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Methodical approach to increase productivity and reduce lead time in assembly and production-logistic processes

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ABSTRACT

The introduced methodical approach connects Value Stream Mapping (VSM) and Methods-Time Measurement (MTM) and offers new distinct advantages to reduce lead time and increase productivity based on lean principles and standardised processes. The mutually aligned design and improvement of assembly and (production) logistic processes takes either the workplaces, their surroundings and the supply areas as well as the overall value chain into account. The identification and exploitation of productivity potentials is realised by the joint application of VSM and MTM focussing the (work) methods, the performance and the utilisation of the processes (the dimensions of productivity).

Principles, benefits and the procedure of application are described in the paper. A practical example highlights the redesign of assembly workplaces and the redesign of (production) logistic processes to reduce inventory/lead time using logistical and ergonomic aspects specially applying MTM logistic process elements.

1. Introduction

Increasing productivity in a defined time frame (e.g. one day, one shift), among other things, causes the increase in overall added value within this defined time frame. A short lead time through a process chain (a value stream) results in a higher output therefore in higher productivity and thus increases the overall added value within this given period of time. On the other hand the same overall added value can be achieved in a shorter period of time. Lead time reduction in a value chain arises from reducing lead times (operating times, idle times, transportation times, etc.) of the sub processes in this value chain. The target for designing a process is therefore to create its added value as fast as possible. Based on this "faster" processes "more" time is available in this given period of time to "produce" more output (see Fig. 1).

2. Value Stream Mapping and Methods-Time Measurement at a glance

A value stream includes all activities, i.e. value-adding, non-value-adding and supporting activities that are necessary to create a product (or to render a service) and to make this available to the customer. This includes the operational processes, the flow of material between the processes, all control and steering activities and also the flow of information. Taking a value stream view means considering the general picture of an organisation and not just individual aspects. Value Stream Mapping was originally developed as a method within the Toyota's Production System and is an essential element of Lean Management. It was first introduced as an independent methodology by Mike Rother and John Shook. Value Stream Mapping is a simple, yet very effective, method to gain a holistic overview of the status of the value streams in an organisation. Based on this picture flow-oriented value streams are planned and implemented. In order to assess possible improvement potential, Value Stream Mapping considers, in particular, the entire operating time compared with the overall lead time. The greater the distinction between operating and lead time the higher the improvement potential [1].

MTM is the abbreviation for Methods-Time Measurement, meaning that the time required to execute a particular activity depends on the method performed for this activity. It is a modern instrument to describe, structure, design and plan work systems by means of defined process building blocks. MTM exhibits an internationally valid performance standard for manual tasks. Today, MTM is the most common predetermined time system in the world, thus establishing a worldwide uniform standard of planning and performance for a global business.

A process building block represents a process step with a defined work content and a distinct purpose for which a standard time

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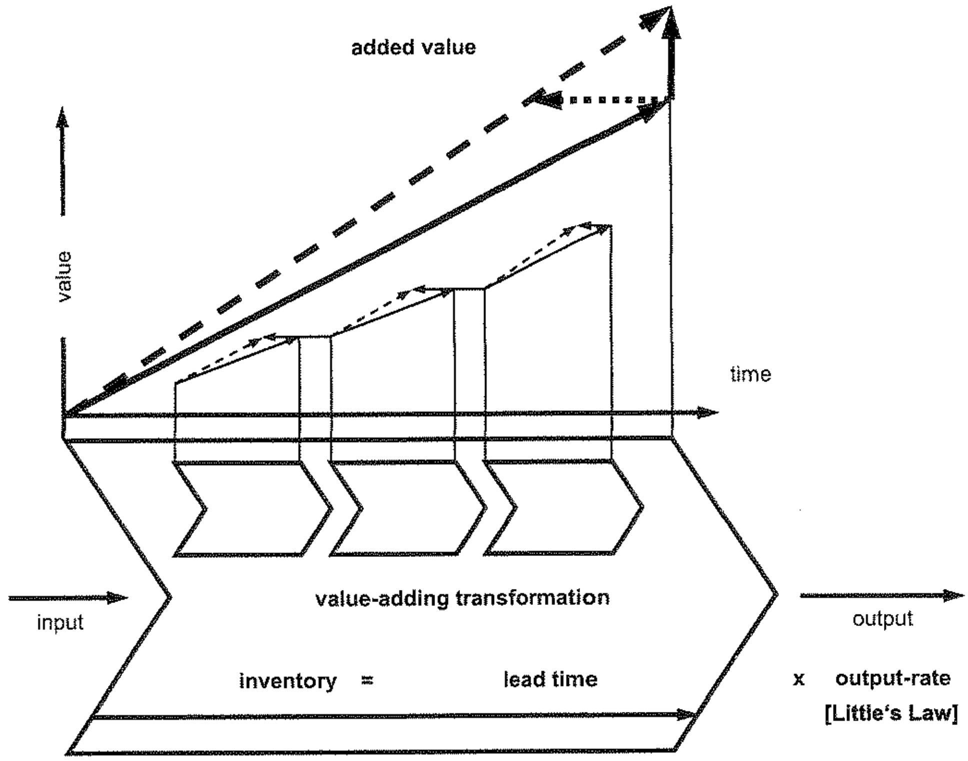

Fig. 1. Optimisation of added value by lead time reduction.

applies. A system of process building blocks consists of a defined amount of process building blocks. A MTM system of process building blocks [2] was developed for a specific, clearly defined process typology, a specific complexity of processes and defined process characteristics. MTM process building block systems are assigned to clearly defined fields of application such as, for example, mass production, batch production or job shop production. The most important MTM process building block systems are the basic MTM-1 system, the higher level UAS (Universal Analysing System) and MEK (MTM for one of a kind and job shop production system). MTM process building block systems provide a formal descriptive language for processes, are used uniformly throughout the world and are keen on recognising the relevant influencing factors in a process. The use of MTM provides a valid base for the evaluation of productivity, time based information to plan and control processes and supports the identification of deficiencies within the organisation.

A value stream analysis provides a very fast overview of the whole value stream from the supplier to the customer, with the focus on lead time and linkage between the processes. MTM is a tool based on a uniform process language to describe and standardise processes. In addition it provides the time (basic time) of the single processes in the value stream.

Value Stream Mapping and MTM aim at identifying, evaluating, reducing and eliminating waste within the value stream in terms of Lean Management.

3. Lead time

Viewed at a high abstract level the lead time is that period of time (hours, minutes, etc.) required by any process to transform the inputs (materials, customers, money, information) into outputs (goods, services). A precondition for determining lead time is the specification of measuring points. In a work system or chain of processes idle time following processing and transport is allocated to the subsequent workplace or subsequent process. The five elements idle time before processing, transport, idle time after processing, set-up and processing determine the lead time of a process [1].

According to Little's Law, the extent of inventory reveals a lot about the lead time. The extent of inventory, more or less, corresponds to the idle and/or transport times. In general terms, the lead time consists of operating and process times as well as of idle, transport and set-up times (see Eq. (1)).

A value stream's lead time results from the sum of all operating, process and set-up times of the processes, as well as, the extent of the various inventories [3]:

$$LT = \sum_i (OT + PT + ST) + \sum_j IR = \sum_i (OT + PT + ST) + \sum_j (IT + TT) \quad (1)$$

LT: lead time (of a specific value stream); OT: operating (processing) time; PT: process time; ST: set-up time; IT: idle time; TT: transport time; IR: inventory range; *i*: no. of processes; *j*: no. of different "work in progress"/inventories.

4. Productivity

Productivity is the expression of the quantitative productiveness of an economic activity (of the product realisation process) and allows conclusions to be considered how well the production factors deployed are used. Productivity is defined as output divided by the input factors. Basically, productivity is differentiated according to the individual production factors (manpower/workforce, machinery, material).

On the one hand, productivity increase results from increases in effectiveness by eliminating what is wrong and/or from doing what is right and on the other hand from increases in efficiency, through accurate assessment and the achievement of levels of capacity and performance. A consideration of the different dimensions of productivity provides a profound understanding

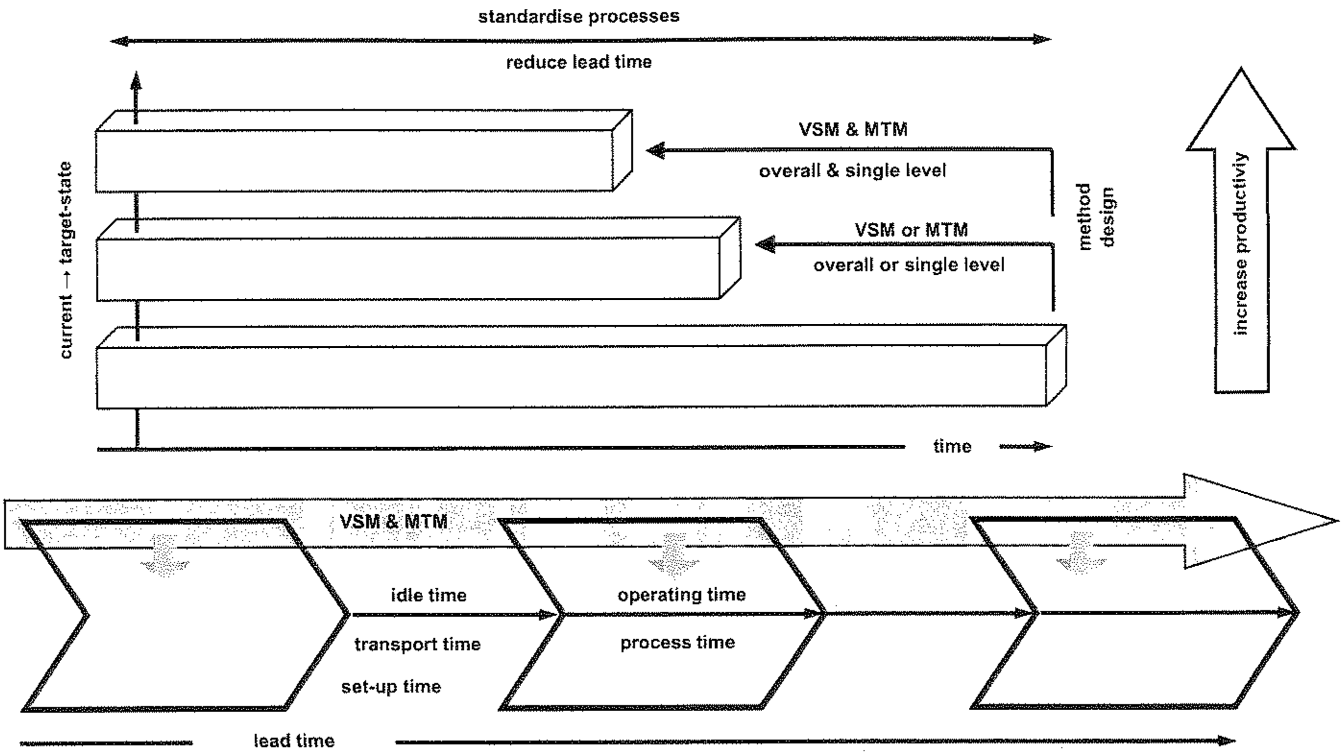

Fig. 2. Method design by VSM and MTM [6].

of this relationship and a basis for measures to increase productivity [4].

The dimension "method" describes "how" a work assignment or work content in a specified work system is fulfilled and refers to the whole process chain (overall processes), as well as, to single processes or executions. The dimension of "utilisation" considers aspects of the degree to which resources are utilised. The "performance" dimension considers aspects of performance level (willingness to perform, achievement potential).

5. Increasing productivity using Value Stream Mapping and MTM

The design of (work) methods is the most important dimension for influencing productivity [4,5]. Planning and implementing "well" designed, i.e. efficient and effective methods are at the very focus of projects to increase productivity (see Fig. 2).

These projects can lead to investment. The achievement of high employee utilisation, however, does not often require investment. Obstacles, such as fluctuations in customer or order-frequency, without flexible employee assignments lead to utilisation losses. This can frequently be recognised in service processes (e.g. trade, administration). The time determination of processes e.g. in production areas to evaluate the performance level opposes these obstacles efficiently. In particular a neutral and valid base to evaluate performance is required to achieve increases in productivity.

Value Stream Mapping does not just contribute to reducing lead times by reducing and avoiding waste, it also contributes to increasing effectiveness and efficiency by improving work methods and the organisation of work, thereby raising productivity.

The focus of optimisation is the alignment and combination of individual processes to form a continuous, efficient value stream throughout the organisation (consideration of overall processes). Through its well-grounded time determination and with its systematic analysis of processes, MTM contributes to evaluation and productivity improvement. The focus of optimisation is the individual activities and work places (consideration of single processes). MTM contributes to determine and assess the performance level correctly. Capacity utilisation is influenced by both MTM and Value Stream Mapping. The two tools complement each other perfectly in contributing to raising productivity as the combined application of Value Stream Mapping and MTM affects the design of all three dimensions of productivity.

Looking at the dimensions and their design areas in Table 1 it becomes obvious that the increase of productivity is achieved by designing smarter processes combined with reduced investment and low cost automation. The focus is set on designing methods (processes) and standardising work. The different aspects of the design areas indicate to possible potentials for improvement.

Table 2 provides an overview of the most important benefits from the joint application of VSM and MTM.

6. Areas of application

Once MTM has been successfully deployed in an organisation, Value Stream Mapping is a valuable extension in order to analyse the whole process chain. Conversely, if an organisation already uses Value Stream Mapping as a tool, the application of MTM is a useful addition. The following practical areas of application and possibilities for use result from the interplay of the combination of Value Stream Mapping and MTM (see Fig. 3):

- assessment of added value rates
- assessment of logistic processes
- ergonomic design of workplaces
- current/target-state comparisons
- balancing
- layout design (overall and single level)

Fig. 3 shows how MTM process buildings blocks provide several different information to a value stream; i.e. the operating time (basic time, t_g), detailed, chronological description of the work

Table 1
Dimensions of productivity – design areas [6,7].

Method/process design	
"Single processes" (indiv. task-orientation) – MTM	**"Overall processes" (flow-orientation) – VSM**
Layout – workplace design (tools, fixtures, machines, etc.)	Process organisation/work organisation
Added value, complimentary work, waste	Production systems
Handling expenditures	Layout – workplace alignment layout (factory, floor, assembly line, cell, etc.)
Expenditures for controlling and supervision	Material flow
Ease of assembly/disassembly	
Ease of grasp/operability	
Manual material handling	
Information flow and control VSM + MTM	
Production planning and control	
Control principles	
Product design	
Design of information flow	
Performance	**Utilisation**
MTM	**VSM + MTM**
Performance standards (performance rate, actual/target-time ratio, standard time, normal performance, etc.)	Net man-hours worked, total amount of hours available
Personal performance	Fluctuations in order-frequency and work content
Labour standards	Balancing (static, dynamic)
Training, routine	Work in progress/inventory
Motivation/disposition	Stock (amount)
Target orientation/monitoring	Idle times/breakdowns
Competences, skills, education	Scrap (quality of work)
Support/instructions, coaching	Set-up times/change over efficiency
	Maintenance
	Machine utilisation
	Material utilisation
	Area utilisation

Table 2
Benefits of the combined application of Value Stream Mapping and MTM.

	VSM	MTM
Exact determination and assessment of		
Operating, transport and set-up times		X
Performance and utilisation		X
Reduction of lead time through		
Minimising and eliminating idle times	X	
Improvement and redesign of methods and reducing in operating and transport times	X	X
Increase in productivity through		
Design of methods		
Flow-oriented consideration (overall processes)	X	
Task-oriented consideration (single processes)		X
Improvement in performance and utilisation		X
Standardising processes		X
Reduction of inventory in form of	X	
Raw materials, work in progress and finished goods		
Improvement in delivery reliability through	X	
Reduction of lead time and reduction of batch sizes		
Smoothing out fluctuations		
Evaluation and planning of flow of material		X
Based on standardised logistics process building blocs		
Reduction in control overhead through	X	
Simplification of information flow		
Application of the principles of self-regulation (supermarket, etc.)		
Reduction in required shop floor areas through		
Material flow optimisation improved workplace layout	X	
Improved workplace design		X
Lower stock quantities (inventory)	X	
Comparability and evaluation of current and target status		X
Internationally applied, standard performance benchmarks for human work		
Simulation capability	X	X
Planning, design, assessment and optimisation of "virtual" methods (flow- and task-oriented) in current and target states		
Simple and comprehensible documentation of methods	X	X
Simple and easily understood documentation of the processes and work procedures and transferability of results		

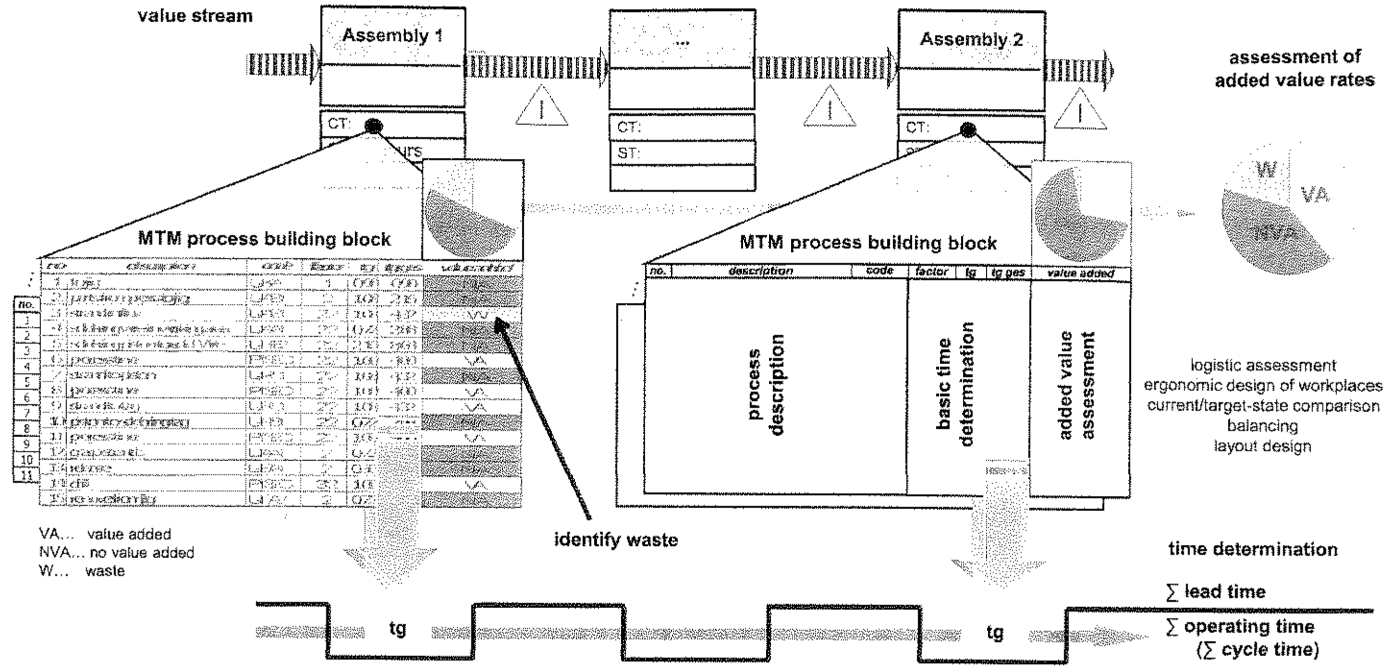

Fig. 3. Principle of the application of VSM and MTM [6].

method, the amount of added value respectively the amount of identifiable waste. MTM process building blocks therefore improve quality in evaluating the lead factor (lead time/operating time).

6.1. Assessment of added value rates

The systematic identification of waste is the precondition for avoiding wasteful activities through the design of target processes. The use of MTM ensures that the time respectively the percentage of waste is assessed. A fundamental concept of Lean Management and the continuous improvement process (CIP) that is decisively responsible for raising productivity is the search for the identification and the elimination of waste. This ensures that e.g. movement, transport, rework and other wasteful or non-value-enhancing aspects are removed from or at least minimised within the processes. It is necessary to assess the amount of waste (see Fig. 2) in order to sustainably and retraceably prove the results of improvement measures. MTM process building blocks meet this requirement particularly well as every simulated or actual change to an operating procedure is immediately quantifiable in terms of time – and subsequently in terms of cost – in the form of the MTM performance norm intrinsic to every process building block.

6.2. Assessment of logistic processes

The extended value stream (see Fig. 4) is taking logistic aspects, such as transportation distances and transportation vehicles especially the resulting transportation times, into account. It applies lean principles (e.g. avoiding waste, applying pull-principles) in order to steer the transformation and the design

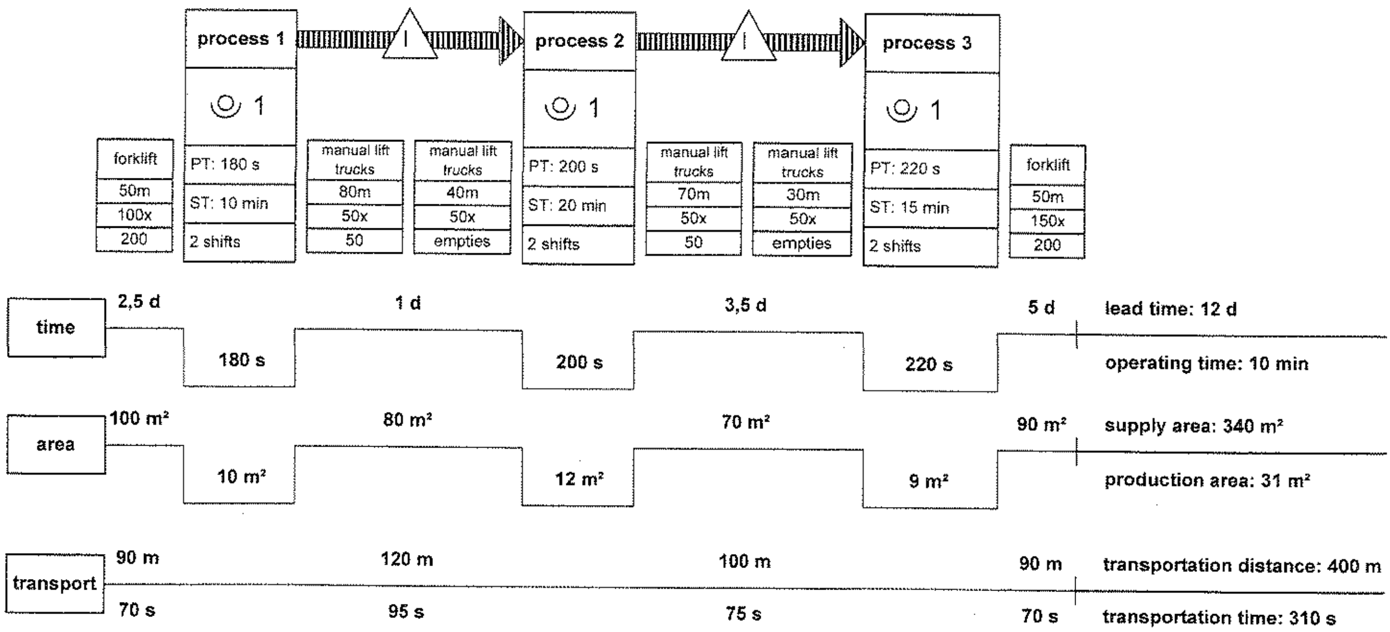

Fig. 4. Extended value stream.

of new logistic processes. Due to the fact that quantitative assessment possibilities are often neither available in the present nor in the target status, an assessment of the intended changes in the processes is very often impossible. VSM as a method is not providing a reliable and retraceable procedure to timely estimate time-aspects of transportation distances or manual material handling (e.g. box handling in supply areas).

By applying MTM process building blocks "logistics" these essential pieces of information can be identified/calculated on a reliable, standardised and retraceable base in the current status as well as in the target status. Particularly during planning future processes quantitative evidence about the target logistic efforts (such as transportation times, utilisation of internal logistic staff) can be estimated.

Applying MTM valuably contributes to the organisation, the design and the evaluation of logistic processes. Logistic issues in different areas of companies are characterised by comparable procedures with a significant level of repetitiveness.

Typical logistical procedures have been standardised and condensed into a process block system. It provides standards for the following logistical processes [8]:

- Transportation (procedures with different transportation vehicles such as forklifts, electric forklifts, manual lift trucks, trolleys)
- Manual handling (of cardboard boxes, containers, barrels of boxes, opening and closing of wrappings/packings, information processing (orders/receipts))
- Process blocks are also available for commissioning tasks.

The arising necessity in a VSM analysis to evaluate the required logistic efforts, it is highly recommended to enlarge the classical VSM by additional logistical aspects and subsequently gain a more convincing and concise holistic picture which provides a sound base for the evaluation procedure. This "extended" value stream extends "classical" value stream data (such as operating time and lead time) by information regarding required inventory, supply and production areas as well as by information about means of transportation, distances and times (see Fig. 4).

From a logistical point of view MTM expands VSM by the aspect of established time assessment. Special attention must be drawn to the fact that the logistic planning of transportation using different means of transport between stock and workplace can be achieved in both the current and target status. MTM process blocks attain special importance to calculate/by calculation box handling between means of transportation and supply areas (e.g. supermarket-racks, flow racks) and further onto the workplaces.

6.3. Ergonomic design of workplaces

The design of processes from the point of view of raising productivity must be balanced with designing work with people in mind. Risk analyses are used to ascertain the ergonomic quality of design. These evaluate stresses on the body such as posture, movement, strain as well as influencing forces, senso-motoric functions and psychological pressures. For this purpose the application of the EAWS (European Assembly Worksheet) is suggested. Among other things, process descriptions based on MTM process building block systems are the basis for the risk analysis. Ergonomic design measures are important particularly in early product and process planning stages as they can often be taken into account in this phase without incurring great additional overheads.

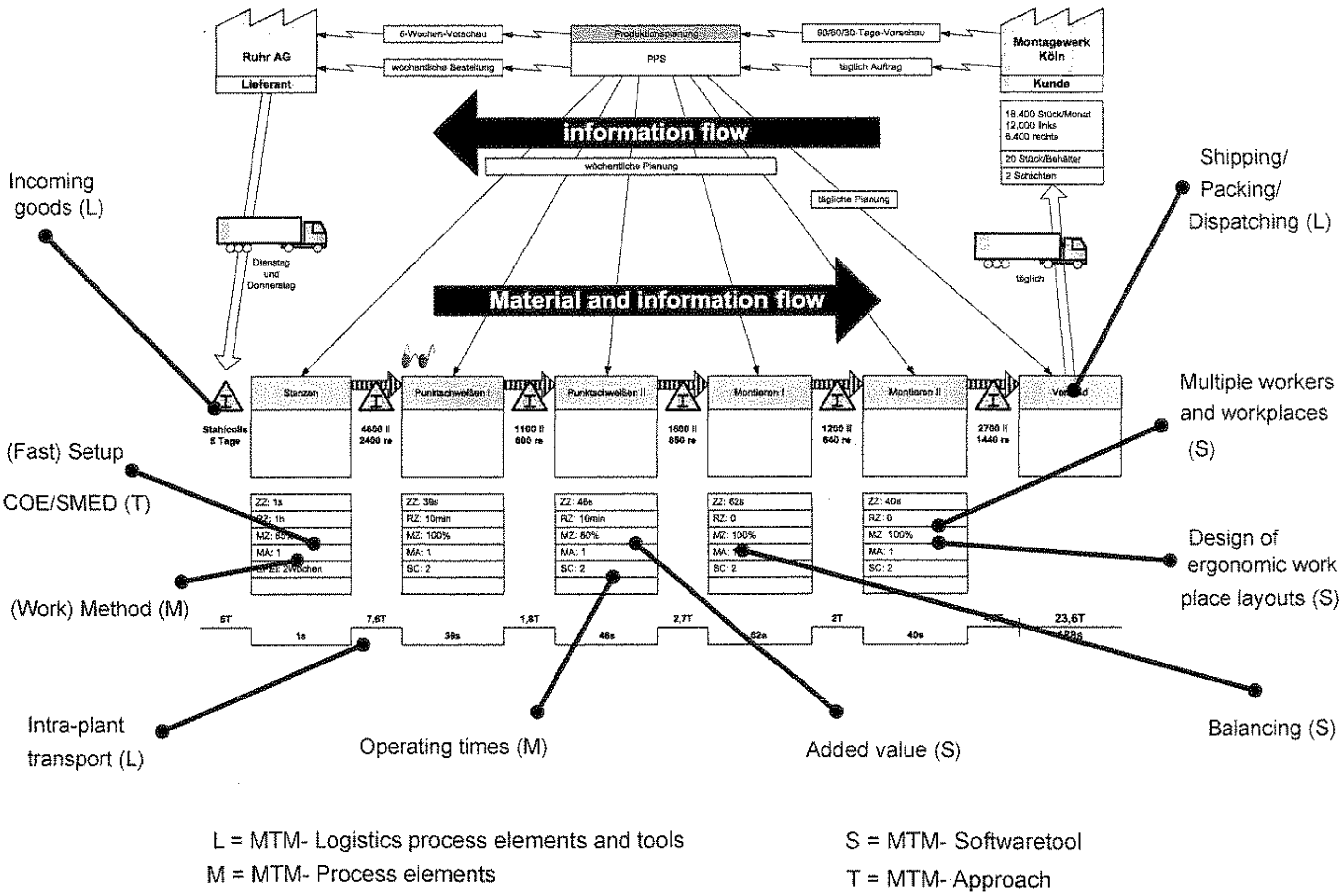

Fig. 5. VSM amendment by MTM.

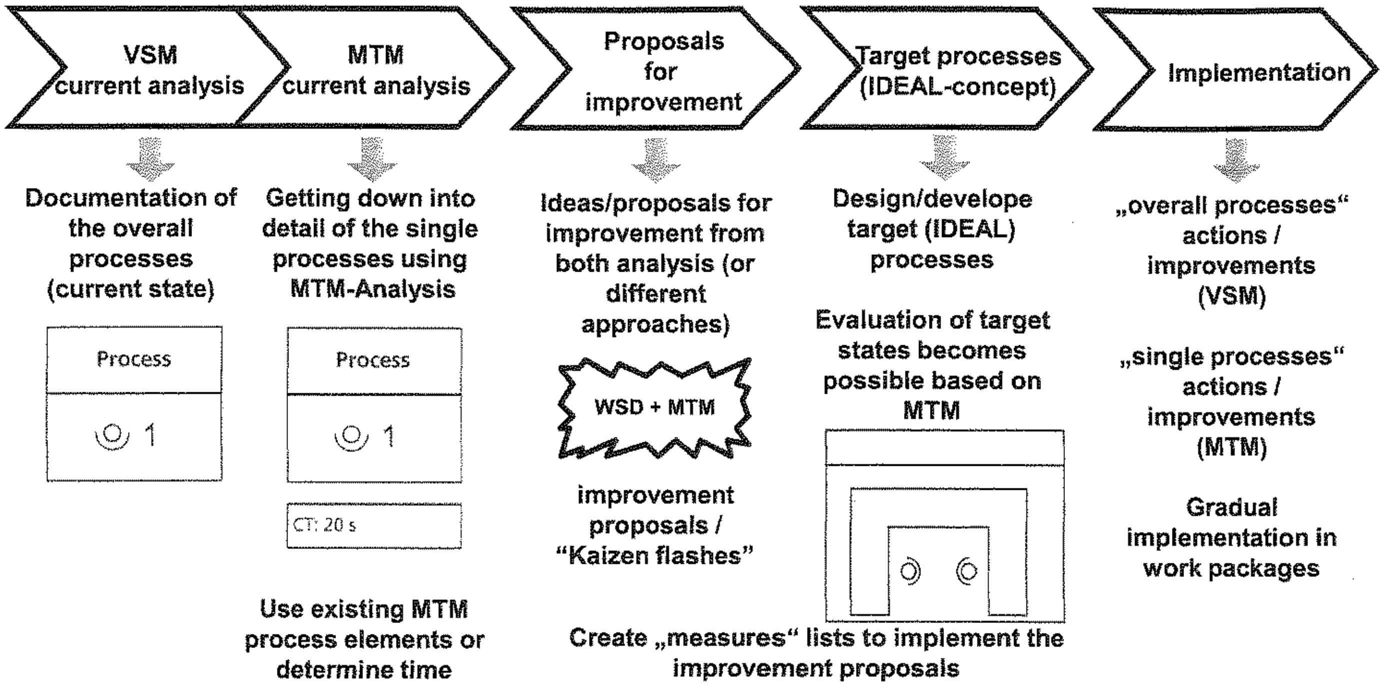

Fig. 6. Procedure to combine VSM and MTM.

6.4. Current/target-state comparisons

The rapid deployment intrinsic to Value Stream Mapping usually leads to less importance often being attached to the current-state. It is therefore often hardly possible to compare the planned and implemented target states. This is especially true in the current value stream for the determination of cycle times (operating times). The simple and rapid application of concentrated MTM process building block systems provides an accurate assessment of the processes of the current value stream. This creates the basis for the comparability of the target state achieved with the current state under consideration and for the assessment of realised improvement potential.

6.5. Balancing

Design principles such as e.g. orientation to customer demand (customer tact time) or the design of one-piece flow production present particular challenges for coordinating the cycles of workplaces and workstations. During balancing, the "circle times" of serially connected work stations are coordinated with one another taking account of technical circumstances. Work content must be assigned and aligned across the individual work stations in such a way that no substantial idle times occur at individual work stations and no staff or equipment is overloaded. Balancing losses and the effectiveness of the line are used as assessment criteria. Using the granularity MTM process building

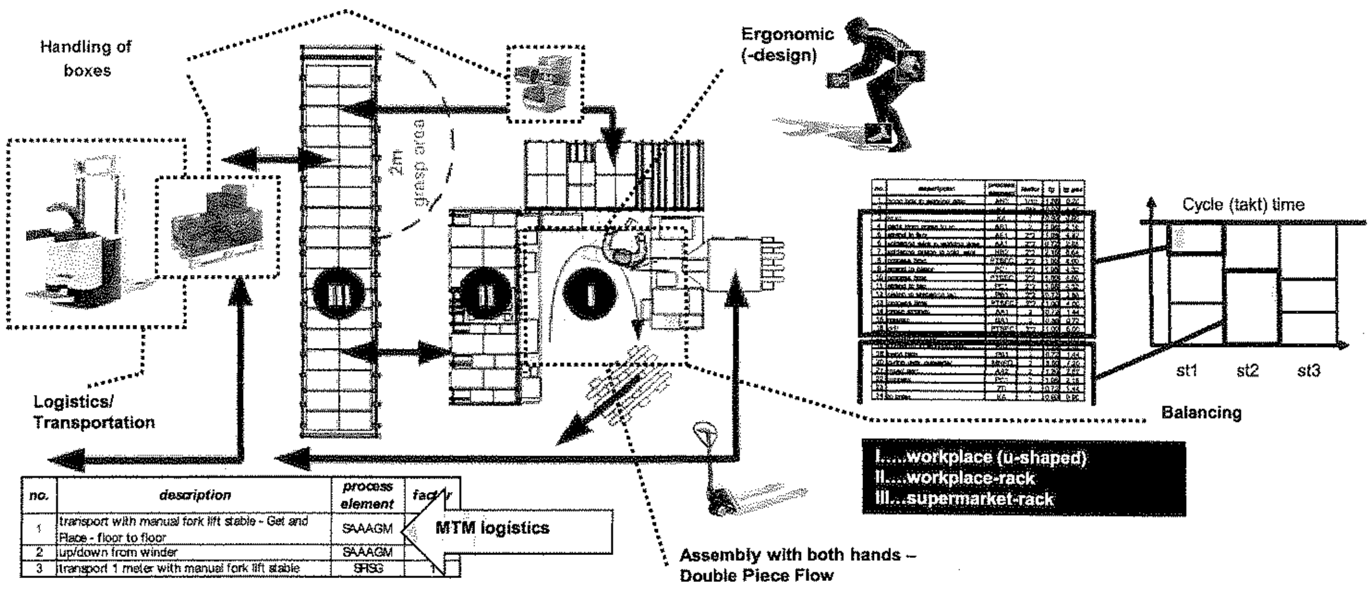

Fig. 7. Layout of a workplace, surroundings, supply areas and transportation flow considering the new design ideas.

blocks facilitates the even distribution of work content across work stations.

6.6. *Layout design (overall and single level)*

The interaction of value stream mapping and MTM as tools for the design of methods at the single and overall process level provides valuable information for the planning and design of layouts for workplace arrangement and workplace configuration.

7. Procedure to combine VSM and MTM

Fig. 5 shows how MTM contributes significantly in all different phases of VSM such as providing detailed (work) method description, balancing, Intra-plant transport, ergonomic assessment. Proposals and ideas to improve the value stream are revealed by visualising and analysing the overall process and the single process. Those proposals are presented in so-called "Kaizen flashes". Approaches such as method- and workplace-design, work alignment (balancing), application of pull- (Kanban) and flow-principles (FIFO, One Piece Flow) are taken into consideration to create measures to implement the improvement proposals and to develop a target-status, respectively an ideal-concept. Finally "flow-orientated" and "individual task-orientated" improvement actions are gradually implemented as shown in the procedure in Fig. 6.

8. Practical application: assembly workplace

Plastic jacks and their components are in the initial situation assembled in three assembly workplaces (pre-assembly, main-assembly and packing). The target of this improvement project was to increase the output representing the productivity in pcs/shift

Table 3
Realised corrective actions and improvements related to the design areas of the dimensions of productivity.

	Dimension of productivity	
Design areas	Corrective actions/improvements	Measures/metrics/indicators Productivity [pcs/shift; pcs/worker]
Method/process design Single and overall processes; information flow and control		
Workplace design and workplace alignment Process organisation	Planning and practical realisation of one u-shaped assembly workplace. The three independent workplaces in the initial situation were combined based on lean principles.	Lead time [min] Operating time (basic time) [s] Area productivity [pcs/m²] Set-up time [min]
Ease of assembly Ease of grasp/operability Manual material handling	Implementing the „Double Piece Flow"-principles by applying suitable fixtures that ensure usage of both hands.	Ergonomic risc [factor]
Process organisation Workplace design Manual material handling Handling expenditures	Quantification of the required volume of manual filling of containers/boxes and handling of containers/boxes in the target status in-between different racks (e.g. in-between supermarket-racks and workplaces) also based on MTM process blocks "logistics".	Utilisation of internal logistic staff [min/lot] Set-up time [min]
Workplace design	Ergonomic design of workplaces (e.g. in height-adjustable work benches, grasp boxes in ergonomic reach distances, permitted body postures, avoid overhead work).	Ergonomic risc [factor]
Material flow	Planning and realisation of new transportation tracks to supply the u-shaped assembly workplace.	Utilisation of internal logistic staff [min/lot]
Control principles Design of information flow	The assembly workplace is supplied by material in an e-Kanban system (pull-principle).	
Performance		
Labour standards Training, routine Motivation Support/instructions	New assembly processes and instructions were established, the workers were trained and mentioned that they found new motivation in the u-shaped assembly workplace. A continuous support for the new methods (assembly processes) is available for the workers.	
Utilisation		
Total amount of hours available/required	The utilisation of internal logistic staff in the target status was calculated based on the planned distances of the new transportation tracks and subsequently its transport efforts using MTM process blocks "logistics".	Utilisation of internal logistic staff [min/lot]
Balancing	Balancing the processes within the assembly workplace and defining transfer and decoupling points between the workplaces in the assembly cell. Forecasting of required amount of workers per shift.	Balancing losses [s] Amount of workers [in cell; per shift]
Fluctuations in order-frequency	The e-Kanban system also stabilised and improved the supply of orders to be performed in the assembly workplace.	
Work in progress	The e-Kanban reduced the work in progress in the u-shaped assembly workplace compared to the inventory within the three workplaces in the initial situation.	Inventory [pcs]
Area utilisation	The u-shaped assembly workplace and its supply areas cover less space.	Area productivity [pcs/m²]

and to redesign the assembly workplaces based on lean and ergonomic principles (by applying VSM and MTM). This practical example also underlines benefits presented in Table 2.

Table 3 connects corrective actions and improvements to the design the areas productivity dimensions realised in the project. Based on combining VSM and MTM the proposed improvements, corrective actions and changes in the assembly workplaces and processes increased the productivity.

Reliable and evaluated figures of the improvement are e.g. the number of pieces (jacks and components) produced per shift and the reduction of the operating time (basic time) per piece (see Table 3).

The workplace-redesign based on VSM and MTM (see Fig. 7) includes e.g. the balancing of the assembly operations and defining a decoupling point between two workers. Ergonomic aspects and internal logistics aspects were also taken into consideration for the redesign. The implemented layout of the assembly workplaces, the surroundings, the supply areas and the transportation flow is depicted in Fig. 7.

9. Summary

The interaction of Value Stream Mapping and MTM (the so-called Hybrid Optimisation of Added Value) at different levels of detail consideration, contributes to the identification, elimination and avoidance of waste and thus leads to the design of efficient and effective processes. The joint mutual benefit of the combined application arises from the increase in productivity, from the standardisation of processes, from the reduction in lead time/ inventory and from the accurately determined times; it also enables and ensures the predictability and the capability to assess the target status.

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