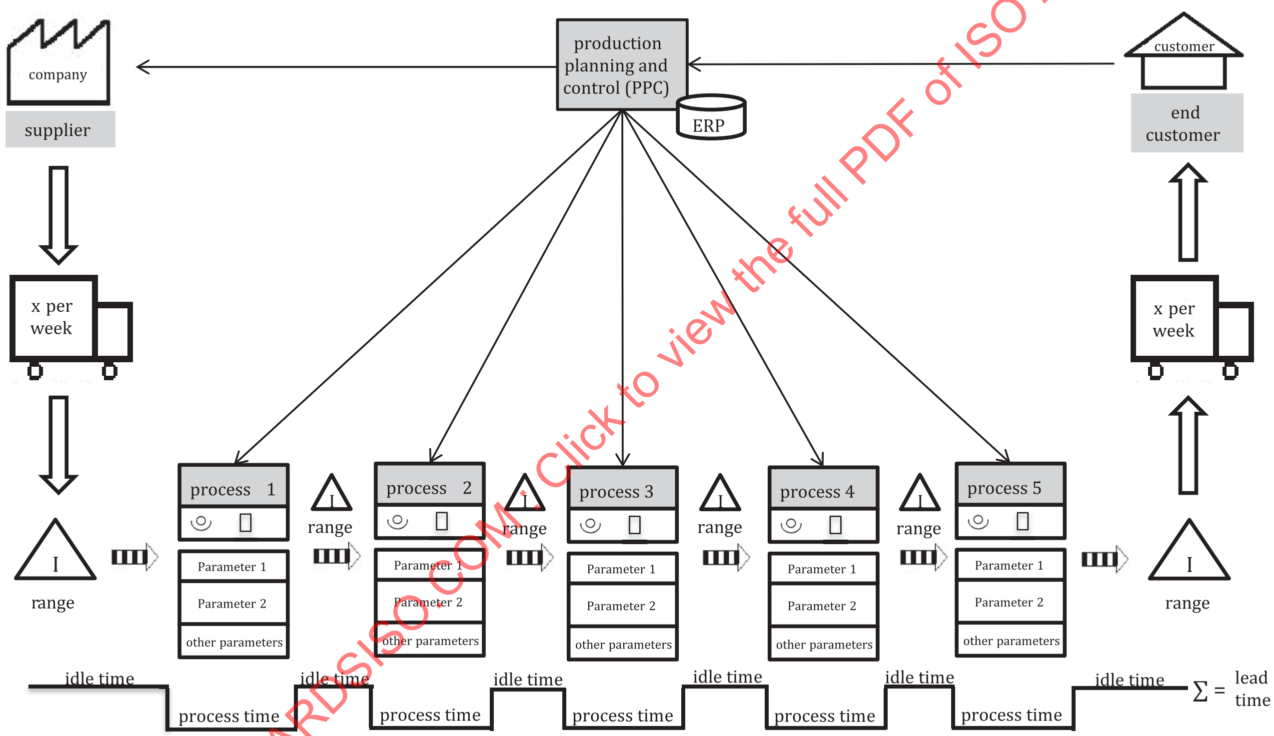
— preferably balanced sales, order or processing volume, no or small takt time variations.

4.2.3 Data collection

For the selected product family, a subsequent collection of value stream relevant data is performed as a second step of the value stream analysis phase (see A.3 for parameters and calculation procedures). For this, i.a. data originating from interviews with process participants, measured or estimated values as well as system data needs to be captured and processed for the later analysis of the current state. A selection of relevant parameters for particular process types is listed in Annex A and Annex B.

4.2.4 Analysis of the current state

Based on the selected product family, the current state of the value stream is analyzed. For this purpose, the captured parameters are mapped comprehensively in form of a value stream map, which shall be in accordance with Annex A. Figure 5 shows the typical setup of a value stream map.



Key

information flow

material flow

Figure 5 — Typical setup of a value stream map, current state

Since the VSM method is oriented to the needs of the end customer, the symbol for the end customer (A.2) is placed first in the right upper part of the value stream map and associated parameters (A.3) are gathered. Then, the external product flow to the end customer is depicted. Subsequently, the actual process flow with associated data boxes (B.1) and the external process flow from the suppliers, which are illustrated with a supplier symbol in the left upper part of the value stream map, are captured. Furthermore, the information flow among customers, suppliers and processes as well as the process planning and control is visualized. Finally, a value stream assessment based on criteria like lead time (bottom line in Figure 5), costs or resource consumption is performed.

A combination of the typical value stream map (Figure 5) with flowchart elements or swim lane diagrams can be advantageous for example in case of data-related process types to illustrate the detailed process sequence or to clarify responsibilities (see an application example in B.4).

4.3 Value stream design

4.3.1 General

The value stream design phase can be divided into three steps: the identification of improvement potentials, the definition of an ideal state as guidance as well as the design of a future state.

4.3.2 Improvement potentials

In consideration of the 7 types of waste[3], the goal of value stream design is to reduce or eliminate deficits with regard to the product and information flow, which have been identified during the value stream analysis phase. Based on the gathered value stream data of the current state, suggestions for a subsequent implementation of improvements in terms of a CIP are collected and documented, e.g. these suggestions for improvement are displayed as continuous improvement flashes in the value stream map, which shall be in accordance with Annex A.

4.3.3 Orientation towards an ideal state

As a second step of the value stream design phase, an envisaged but practically not achievable ideal state is defined as guidance. This ideal state represents a perfect, waste-free process flow, which can be carried out in minimal lead time.

4.3.4 Design of a future state

By means of the ideal value stream and under consideration of the following guidelines[4], an improved future state as compared to the current state is developed. The value stream map of the future state shall be in accordance with Annex A.

- takt time at the pacemaker process;
- supermarket or direct shipping;
- continuous product flow;
- supermarket pull systems;
- definition of pacemaker process;
- levelling of product mix at the pacemaker process;
- release of products at the pacemaker process;
- further process improvements in terms of a CIP.

During the design of a future state also the collected potentials or developed suggestions need to be considered for the continuous improvement of the value stream. This future state is to be pursued subsequently.

4.4 Value stream planning

4.4.1 General

The value stream planning phase comprises a collection of improvement suggestions in form of a catalogue of measures to achieve the envisaged future state, a cross-departmental workshop with the responsible employees as well as the implementation of the previously discussed measures.

4.4.2 Catalogue of measures for improvement

For the documentation of improvement suggestions, a catalogue of improvement measures for defining, limiting and linking the actions to responsibilities is suitable. With regard to the detailed definition of individual measures, the so-called SMART method shall be applied, so that individual goals are "specific, measurable, accepted, realistic, and time-related[5]". In addition, the status of implementation of the different measures or actions shall be noted.

4.4.3 Workshop on value stream plan

Subsequently, the compiled catalogue of measures shall be communicated to the responsible employees within the organization and, if required, internally discussed. This allows identifying and addressing risks of the suggested changes and accordingly concludes “plan”.

4.4.4 Implementation

Based on the agreement, the determined measures are implemented within the organization in the context of a CIP. This step deals with the realization of what was planned and complies with “do”.

4.5 Assessment of value streams

4.5.1 General

For the assessment of value streams, the following key performance indicators and assessment concepts are suitable (see A.3 for parameters, calculation procedures and example). In addition, a later monitoring of the changed value stream is required. Thus, this function corresponds to “check”.

4.5.2 Value stream performance indicators and assessment concepts

Relative value stream performance indicators provide an analysis with regard to the performance of the future or target state in comparison with the current or actual state of the value stream (indices ACT and TAR). Thus, to assess value-adding and non-value-adding value stream shares, the following KPIs for a relative assessment of (non-) value adding shares (VAS and NVAS) from a customer perspective shall be determined.

TOTAL lead time: $t_{\text{LT}} = \sum t_{\text{PT}} + \sum t_{\text{IT}}$

ACTUAL value adding share: $S_{\text{VA ACT}} = \frac{t_{\text{PT ACT}}}{t_{\text{LT ACT}}}$

ACTUAL non-value adding share: $S_{\text{NVA ACT}} = \frac{t_{\text{IT ACT}}}{t_{\text{LT ACT}}}$

TARGET value adding share: $S_{\text{VA TAR}} = \frac{t_{\text{PT TAR}}}{t_{\text{LT TAR}}}$

TARGET non-value adding share: $S_{\text{NVA TAR}} = \frac{t_{\text{IT TAR}}}{t_{\text{LT TAR}}}$

Based on the determined value stream performance indicators, relative comparison indicators (ω_{PT}, ω_{IT}, ω_{LT}) shall be conducted to assess the benefit of the future state in contrast to the current state.

Key comparison figure process time:
$$\omega_{PT} = \frac{t_{PT\ TAR}}{t_{PT\ ACT}}$$

Key comparison figure idle time:
$$\omega_{IT} = \frac{t_{IT\ TAR}}{t_{IT\ ACT}}$$

Key comparison figure lead time:
$$\omega_{LT} = \frac{t_{PT\ TAR} + t_{IT\ TAR}}{t_{PT\ ACT} + t_{IT\ ACT}} = S_{VA\ ACT} \times \omega_{PT} + S_{NVA\ ACT} \times \omega_{IT}$$

Also an analysis with regard to multiple assessment criteria, beyond the pure consideration of lead time, is useful in some applications of VSM. In this context, a value stream assessment based on criteria like space requirements, resource consumption or costs can be performed (see Reference [6] p. 156 ff.).

Furthermore, a cost-benefit analysis for the assessment of costs and benefits of suggestions for improvement provides a means to get a quantitative analysis with regard to the advantageousness of individual improvement measures. The improvement measures shall be prioritized according to the result of the cost-benefit analysis and subsequently considered and implemented within the process.

In addition to the assessment of the value stream, it is important to monitor the modified value stream over time to detect weaknesses. This helps to determine if all the planned activities are working as expected and to see if any of them has negative impacts on any other areas.

4.6 Adjustment of value streams

4.6.1 General

After a successful assessment and monitoring of the modified value stream, it is important to take actions to further improve the performance and adjust detected inconveniences. Doing so, “act” of the PDCA cycle is as well covered.

4.6.2 Actions for continuous improvement

Based on the previous assessment and monitoring of the modified value stream, it is now possible to adjust detected weaknesses of the operating processes. It is a repetition of the described VSM procedure in context of continuous improvement.

Annex A
(normative)

References for the application of VSM

A.1 General

The selection of value stream symbols (Table A.1), data boxes, parameters (Table A.2) and calculation procedures are based on a comparison of different existing VSM approaches (see References [4], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24]).

A.2 Symbols and terminology

Table A.1 — Value stream symbols

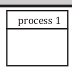
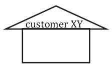
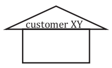
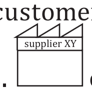
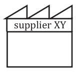
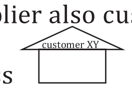
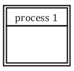
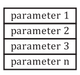
Symbols			
Category	**Symbol**	**Term**	**Additional information/position in value stream diagram**
processes		process	material-, energy- or data-driven process
processes		customer process	differentiation: end customer (symbol customer process)  vs.  customer/plant (symbol external sources) position in value stream diagram: top right
processes		supplier process/ external source	if supplier also customer: use of symbol for customer process  position in value stream diagram: top left
processes		business process, indirect area	use of business process for the detailed definition of communication means (e.g. telephone, mail, IT system, etc.) if needed, number of operators [number or full-time equivalent (FTE)]
processes		shared process/ process with shared resources	double framing
processes		operators	number of operators [number or full-time equivalent (FTE)] position in value stream diagram: within process symbol
processes		resources	define resources for every process type (e.g. machines, area, tools, etc.) position in value stream diagram: within process symbol
processes		data box	(pre-)selection of process parameters, cf. data per process type position in value stream diagram: within process symbol

Table A.1 *(continued)*

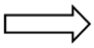
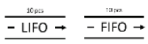
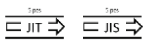
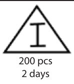
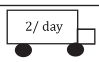
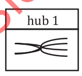
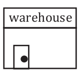
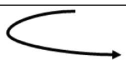
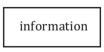
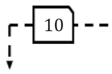
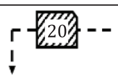
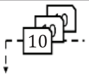
Symbols			
Category	**Symbol**	**Term**	**Additional information/position in value stream diagram**
processes		repetitive process	additional information: number of repetitions position in value stream diagram: above process symbol
processes		bottleneck	position in value stream diagram: above process symbol
product flow		push product flow	product flow controlled by upstream processes
product flow		external product flow	shipments, external logistics
product flow		LIFO lane or FIFO lane	element of process flow control, additional information: process quantity
product flow		Just-in-Time delivery or Just-in-Sequence delivery	element of process flow control, additional information: process quantity
product flow		stock	inventory triangle incl. I for inventory, additional information: number of products or range
product flow		warehouse	organized warehouse, safety stock, additional information: number of products or range
product flow		supermarket	element of pull system (product flow controlled by downstream processes) additional information: number of products or range
product flow		withdrawal	element of pull system (product flow controlled by downstream processes)
product flow		truck transport	additional information: delivery frequency
product flow		other transport means	additional information: delivery frequency, Microsoft Visio symbols
product flow		distribution center / hub / cross-dock	external logistics, distribution of product
product flow		external warehouse	external logistics, storage and distribution of product, additional information: number of products or range
product flow		milk run	delivery concept
product flow		express delivery	exceptional delivery with reduced delivery time
Planning/ controll		manual information flow	e.g. list, label, document
Planning/ controll		electronic information flow	e.g. telephone/fax, mail, EDI
Planning/ controll		information	detailed information: data set document list 
Planning/ controll		synchronization	in case of branched value streams possible differentiation between and linking of main and ancillary routes

Table A.1 *(continued)*

Symbols			
Category	**Symbol**	**Term**	**Additional information/position in value stream diagram**
Planning/ controll		production control-ticket	process flow control from supermarket to upstream process, additional information: release unit
Planning/ controll		withdrawal control-ticket	process flow control from downstream process to supermarket, shaded, additional information: release unit
Planning/ controll		control-ticket in batch size	collection of production Kanban
Planning/ controll	OXOX	load levelling	balancing of product mix
Planning/ controll		GoSee production planning	manual observation of process flo
Planning/ controll		order backlog	for business processes, similar to inventory triangle for production processes
general		Continuous Improvement flash	incl. description, numbering and possibly colored highlighting (e.g. yellow/orange)

A.3 Parameters, calculation procedures and example

A.3.1 Parameters

Table A.2 — Parameters

List of symbols				
Symbol	**Indicator**	**Unit**	**Type**	**Definition**
K_{CUT}	**customer takt**	time unit per pieces	key performance indicator	CUT: Operating time in relation to the (expected) customer demand per period under review
K_{INVT}	**inventory turns**	pieces per time unit	key performance indicator	INVT: Number of complete withdrawals of average stock level from inventory for selected product family per period under review
K_{OTIF}	**on-time in-full**	%	key performance indicator	OTIF: Delivery of the product to the end customer in the right quantity, location and time
K_{RR}	**rework rate**	%	key performance indicator	RR: Number of intermediates or products that can be corrected subsequently
K_{SR}	**scrap rate**	%	key performance indicator	SR: Number of defective intermediates or finished products in relation to the total amount
K_{VAR}	**value added ratio**	%	key performance indicator	VAR: Ratio of value adding time to total lead time
K_{YF}	**yield factor**	%	key performance indicator	YF: Number of correct intermediates or finished products in relation to the total amount

Table A.2 *(continued)*

List of symbols				
Symbol	**Indicator**	**Unit**	**Type**	**Definition**
t_{AT}	**ancillary time**	time unit	time	AT: Time period parallel to the actual process time in which secondary activities associated with the processing are performed
t_{CT}	**cycle time**	time unit	time	CT: Time interval for the completion of one product within a process
t_{DT}	**downtime**	time unit	time	DT: Total time period needed to detect and correct errors or failures
t_{HT}	**handling time**	time unit	time	HT: Time period in which the product is moved or handled within a process
t_{IT}	**idle time**	time unit	time	IT: Time period between two processes (i.e. storage and transport)
t_{LT}	**lead time**	time unit	time	LT: Time period from the date of order receipt to the transfer of the product to the end customer LT_p :Process lead time, equivalent to process time
t_{NNVAT}	**necessary, non-value adding time**	time unit	time	NNVAT: Time period, during which no value from a customer perspective is added to the product, but necessary actions are performed $NNVAT_p$: refers to the process
t_{NVAT}	**non-value adding time**	time unit	time	NVAT: Time period, during which no value from a customer perspective is added to the product $NVAT_p$: refers to the process
t_{OT}	**operating time**	time unit	time	OT: Available time period of employees or other resources per period under review
t_{PRT}	**processing time**	time unit	time	PRT: Time period in which the product is actually or actively processed within a process
t_{PT}	**process time**	time unit	time	PT: Dwell time of the product within a process, machine or station
t_R	**range**	time unit	time	R: Time period, which corresponds to the current inventory levels in stock and warehouse R_S: Range, stock R_W: Range, warehouse
t_{RT}	**repetition time**	time unit	time	RT: Time period for the completion of an iteration within a process
t_{ST}	**setup time**	time unit	time	ST: Time period required for the preparation or the changeover of the process
t_{STT}	**storage time**	time unit	time	STT: Time period for the storage of the product, consisting of inventory range for warehouse and stocks
t_{TBF}	**time between failures**	time unit	time	TBF: Error-free or Failure-free time period between the occurrence of faults
t_{TRT}	**transport repetition time**	time unit	time	TRT: Time period for the movement of single or grouped raw materials, intermediates or finished products
t_{TT}	**transport time**	time unit	time	TT: Time period for the transport or movement of raw materials, intermediates or finished products TT_p: Time period for the transport or movement within a process
t_{TTR}	**time to repair**	time unit	time	TTR: Time period required for detecting and correcting an error or failure

Table A.2 *(continued)*

List of symbols				
Symbol	**Indicator**	**Unit**	**Type**	**Definition**
t_{VAT}	**value adding time**	time unit	time	VAT: Time period, during which value from a customer perspective is added to the product VAT_p: refers to the process
t_{WT}	**waiting time**	time unit	time	WT: Time period, which corresponds to the number of waiting orders WT_p: Waiting time, process
$q_{\#\ (T)Rep.}$	**number of (transport) repetitions**	pieces	quantity	# (T)Rep.: Number of recurring process or transport steps
$q_{\#\ EMP}$	**number of employees**	FTE	quantity	# EMP: Number of employees in Full Time Equivalent (FTE) per process
$q_{\#\ RES}$	**number of resources**	pieces	quantity	# RES: Number of resources per process, e.g. equipment (machines, units, tools, devices), area, energy or financial means
$q_{\#\ F}$	**number of failures**	pieces	quantity	# F: Number of failures in the process flow per period under review
q_{CD}	**customer demand**	pieces	quantity	CD: Required amount of products from end customers per period under review (e.g. customer demand per year)
q_{PQ}	**process quantity**	pieces	quantity	PQ: Total number of orders being processed
q_{SQ}	**stock quantity**	pieces	quantity	SQ: Total inventory (stocks and warehouses) or number of waiting orders of the selected product family

A.3.2 Calculation procedures

All of the used abbreviations of the different parameters can be found in the table above.

$$t_{DT} = \sum t_{TTR} \quad \text{(A.1)}$$

$$t_{IT} = t_{TT} + t_{WT} + t_{STT} \quad \text{(A.2)}$$

$$t_{LT} = t_{VAT} + t_{NVAT} + t_{NNVAT} \quad \text{(A.3)}$$

$$t_{LT} = \sum t_{PT} + \sum t_{IT} \quad \text{(A.4)}$$

$$t_{PT} = t_{CT} * \left(q_{PQ} * q_{\#\ RES}\right) \quad \text{(A.5)}$$

$$t_{PT} = t_{ST} + \left(t_{RT} * q_{\#Rep.}\right) \quad \text{(A.6)}$$

$$t_R = \frac{q_{SQ}}{q_{CD}} \quad \text{(A.7)}$$

$$t_{ST} = t_{PT} - \left(t_{PRT} + t_{WT} + t_{HT} + t_{DT}\right) \quad \text{(A.8)}$$

$$t_{STT} = \sum t_R \quad \text{(A.9)}$$

$$t_{TT} = t_{\#TRep.} * t_{TRT} \quad \text{(A.10)}$$

$$t_{WT} = q_{SQ} * K_{CUT} \quad (A.11)$$

Formulae (A.1) to (A.11) represent the main calculation procedures and below, the calculation procedures of the key performance indicators can be found. All of them are in alphabetical order.

A.3.3 Key performance indicators

$$K_{CUT} = \frac{t_{OT}}{q_{CD}} \quad (A.12)$$

$$K_{INVT} = \frac{q_{usage}}{q_{\varnothing stock}} \quad (A.13)$$

$$K_{OTIF} = \frac{q_{\#\,complete\,\&\,in\,time\,deliveries}}{q_{\#\,total\,deliveries}} \quad (A.14)$$

$$K_{RR} = K_{YF(n+1)} - K_{YF(n)} = K_{SR(n)} - K_{SR(n+1)} \quad (A.15)$$

$$K_{VAR} = \frac{t_{VAT}}{t_{LT}} \quad (A.16)$$

$$K_{SR} + K_{YF} = 100\,\% \quad (A.17)$$

Note for the use of parameters: For calculations, single letter symbols (see Table A.2, first column) are used. For the value stream maps, multiletter abbreviated terms (see Table A.2, last column) are used.

A.3.4 Example and schematically representation of total lead time

The following example should help to visualize and clarify the calculation procedures. In order to do so, certain assumptions and simplifications need to be taken. Therefore, an individual and automated wave soldering process is considered. This is a fictive process, which is separated from all the previous and consequent processes of the value stream.

The aim is to calculate the handling time (HT) of this process. To do so, the following parameters are given in advance:

— $q_{\#Rep} = 2$

— $t_{CD} = 20$ pieces

— $t_{IT} = 10$ s

— $t_{LT} = 45$ s

— $t_{OT} = 3$ s

— $t_{PRT} = 8$ s

— $t_{R} = 3$ s

— $t_{RT} = 12{,}5$ s

— $\sum t_{TTR} = 2$ s

By knowing LT and IT, it is possible to calculate PT by transforming Formula (A.4):

$$\rightarrow t_{PT} = t_{LT} - t_{IT} = 45\,s - 10\,s = 35\,s$$

By transforming Formula (A.6), it is possible to calculate ST:

$$\rightarrow t_{ST} = t_{PT} - \left(t_{RT} * t_{\#pre.}\right) = 35\,s - (12{,}5\,s * 2) = 10\,s$$

In order to calculate SQ, Formula (A.7) needs to be transformed:

$$\rightarrow q_{SQ} = t_R * q_{CD} = 3\,s * 20\,{}^{pieces}\!/_{s} = 60\,pieces$$

And to calculate CUT, Formula (A.12) can be used:

$$\rightarrow K_{CUT} = \frac{t_{OT}}{q_{CD}} = \frac{3\,s}{20\,pieces} = 0{,}15\,{}^{s}\!/_{pieces}$$

Further, it is now possible to calculate WT by using Formula (A.11):

$$\rightarrow t_{WT} = q_{SQ} * K_{CUT} = 60\,pieces * 0{,}15\,{}^{s}\!/_{pieces} = 9\,s$$

The last missing parameter is DT, which can be calculated by using Formula (A.1):

$$\rightarrow t_{DT} = \sum t_{TTR} = 2\,s$$

Now it is possible to calculate the HT, by transforming Formula (A.8):

$$\rightarrow t_{HT} = t_{PT} - \left(t_{ST} + t_{PRT} + t_{WT} + t_{DT}\right) = 35\,s - (10\,s + 8\,s + 9\,s + 2\,s) = 6\,s$$

The handling time (HT), so the time, in which the product is moved or handled within the process, amounts to 6 seconds.

As seen in the example above, all of the listed calculation procedures are easy to handle, in order to calculate different parameters.

In addition to the calculation example, Figure A.1 shows schematically the basic elements of the total lead time of the considered value stream.

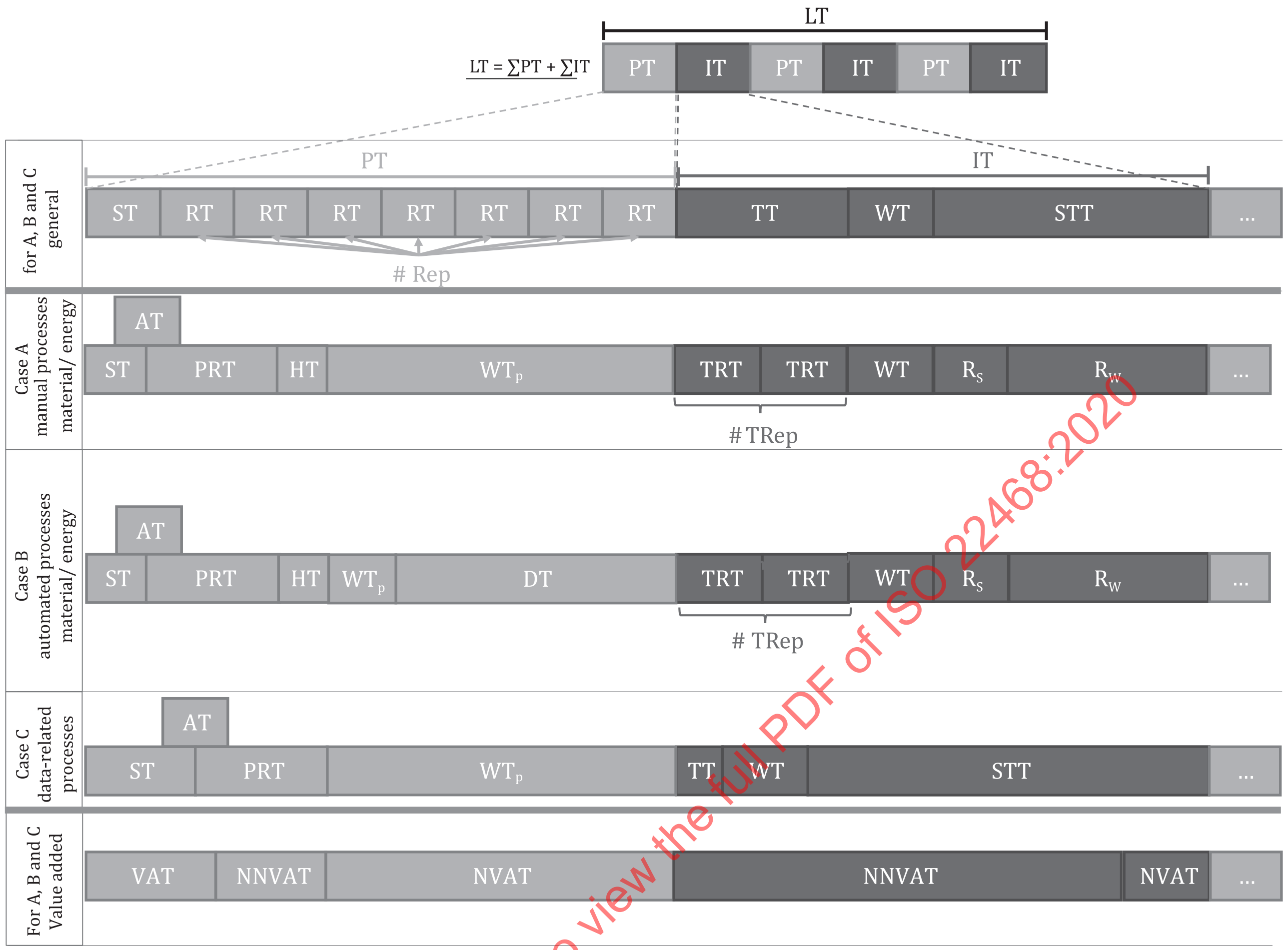


Figure A.1 — Total lead time

This schematic overview contains relevant process parameters to be captured in terms of a holistic lead time analysis. The lead time (LT) of the process flow is composed of the total process time and the total idle time, which in turn results from the sum of the individual process times (PT) and idle times (IT).

The general definition of the process parameters in regard to the process time includes a setup time (ST) and, in case of repetitive processes, the possibility of specifying the number of repetitions (# Rep.) and the time per repetition (RT). The idle time is generally divided into the three time shares transport time (TT), waiting time (WT) and storage time (STT).

Based on the structure of different process types (see Figure 4), three individual cases A, B and C are distinguished below. Case A deals with manual, material- or energy-related processes, Case B takes account of automated, material- or energy-related processes, and in case C, data-related processes are described. In the case of manual, material or energy-related processes (case A), the process time consists of setup time (ST), processing time (PRT), handling time (HT) and waiting time within the process (WT_p). In addition, ancillary times (AT) can be specified in order to take into account activities that run parallel to the actual process time. In case A, the general definition of idle time can be detailed. For multiple repetitions, the number of transport repetitions (# TRep.) and the time per transport repetition (TRT) can be included. The storage time can be divided into a range of stock (R_S) and a range of an organized warehouse (R_W). In the case of automated, material or energy-related processes (case B), the process and idle time are described in analogy to the manual processes, whereby a downtime (DT) of the machine can be considered in the process time if necessary. The process time of the data-related process type in case C is determined based on set-up times, processing times and waiting times within the process. An ancillary time can also be added, which runs in parallel to the actual process time. The idle time for data-related processes is generally divided into the three time shares transport time, waiting time and storage time.

For all three cases, there is a general definition of process parameters as well as a description of process parameters with regard to value-adding, non-value-adding as well as necessary but non-value-adding time shares. As part of a value-added evaluation of the three cases A, B and C, the evaluation parameters value-adding time (VAT), necessary but non-value-adding time (NNVAT) and non-value-adding time (NVAT) can be finally assigned to the described process parameters for the process and idle times.

Annex B
(informative)

Data boxes and application examples

B.1 Data boxes

Table B.1 contains an overview of potential process parameters for the respective data boxes as well as suitable process parameters depending on the process type. Table B.2 summarizes the different process parameters, which are needed for a specific process type.

Table B.1 — Overview of process parameters for data boxes

process parameter per data box	
process parameter	**additional information**
customer process	
product family	
number of variants	
delivery quantity	
customer takt	
delivery reliability	in case of customer specific requirements
production process	
process time	
cycle time	
setup time	
EPEI, batch size	every product every interval
operator	number or full-time equivalent (FTE)
number of product variants	
number of resources	detailed definition of "resource" required
yield factor, scrap rate	
rework rate	in percent, pieces or time unit
time per repetition	
number of repetitions	
transport distance	in case of large distances between processes
value added (VAT, NVAT, NNVAT)	alternatively as bottom line criteria
transport or storage process	
product	
stock quantity	
range of inventory	
value added (VAT, NVAT, NNVAT)	alternatively as bottom line criteria
supplier process	
raw material	
delivery quantity	
replenishment time, delivery time, delivery frequency	

Table B.1 *(continued)*

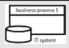
process parameter per data box	
process parameter	**additional information**
value added (VAT, NVAT, NNVAT)	alternatively as bottom line criteria
 **business process**	
business cases	
tasks	
IT system	
operator	number or full-time equivalent (FTE)
value added (VAT, NVAT, NNVAT)	alternatively as bottom line criteria

Table B.2 — Process parameters per process type

relevant process parameter	manual single production	manual series production	manual mass production	automated single production	automated series production	automated mass	services	trade	management	minimum entry
	process parameters per process type									
customer process										
product family	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
number of variants	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
representative	No	possibly	possibly	No	possibly	possibly	possibly	possibly	possibly	
delivery quantity	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
container size, number of parts per	No	possibly	possibly	No	possibly	possibly	No	possibly	No	
available working time	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	
customer takt	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
delivery frequency	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	
delivery time	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	
delivery reliability	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	
value added (VAT, NVAT, NNVAT)	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	
production process										
process time	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
time per repetition	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	
number of repetitions	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	
setup time	possibly	possibly	possibly	Yes	Yes	Yes	possibly	possibly	possibly	
processing time	Yes	Yes	Yes	Yes	Yes	Yes	possibly	possibly	possibly	
cycle time	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
value adding time	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	
waiting time	No	No	No	No	No	No	possibly	possibly	possibly	
machine reliability, availability	No	No	No	possibly	possibly	possibly	No	No	No	
EPEI, batch size	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	
operator	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
number of product variants	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	
number of shifts	Yes	Yes	Yes	possibly	possibly	possibly	No	No	No	
number of resources	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
container size	No	possibly	possibly	No	possibly	possibly	No	possibly	No	
container type	No	possibly	possibly	No	possibly	possibly	No	possibly	No	
number of parts per container	No	possibly	possibly	No	possibly	possibly	No	possibly	No	
available working time	Yes	Yes	Yes	possibly	possibly	possibly	Yes	Yes	Yes	
yield factor, scrap rate	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
rework rate	Yes	Yes	Yes	possibly	possibly	possibly	possibly	possibly	possibly	
customer takt	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	
process quantity	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
number of parts per product	possibly	possibly	possibly	possibly	possibly	possibly	No	No	No	
transport distance	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	No	
section	No	No	No	No	No	No	possibly	possibly	possibly	
area requirement	Yes	Yes	Yes	possibly	possibly	possibly	No	No	No	
value added (VAT, NVAT, NNVAT)	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	

Table B.2 *(continued)*

relevant process parameter	manual single production	manual series production	manual mass production	automated single production	automated series production	automated mass	services	trade	management	minimum entry
	process parameters per process type									
transport or storage process										
name of storage (with/without specification)	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	
type (e.g. FIFO, neutral, manual, unmixed, mixed)	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	
warehouse access (manual/automated)	possibly	possibly	possibly	possibly	possibly	possibly	No	No	No	
product	Yes	Yes	Yes	Yes	Yes	Yes	possibly	Yes	possibly	
storage quantity	Yes	Yes	Yes	Yes	Yes	Yes	possibly	Yes	possibly	
range of inventory	Yes	Yes	Yes	Yes	Yes	Yes	possibly	Yes	possibly	
number of variants	No	Yes	Yes	No	Yes	Yes	possibly	possibly	possibly	
number of parts per product	possibly	possibly	possibly	possibly	possibly	possibly	No	possibly	No	
number of storage spaces	possibly	possibly	possibly	possibly	possibly	possibly	No	possibly	No	
storage capacity	possibly	possibly	possibly	possibly	possibly	possibly	No	possibly	No	
number of containers	No	possibly	possibly	No	possibly	possibly	No	possibly	No	
nontainer size	No	possibly	possibly	No	possibly	possibly	No	possibly	No	
yield per container	No	possibly	possibly	No	possibly	possibly	No	possibly	No	
area requirement, area/piece	possibly	possibly	possibly	possibly	possibly	possibly	No	possibly	No	
transport distance	possibly	possibly	possibly	possibly	possibly	possibly	No	possibly	No	
transport time/piece	possibly	possibly	possibly	possibly	possibly	possibly	No	possibly	No	
operator	possibly	possibly	possibly	possibly	possibly	possibly	No	possibly	No	
value added (VAT, NVAT, NNVAT)	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	
supplier process										
raw material	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
delivery quantity	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
number of types/variants	No	possibly	possibly	No	possibly	possibly	possibly	possibly	possibly	
replenishment time, delivery time, delivery frequency	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
error rate	No	possibly	possibly	No	possibly	possibly	possibly	possibly	possibly	
quantity reliability	possibly	possibly	possibly	possibly	possibly	possibly	No	possibly	No	
delivery reliability	possibly	possibly	possibly	possibly	possibly	possibly	No	possibly	No	
distance	possibly	possibly	possibly	possibly	possibly	possibly	No	possibly	No	
value added (VAT, NVAT, NNVAT)	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	
business process										
business cases	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
tasks	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IT system	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
lead time	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	
order backlog	possibly	possibly	possibly	possibly	possibly	possibly	Yes	possibly	Yes	
operator	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
value added (VAT, NVAT, NNVAT)	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	possibly	

In B.2 to B.4, three examples with respect to the application of VSM in practice are explained. The selected application examples reflect the structure of the main process types shown in Figure 3.

B.2 Application example: industrial production process, automated series

B.2.1 General

The first use case describes the application of VSM in the field of automated series production, which includes i.a. valve or cable production.

B.2.2 Value stream analysis

At the beginning of the value stream analysis phase, a representative product family needs to be selected. Thus, following parameters of the individual product variants are captured and analyzed (Table B.3) .

Table B.3 — Selection of a representative product family

product family	**sales volume**	***rank 1***	***weighting factor 1***	**number of customer orders**	**average customer order quantity**	***rank 2***	***weighting factor 2***	**standard deviation**	**relation standard deviation / average customer order quantity**	***rank 3***	***weighting factor 3***	**observation**	***result***
A	3 500	*0*	*1*	4	875	*4*	*1*	718	82 %	*4*	*4*	variable	**26**
B	6 570	*4*	*1*	7	939	*3*	*1*	1 005	107 %	*6*	*4*	very variable	**31**
C	14 000	*3*	*1*	5	2 800	*1*	*1*	280	10 %	*1*	*4*	stable	**8**
D	6 500	*5*	*1*	17	382	*6*	*1*	214	56 %	*3*	*4*	variable	**23**
E	790	*7*	*1*	7	113	*7*	*1*	36	32 %	*2*	*4*	relatively stable	**22**
F	63 945	*2*	*1*	77	830	*5*	*1*	1 137	137 %	*7*	*4*	very variable	**35**
G	91 485	*1*	*1*	59	1 551	*2*	*1*	1 427	92 %	*5*	*4*	variable	**23**

In this case, product family C is selected, since it shows according to the weighting function a relatively high sales volume and a low volatility of the sales volume within the period under consideration. Based on this product family, the current state of the value stream is subsequently captured, visualized and analyzed (see Figure B.1).

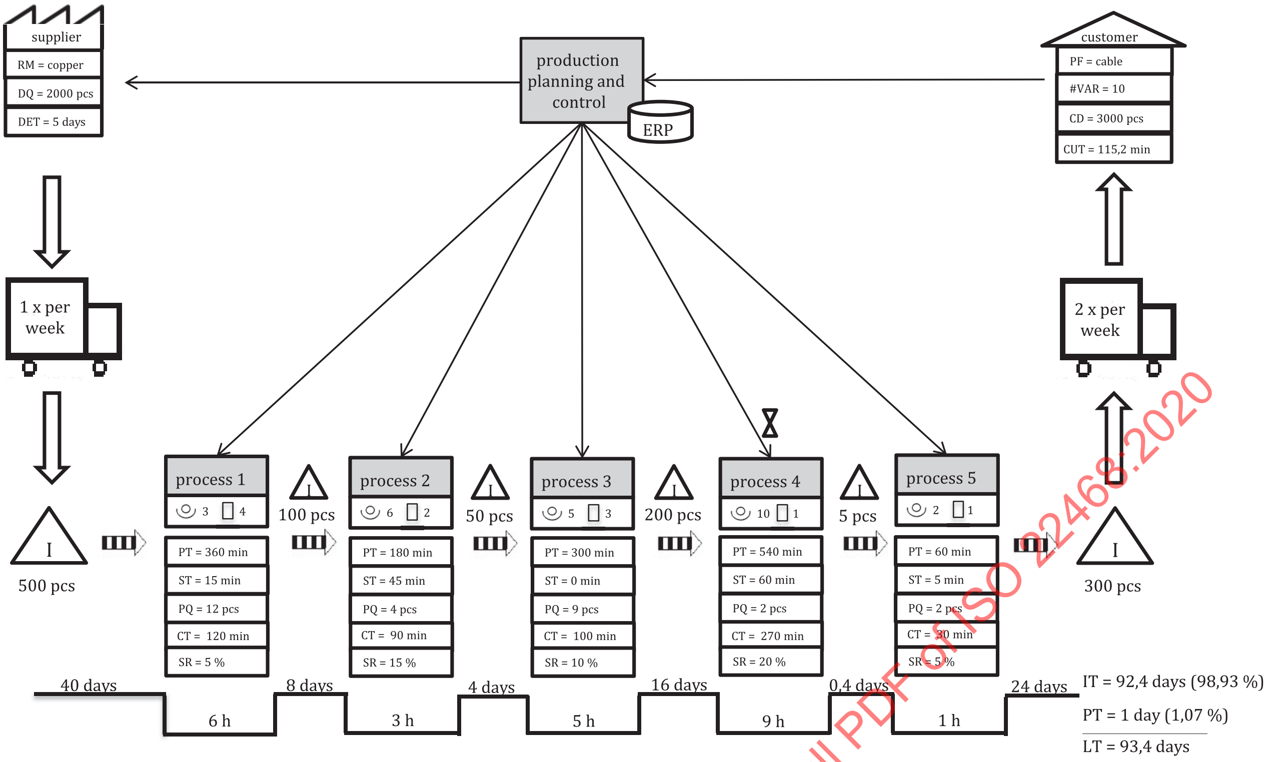


Figure B.1 — Value stream map, automated series production, current state

The available working time in this example of automated series production amounts to 5 760 hours per year (240 days per year, 24 hours per day). The required annual quantity, which equals the yearly customer demand, amounts to 3 000 pieces. Thus, the customer takt in this example is 115,2 minutes per piece.

B.2.3 Value stream design

As a first step of the value stream design phase, several improvement potentials shall be identified based on the results of the Value Stream Analysis phase. These improvement potentials are visualized by means of continuous improvement bursts (see Figure B.2).

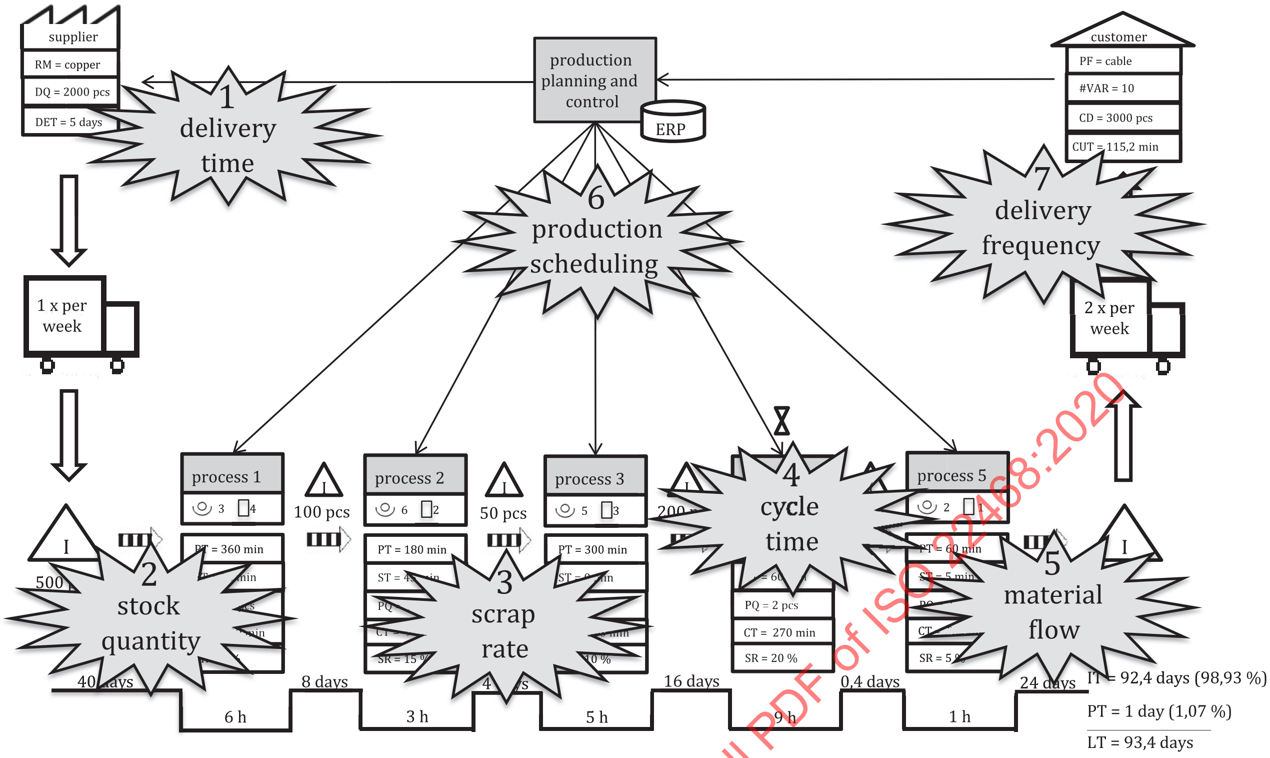


Figure B.2 — Value stream map, automated series production, continuous improvement flashes

An exemplary improvement potential is to enhance the material flow, e.g. by means of visual signals. With the help of an ideal state as guidance and according to the value stream design principles formulated by Rother and Shook[4], a future state is developed (see Figure B.3).

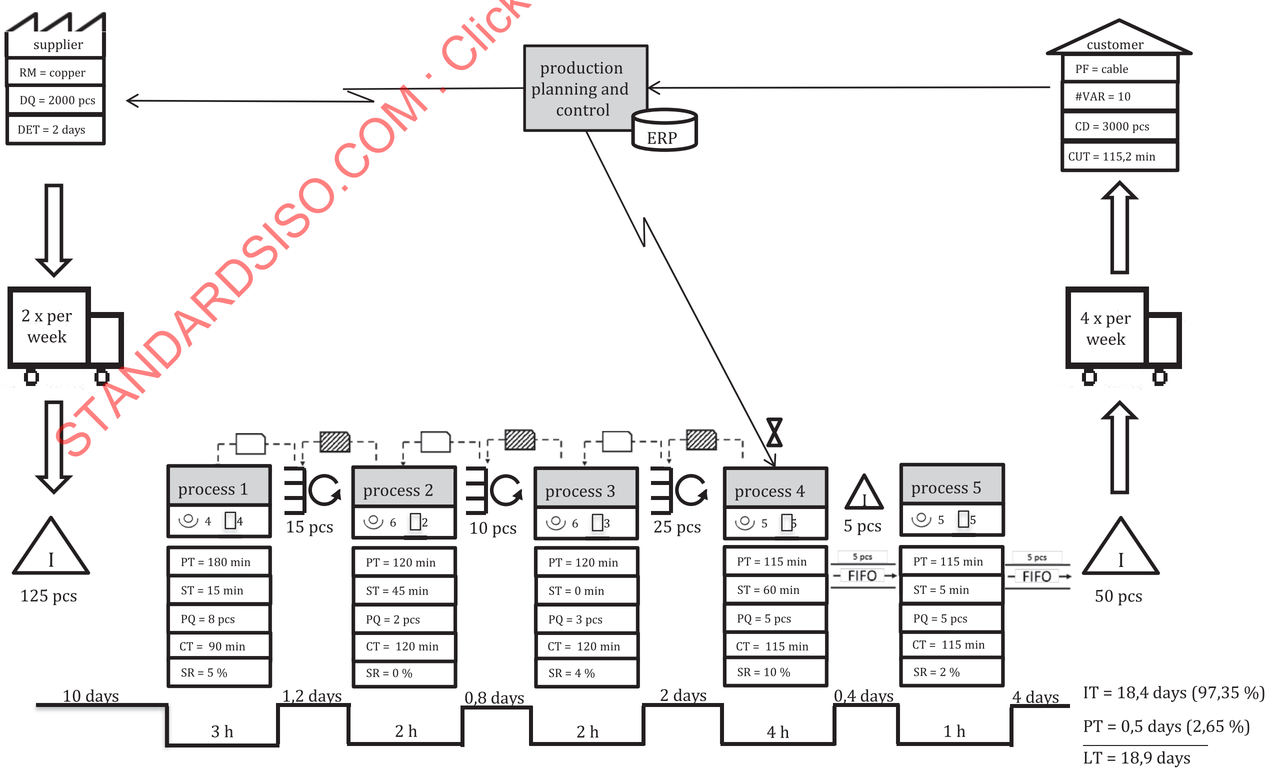


Figure B.3 — Value stream map, automated series production, future state

This future state implies a reduction of the overall lead time to 19 days and is oriented according to the required customer takt. In addition, the planning and control of processes is facilitated and the stock levels and thus the capital commitment between the individual process steps are reduced.

B.2.4 Value stream planning

Based on the identified improvement potentials, a catalogue with measures for improvement in line with the SMART methodology is developed (see Table B.4).

Table B.4 — Catalogue of measures for improvement, application example automated series production

Date	08/04/2017	Catalogue of measures for improvement	signatures			
		automated series production	plant manager | works council | technician | maintenance			
Nr.	**Improvement Potential**	**measure incl. goal (SMART)**	**Deadline**	**Responsible**	**Process/ Department**	**Status**
1	delivery time	Reduction of delivery time in cooperation with copper suppliers in the range of 60 % in comparison to current state	09/15/2017	employee PUR4	Purchasing	◕
2	stock quantity	Reduction of stock quantities of incoming goods, WIP and outgoing goods by more than 50 % each in comparison to current state	11/01/2017	employee LOG1	Logistics	◑
3	scrap rate	Reduction of scrap rate by min. 50 % in comparison to current state at processes 2-5	02/15/2018	employee PRO2	Production	◔
4	cycle time	Adjustment of cycle time according to required customer takt with a max. deviation of ±25 %	06/01/2018	employee PRO5	Planning / Production	◔
5	material flow	Conversion of push system to pull system incl. FIFO scheduling after pacemaker process	03/01/2018	employee PRO1	Planning / Production	○
6	production scheduling	Planning and scheduling of pacemaker process in contrast to planning and scheduling of complete process chain	03/01/2018	employee PRO1	Planning / Production	○
7	delivery frequency	50 % increase of delivery frequency to customers in comparison to current state and adjustment of supplier delivery frequency	10/01/2017	employee SAL3	Purchasing/ Sales	◕

Key

○ Problem detected

◔ Responsibilities clarified

◑ Measure created and checked

◕ Implementation of measure

● Measure implemented and reviewed

This catalogue of measures for improvement is presented to the responsible employees and discussed collectively. After consultation with the responsible employees or the management board, the measures for improvement are prioritized and subsequently implemented within the organization.

B.2.5 Value stream assessment

Key performance indicators and assessment concepts are useful for the evaluation of different value stream states. In the following, value stream performance indicators for this application example are determined.

ACTUAL value adding share: $$s_{\text{VA ACT}} = \frac{t_{\text{PT ACT}}}{t_{\text{LT ACT}}} = \frac{1\ \text{day}}{93{,}4\ \text{days}} = 0{,}011$$

ACTUAL non-value adding share: $$s_{\text{NVA ACT}} = \frac{t_{\text{IT ACT}}}{t_{\text{LT ACT}}} = \frac{92{,}4\ \text{days}}{93{,}4\ \text{days}} = 0{,}989$$

TARGET value adding share: $$s_{\text{VA TAR}} = \frac{t_{\text{PT TAR}}}{t_{\text{LT TAR}}} = \frac{0{,}5\ \text{days}}{18{,}9\ \text{days}} = 0{,}026$$

TARGET non-value adding share: $$s_{\text{NVA TAR}} = \frac{t_{\text{IT TAR}}}{t_{\text{LT TAR}}} = \frac{18{,}4\ \text{days}}{18{,}9\ \text{days}} = 0{,}974$$

Based on the determined value stream performance parameters, the following relative comparison parameters are generated to assess the advantageousness of the future state compared to the current state.

Key comparison figure process time: $$\omega_{\text{PT}} = \frac{t_{\text{PT TAR}}}{t_{\text{PT ACT}}} = \frac{0{,}5\ \text{days}}{1\ \text{day}} = 0{,}5$$

Key comparison figure idle time: $$\omega_{\text{IT}} = \frac{t_{\text{IT TAR}}}{t_{\text{IT ACT}}} = \frac{18{,}4\ \text{days}}{92{,}4\ \text{days}} = 0{,}199$$

Key comparison figure lead time: $$\omega_{\text{LT}} = \frac{t_{\text{PT TAR}} + t_{\text{IT TAR}}}{t_{\text{PT ACT}} + t_{\text{IT ACT}}} = \frac{18{,}9\ \text{days}}{93{,}4\ \text{days}} = 0{,}202$$

According to these key comparison figures, the idle time and the overall lead time of the future state can be reduced to one fifth in comparison to the current state.

B.3 Application example: industrial production process, manual single

B.3.1 General

The second use case shows the application of the VSM method for the process type manual single production. In the following, an exemplary process sequence of a gastronomic business is described.

B.3.2 Value stream analysis

First, a representative product family, which is typical for the present make-to-order process, needs to be selected. The product family burger is selected with respect to historical order data.

Based on this, relevant data such as measured or estimated data originating from interviews with the responsible employees as well as system data, are collected and processed as a second step of the value stream analysis phase.

After the data collection the analysis of the current state starts. For this purpose, a value stream map is prepared, which consists in this specific case of two partial value streams (see Figure B.4).

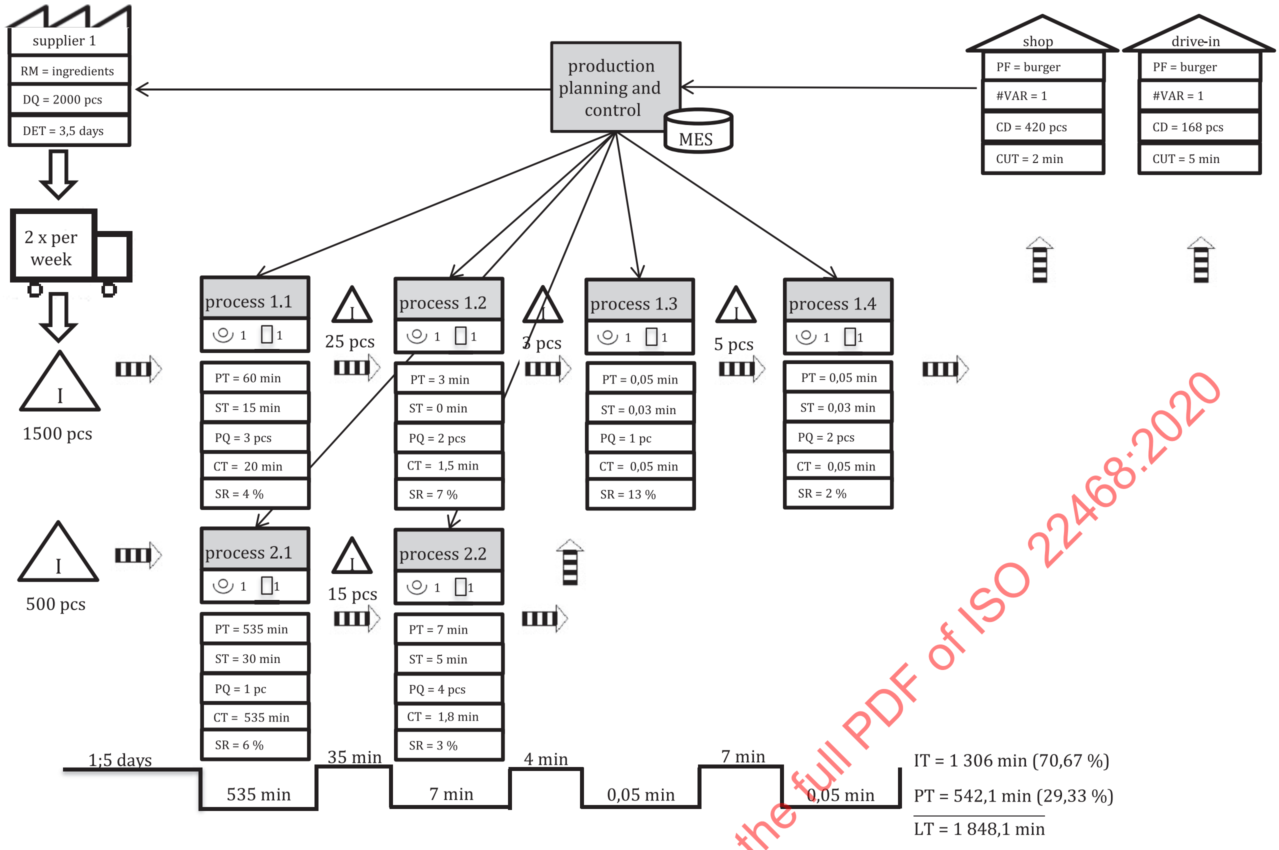


Figure B.4 — Value stream map, manual single production, current state

The shown value stream map reveals some differences between automated and manual process types. On the one hand, the available production time changes depending on the shift system (in this case: 2 shift system, i.e. available production time 14 hours per day in contrast to 24 hours per day as indicated in the application example B.2 for automated production). On the other hand, scrap rates or rework rates are of particular importance in case of manual process types.

Furthermore, different parameters are used with respect to single, series or mass production. In case of single production for example, there is no use of representative, container size or number of types. A consideration of the error rate is also not required in case of a single production.

In complex scenarios it can be useful to perform a detailed analysis of individual processes (see process 2.1 in Figure B.4). For this purpose, the processes are divided into smaller segments, i.e. process steps and analyzed individually. However, the continuous improvement of the global value stream in consideration of the relevant value-adding processes shall be the main objective. Thus, local optimizations are not pursued as an overall goal.

The assessment of the process sequence in Figure B.4 is traditionally related to the lead time. If there is a robust and extensive data base, the value stream assessment can also be performed with further evaluation criteria (e.g. area, resource consumption, cost).

B.3.3 Value stream design

Based on the captured current state, improvement potentials are defined by means of value stream design guidelines (see Figure B.5).

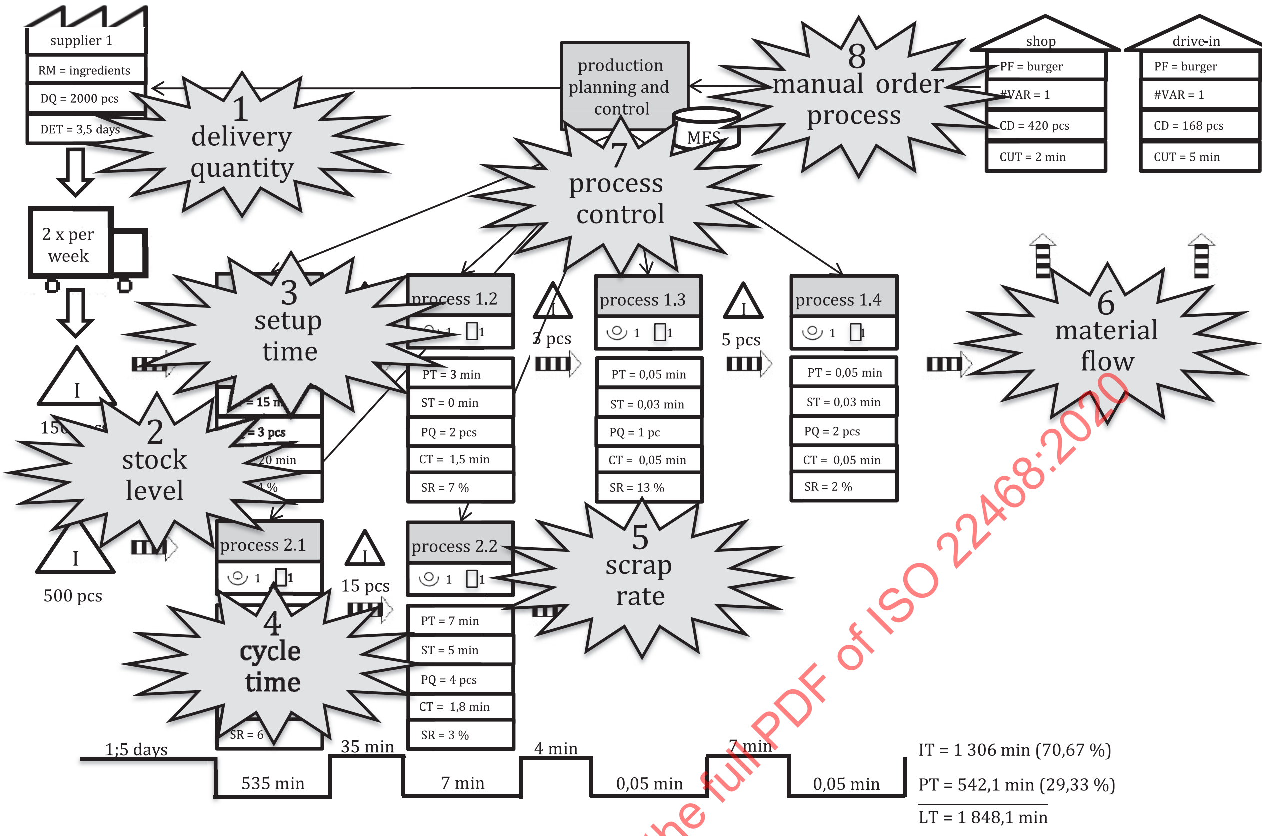


Figure B.5 — Value stream map, manual single production, continuous improvement flashes

Subsequently, a future value stream state is developed under consideration of an ideal value stream state (see Figure B.6).