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Vol. 17
Vol. 16
Vol. 15
Vol. 14
Vol. 13
Vol. 12
Vol. 11
Vol. 10
Vol. 9
Vol. 8
Vol. 7
Vol. 6
Vol. 5
Vol. 4
Vol. 3
Vol. 2
Vol. 1

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Morphology of time data management – systematic design of time data management processes as fundamental challenge in industrial engineering

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Abstract: During the last 10 to 15 years, a renaissance of industrial engineering can be observed in manufacturing industry, as well as in scientific research. As a consequence, time and motion studies (TMS) become more important again. During the downturn of methodical approaches in industrial engineering in the 1980s, TMS-related competencies were lost in industry. Many companies are still missing the know-how for establishing a proper time data management (TDM). This paper presents a morphology of time data management (MoTDM), which was developed in order to create a comprehensive view on the processes of TDM as well as to detect relevant areas of improvement. The MoTDM can be used to optimise TDM processes within a company and also acts as scientific fundament for research in the field of industrial engineering.

Keywords: industrial engineering; morphology; time data management; TDM; standard time; time determination.

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1 Motivation and introduction

Time data management (TDM) in the manufacturing companies plays a central role in management's control over its strategic and operative planning and decision making business criteria. The current, quantitative survey 'Ifaa-Trendbarometer for working environment' clarifies the importance of TDM (ifaa, 2012). In this survey, different topics in the field of industrial engineering are evaluated by experts from industry, science and non-profit organisations and ranked according to their relevance. The most relevant topics of the surveys in the years 2009 to 2012 require current time data as a fundament, e.g., flexibility of labour time, process organisation, continuous improvement, (ergonomic) workplace design, assessment of performance. Time data in particular is vital for a lot of relevant information to manage a company and of high relevance for production systems analysis and design, modelling, simulation as well as for design of human work (Wiendahl, 2010; Groover, 2007; Chryssolouris, 2006; Lotter and Wiendahl, 2006; Jiao and Tseng, 1999).

Although the relevance of TDM is obvious, its establishment and operation is manifold assessed as time- and cost-consuming. As a consequence, many companies refrain from operating TDM-related functions and produce goods without a valid (time) data fundament for planning, control and decision making. Outdated time databases are often not representative for prevailing manufacturing conditions and work methods. Due to lack of time-related competences or concerns about additional expenditures for TDM, decisions considering its establishment, alignment or operation often do not utilise scientific approaches.

Due to this reasons, it is astonishing that only a few current publications address TDM-related issues (e.g., Erohin et al., 2012; Desai and Mital, 2011; Kuhlang et al., 2011; Nakayama et al., 2002). In scientific literature, especially in journal publications, many authors consider the fundamental necessity of time data and apply them, e.g., in lean production systems and lean methods as well as in supply chain management and dynamics (Al-Tahat et al., 2012; Azadeh et al., 2011; Peter and Lanza, 2011; Dombrowski et al., 2010; Jain et al., 2006). Authors often refer to time data, such as lead times, operating times, setup times (Duanmu and Taaffe, 2012; Soroush, 2012; Esfandyari et al., 2011; Gurumurthy and Kodali, 2011). Nevertheless they do not consider how this time data is determined and assume this data as already existing.

Based on this identified need for research and a comprehensive literature review, this paper[1] presents a morphological approach to offer support for companies in establishing, aligning and operating TDM. This morphology of time data management (MoTDM) represents a comprehensive and independent overview about the functions of TDM.

In the following the importance of time as a planning, control and decision making factor is presented in Section 2. Section 3 defines the processes of TDM and illustrates their correlations. In Section 4, MoTDM with relevant attributes of TDM processes as well as their typical characteristics is described. Finally, a case study about the practical application of MoTDM is shown in Section 5. Section 6 summarises the results of the MoTDM development and indicates further need for research.

2 Time as planning, control and decision making factor

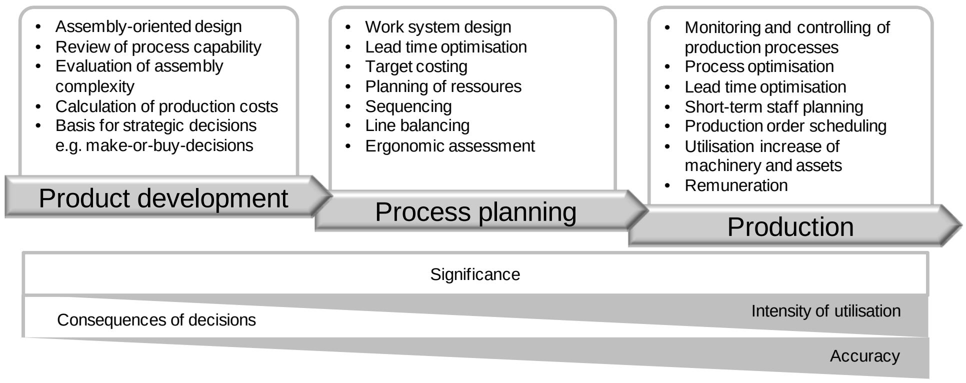
Time and time-related data are important factors for strategic and operative planning as well as for decision making in manufacturing companies in different branches (Al-Tahat et al., 2012; Peter and Lanza, 2011; Almström and Kinnander, 2011; Dombrowski et al., 2010; Becks, 1998; Heinz, 1995). During the 1980s and 1990s the significance of time data was consistently reduced. A renaissance of TDM took place within the field of industrial engineering from the end of the 1990s – especially in German speaking countries (Bokranz and Landau, 2012; ifaa, 2012; Kuhlang and Sihn, 2012; Stowasser, 2010; Deuse et al., 2006). During the last 10 to 15 years companies, non-profit organisations and research institutes recognised again the significance of time as planning, control and decision making factor. Equally the consequences of wrong decisions taken on the basis of outdated or missing time data became obvious. These days, many companies are facing the challenge to (re-)design or (re-)establish TDM rapidly and with reasonable expenditure.

In the sense of modern industrial engineering time data represents a work process and its inherent time-determining factors. In this context, e.g., the German MTM-Association [methods-time measurement (MTM)] applies a bold and simple slogan: "the method determines the time!" (DMTMV, 2012). Therefore, not only the factor 'time' is significant in TDM, but also a lot of additional time-relevant data such as underlying work methods and their rate of repetition.

Time data is determined and utilised during the entire product emergence process (PEP), consisting of product development, process planning and production phases (Petzelt, 2010). During product development, time data is used for an assembly-oriented design of products, components or parts as for example assessed by design for assembly approaches or for first calculations of production costs (Boothroyd et al., 2011; Eversheim, 1996). In process planning phase the utilisation of time data is concentrated on designing work systems. Exemplarily, the ergonomic assessment of manual work by means of Ergonomic Assembly Worksheet (EAWS) can be mentioned here (Schaub et al., 2012). During production phase time data is an essential fundament for monitoring and controlling production processes as well as for a performance-oriented remuneration of employees or continuous improvement (Wiendahl, 1996; Zülch, 1996).

In PEP progress time data, e.g., for assembly tasks, is determined prospectively in several iteration circles. Thereby predictions can be made considering the expected production costs or possible shift models, e.g., based on MTM planning analyses (Deuse, 2010). As PEP progresses the accuracy and intensity of utilisation increase, as until now the focus for TDM was set more on production processes in practical application. However the consequences and implications of decisions based on time data are most relevant in early phases of PEP. These examples of time data utilisation indicate its constant high significance throughout all phases of PEP (see Figure 1).

Figure 1 Time data utilisation in PEP



Source: Referring to Petzelt (2010)

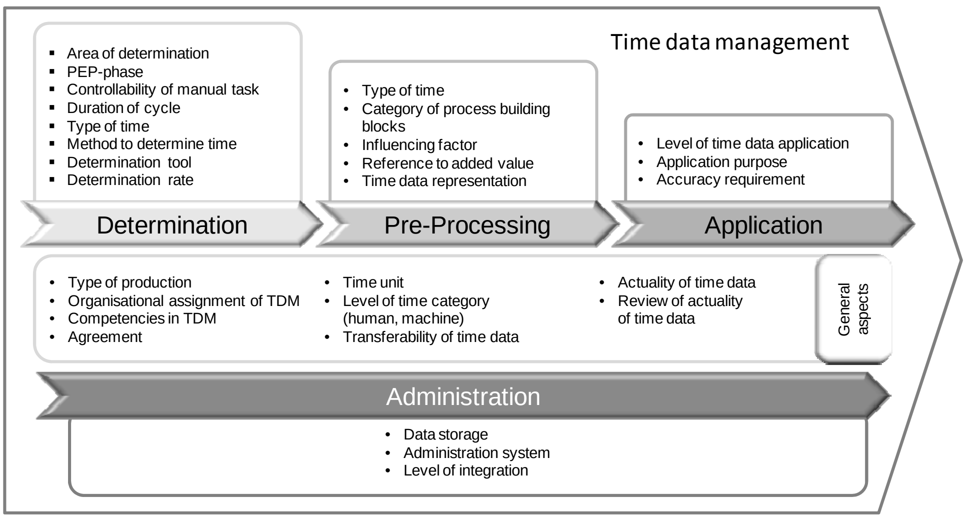
The manifold opportunities of utilising time data and the significance of time data are highlighting the necessity of TDM for planning and decision making for manufacturing companies. Therefore the establishment and solid operation of TDM have a vital function for manufacturing companies.

3 Processes of TDM

TDM is not defined consistently in scientific literature. On the one hand it is referred to an organisational (institutional) unit within a company (Ohm, 1997). Consequently the focus of this perspective is set on organisational aspects. On the other hand TDM is summarised as all activities to manage the factor 'time' (Hinrichsen, 2009; Heinz, 1995). Within this perspective the significance and functions of TDM, especially the establishment and operation of TDM, are considered. In the function-oriented context Tschich subdivided TDM in time data determination, pre-processing and application (Tschich, 2000). Time data determination covers all functions and responsibilities to specify time data. The analysis, composition, representation and application-oriented preparation are summarised in time data pre-processing or administration. In comparison to this definition, REFA association put emphasis on 'data determination' (REFA, 1997). This implies that in addition to time data determination time-relevant factors and referenced quantities have to be determined. Nevertheless, a detailed characteristic of TDM-processes does not exist.

Whereas TDM is an important topic in the field of industrial engineering, there is no comprehensive view on TDM in scientific literature. In order to eliminate this gap, the paper defines TDM as the processes 'determination', 'pre-processing', 'application' and 'administration' of time data. This holistic view on TDM is essential due to strong interdependences and temporal overlaps of the processes of TDM. The time data application, e.g., already influences the methods and procedures for determination and pre-processing. Figure 2 shows general aspects and the processes of TDM – sequentially arranged to clarify the image – and their characterising attributes, which are specified in MoTDM in Section 4.

Figure 2 Processes of TDM



Time determination specifies time values for defined work content. Different methods to determine time such as time study, estimating and comparing or predetermined motion time systems (PMTS) can be used for this purpose. These determined time values are usually not directly applicable for new decision making or planning situations. On the one hand, they have to be pre-processed application-oriented. Hereby the determined time values have to be statistically evaluated to ensure plausibility. On the other hand, they have to be depicted as a function of time-determining factors in order to enable a further use. The application process provides time data for strategic and operative issues in a company, such as identifying and performing time-related continuous improvement process in production systems (Sackermann, 2009). Finally, time data administration accompanies the other processes of TDM. Nowadays, IT-support is often realised in different systems along product emergence or in special TDM systems.

Based on the processes of TDM the developed morphology faces the challenge to comprehensively represent the complex field of TDM. For the first time the MoTDM allows a detailed view into the processes of TDM in contrary to sporadic applied, consulting-oriented approaches (e.g., Bokranz and Landau, 2006).

4 Morphology of TDM

The MoTDM is firstly based on a state-of-the-art literature review and secondly on the author's expertise gained in industrial applications and research projects. Furthermore, the developed morphology depicts attributes and their typical characteristics for determination, pre-processing, application, administration processes and general aspects of TDM, with potential for company-specific modification and enhancement (see Figure 2). Figure 5 shows the MoTDM including the specific characteristics of the case study. The attributes and their characteristics are briefly described subsequently.

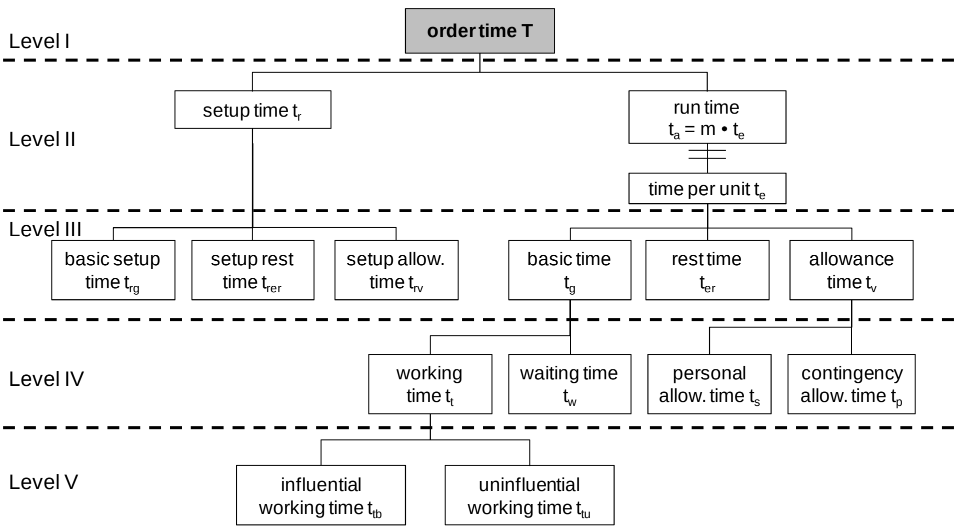
4.1 General aspects

- *Type of production:* The type of production represents the repetition rate of production processes (Eversheim, 1996). Additionally, the organisation level of processes and work systems as well as the routine of employees are indicated by the type of production. It is also an indicator for selecting a suitable method of time determination (e.g., the MTM process building block system).
- *Organisational assignment of TDM:* TDM-related functions are assigned differently in companies, depending on the size and type of organisation (e.g., multinational enterprises or small and medium sized enterprises). The characteristics of this attribute cover a central assignment of TDM department (typical in global acting companies) as well as local TDM functions, which are directly performed by employees in process planning. Central assignment of TDM should be favoured, because it is possible to concentrate TDM knowledge and competencies.
- *Competence in TDM:* This attribute represents the overall TDM competence of a company based on employees' individual TDM qualifications and expertise. The defined competencies are based on the levels of Dreyfus (Dreyfus and Dreyfus, 1980). A novice, e.g., is an employee being able to understand TDM-related coherencies and is aware of certain methods of time determination. At this competence level a company is usually dependent on external support in performing TDM tasks. A company is competent in TDM, if employees are able to apply methods of time determination autonomously and properly. This practical application competence implies that employees are able to determine time data for an

intended purpose. The highest level of competence is reached, if a transfer of knowledge in form of training is practised.

- *Agreement:* This attribute comprises whether, and if so, which instances in a company have to be involved in time data-related issues. Due to strong labour unions in German-speaking countries works councils have to be involved in case of remuneration in general and specially in performance-oriented remuneration. An agreement is usually not necessary, if time data is not used for remuneration. The detailed scope of workers participation is commonly regulated by country-specific law.
- *Time unit:* The duration of work processes are stated in work and time study in form of time units such as shifts, days, hours (h), minutes (min), seconds (s), one-hundredth of a minute (HM), in multiples of finger motions (MOD) and time measurement units (TMU). Here, 27.8 TMU and 8 MOD correspond to one second (Niebel, 1993; Maynard et al., 1948).
- *Level of time category:* This attribute indicates the level of detail in segmenting time categories for humans and machines. The level corresponds to the hierarchic time category structure by REFA (2002) (see Figure 3). Level I represents the order time for humans or the holding time for machines. In Level II, this time is subdivided into setup and run time referring either to quantity units or orders. Time per unit – an important figure in work and time study – is also assigned to this level. In Level III, the fact is caught, that besides basic time for performing a work process also rest and allowance time are required (Niebel and Freivalds, 2003; Kanawaty, 1992; Barnes, 1980). The segmentation in several categories of basic time and allowance time is performed in Level IV. Level V finally depicts a segmentation of basic time into influential and non-influential working time. A correct definition of the level of time category is a challenge in practical application.

Figure 3 Level of time category (human)



Source: REFA (2002)

- *Transferability of time data:* This attribute characterises the opportunity to apply time data manifold in several areas. In this context Picker defines company-specific or company-overlapping time data depending on time-influencing factors (Picker, 2006). Company-overlapping time data is defined by time-influencing factors which can be found in many companies. Therefore they enable and ensure an industry-neutral or industry-specific transferability. The standard data catalogues of PMTS such as MTM, work factor (WF), Maynard operation sequencing technique (MOST), MODular arrangement of predetermined motion time systems (MODAPS) are examples for company-overlapping time data (Carey et al., 2007; Zandin, 2003; Quick et al., 1965; Maynard et al., 1948). A specified manifestation of one of these systems to circumstances and work processes within a company leads to company-specific time data such as the so called Daimler 'C-values'.
- *Currentness of time data:* This attribute focuses the contemporary relevance of work methods underlying time data. In this way it declares how accurate time duration represents the current work content. There is no need for action regarding time determination in case of up-to-date time data. Whereas, if they are not corresponding an adaption of time data to the current work methods is essential, due to a not assured planning fundament.
- *Review of currentness of time data:* This attribute states how regularly time data is checked and revised by a company. The characteristics of this attribute are defined with non-periodical and periodical. These characteristics are related to the regularity of checking time data. On the other hand a change of work methods (with each, or a large number of changes) requires a review of time data.

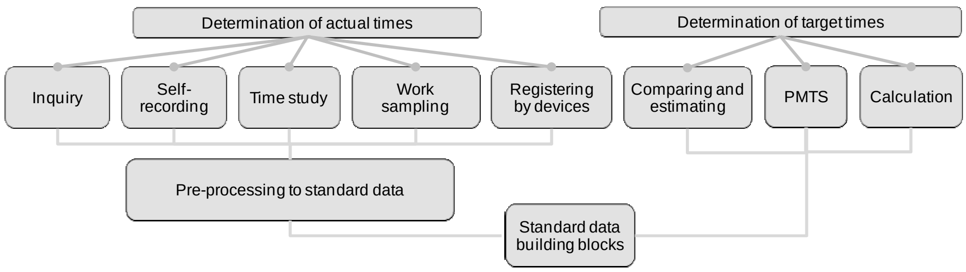
4.2 Determination

- *Area of determination:* This attribute describes those areas in a company, where time data may be determined. Its characteristics are defined with production, assembly, maintenance and logistics (transport and storage in procurement and distribution) [referring to Wiendahl (2010)].
- *PEP phase:* This attribute specifies if time data is determined pre- or post-start of production (SOP). Different constraints (e.g., which time-influencing factors are known) have to be taken into consideration depending on PEP's phase in determining time data or selecting suitable methods of time determination. Comparing and estimating, PMTS or simulation is appropriate methods to determine target times in pre-SOP. Post-SOP time is specified by methods to determine actual times such as time study, self-recording, registering by special time determination devices or work sampling.
- *Controllability of manual task:* This attribute represents the opportunities for employees to influence the way of performing a task and therefore the time of this task. The characteristics of this attribute have a significant impact on the choice of the time determination method, since the controllability of tasks performed by human beings may well be a precondition for its application. Tasks may be influenced in three different ways. An employee is able to influence mere manual tasks totally. In mechanised tasks the controllability by humans is reduced,

since the speed of a machine has to be considered. Machines determine the duration in automated tasks totally. Accordingly, e.g., PMTS may be applied for manual tasks, whereas evaluations or simulations are suitable for automated tasks.

- *Extent of work content:* This attribute specifies the duration of recorded work. Hence, it represents the extent of an observed work content (e.g., in hours, minutes or seconds) and is also an indicator for the choice of a time determination method and the extent of the process building blocks.
- *Type of time (determination):* TDM distinguishes between different characteristics of time data – so-called types of time. From an employee-oriented point of view especially actual times, target times, standard data, normal times and time standards are relevant (Petzelt, 2010). For time determination only actual and target times are relevant. Actual time is defined as the duration of a really performed task. The target time indicates the time for a planned task (Landau, 2007).
- *Methods to determine time:* Methods to determine time depicted in the MoTDM are generally distinguished in methods to determine actual or target times (see Figure 4). Actual times are specified by an observer measuring tasks directly at a work place (e.g., time study), by asking the worker (e.g., inquiry), through the worker himself (e.g., self-recording) or by automatic data collection by machines (e.g., registering by plant data collection systems) (Groover, 2007; Niebel and Freivalds, 2003; Meyers and Stewart, 2002; Kanawaty, 1992). Target times are derived from actual times and their time-influencing factors (Petzelt, 2010; REFA, 2002; Heinz and Olbrich, 1994). To determine target times such methods as comparing and estimating, PTMS and calculation con be applied. The reproducibility of work method descriptions and the accuracy of time data are significantly influenced by the methods of time determination.

Figure 4 Methods of time determination



Source: Heinz and Olbrich (1994)

- *Determination tools:* This attribute describes different tools to determine time subject to constraints such as applied methods of time determination, purpose of application and available IT systems. The choice of determination tools ranges from a conventional application of (stop-) watches and paper, via specialised time determination means (e.g., digital recording board) to the application of modern, universal devices (e.g., smart phones, tablet computers) with TDM software tools or plant data collection systems (e.g., Groover, 2007; Meyers and Stewart, 2002). Following the current trend of digitalisation, IT systems are also used increasingly in TDM. Video analysis, motion capturing, simulation and digital factory tools in particular in process planning are applied, too.

- *Determination speed ratio:* The determination speed ratio is defined as the ratio between the work content and the effort to determine this work content. The various time determination methods cause different expenditures in observing and evaluating work contents. These expenditures rise depending on an increasing accuracy of time data. For time studies the determination rate is approximately 1:1 (without pre- and post-processing). Utilising analytical methods of time determination such as PMTS this ratio may rise up to 1:200 with MTM-1 (Groover, 2007; Bokranz and Landau, 2006).

4.3 Pre-processing

- *Type of time (pre-processing):* Pre-processing also distinguishes (analogue to determination) between different characteristics of time data – so-called types of time. Target times, standard times and standard data are relevant in pre-processing. Depending on the purpose of application target times are derived from actual times normally through statistical evaluations. They also can be composed by other target times or calculated by formulas (Vainio et al., 2010; Landau, 2007; Meyers and Stewart, 2002; Nakayama et al., 2002). Target times are fundamental to set standard times. Standard times are defined as the time targeting the duration of a work process for humans or machines (Sakamoto, 2010; Groover, 2007; Landau, 2007; Niebel and Freivalds, 2003; REFA, 2002; Hammer, 1997; Kanawaty, 1992). Standard times contain target times and additions for rest and allowance time. Standard data specifies target times for work elements describing work processes and their duration by means of time-influencing factors. These work elements are composed to establish new target times respectively standard times by specifying their influencing factors (Groover, 2007; Hammer 1997).

- *Category of process building blocks:* This attribute describes the work content depicted in a process building block. It represents the level of compression and hierarchically assignment of process building blocks in terms of the intended application purpose. This attribute is based on the hierarchy levels of MTM's universally applicable process building block systems (Bokranz and Landau, 2006). The blocks are getting more specific the more they are aggregated and their re-usability declines. The attributes' characteristics for company-specific process building blocks are defined with 'product-neutral' (e.g., basic operation, operation sequence or operation), 'product-related' (e.g., to parts, components or products) and 'application-related' (e.g., staff requirement planning, calculation of product-variants).

- *Influencing factors:* Time-influencing factors determine the duration of work content. Hereby, it is important to consider significant influencing factors, which changes modify time data. REFA distinguishes the significant influencing factors into changeable and fixed (REFA, 1997). Furthermore the changeable influencing factors are subdivided into quantitative (measurable, countable) and qualitative (assessable).
- *Reference to added value:* This attribute refers to a so called primary-secondary analysis based on the duration of work processes. Hereby, an economic efficiency factor is calculated in order to assess improvement or optimisation possibilities. In this way a connection to added values and thereby customer benefit is achieved (Lotter and Wiendahl, 2006). Primary tasks represent all expenditures concerning time, energy, information and parts accomplishing products in order to increase added value during assembly such as grasping, inserting or screwing parts. Secondary tasks represent all expenditures concerning time, energy, information and parts accomplishing products without increasing added value during assembly such as transporting, turning, putting down and re-grasping of parts.
- *Time data presentation:* In order to achieve an extensive utilisation of time data a proper pre-processing and presentation are necessary. Hereby time data is depicted in form of explicitly described work processes and depends on current parameters and influencing factors. In general three different categories are recommended by REFA (2002). A table (e.g., in form of time classes or calculation sheets) presents time data subject to qualitative or quantitative influencing factors. The number of factors should be limited in this context in order to ensure clarity. The graphical form (e.g., nomogram) to represent time data as a function of influencing factors is another appropriate way. Finally time data can be calculated in a formula, especially if influencing factors appear in many different characteristics (Niebel and Freivalds, 2003; REFA, 2002).

4.4 Application

- *Level of time data application:* This attribute distinguishes between strategic (e.g., investment planning), tactical (e.g., work system design) and operational (e.g., order monitoring) characteristics depending to the level of compression and the purpose of time data application [referring to Olbrich (1993)].
- *Application purpose:* This attribute specifies the manifold company-internal or -external application of time data. On the one hand, time data provides management-related information, e.g., for investment planning. On the other hand, time-related data is fundamental to design remuneration systems and ergonomic work places. Order-oriented (e.g., order monitoring) and product-oriented time data represent important information for operational decisions in companies. In addition, time data also plays an important company-overlapping role and provides information for decisions to be taken in the context of supply chains or scheduling of just-in-time deliveries.

- *Accuracy requirement:* Subject to the aspired application purpose, time data has to fulfil different accuracy requirements. The accuracy requirement is defined as the maximal accepted deviation from pre-defined time values. Time data used for remuneration, for example, has to be more accurate than that used for make-or-buy decisions. As accuracy rises, the effort to determine and pre-process time data increases too, but the determination speed ratio decreases. So therefore time data should be determined ‘as accurate as necessary’ and ‘as inaccurate as possible’ (Heinz and Olbrich, 1994). Accuracy requirements are usually company-specific but an orientation aid is given by Groover (2007) and Heinz and Olbrich (1989). According to this recommendation an accuracy requirement of +/– 20% for a long-term capacity planning and of maximum +/– 5% deviation for remuneration is acceptable.

4.5 Administration

- *Data storage:* The design of data storage is highly relevant for a long-term retention of time data. In general centralised as well as decentralised data storage is possible. Thereby a centralised database increases the efficiency of usage by providing a consistent time database.
- *Administration system:* The administration system is related to data storage. Specialised TDM IT systems, IT systems in production (PDL/MDL, MES, PPC/ERP), IT systems in planning (CAP, CAM, Dig. Mnfct.) and spread sheet solutions are distinguished within this attribute.
- *Level of integration:* The data exchange between different IT systems plays an important role in TDM. Full integrated means that determination, pre-processing, application and administration of time data occur in one IT system. Time data for different IT systems is provided via interfaces.

The described attributes of MoTDM offer an orientation guide as well as a decision aid in establishing or operating a modern TDM and provide a comprehensive overview of TDM functions. Subsequently a practical application of MoTDM is presented exemplary in a case study.

5 Case study: MoTDM’s practical application

In order to depict the practical application of MoTDM (see Figure 5) it was utilised in a mechanical engineering company operating in capital goods industry.

5.1 Initial situation and future challenges

Due to a strong rise in sales, this company was facing the challenge to increase the capacity of the existing assembly areas. Depending on the annual production volume the type of production was classified as job shop production. The aspired change of assembly principles, towards a flow-oriented assembly in the new layout, required information concerning the duration of the assembly tasks.

In order to plan the new assembly line, fundamental data such as standard times or assembly tasks, work plans, attendance times, number of assembly staff, planned annual production was collected. During this data collection the company figured out step by step, that the current available time data had not the required quality and currentness. They also perceived that TDM processes did not perform properly. Especially the understanding of the relevance of actual and available time-related data as an essential planning and calculation basis did not exist in the company. This is underlined by the fact that 30-year old standard times (and the underlying work methods) were utilised for planning the new assembly. The standard times were determined by work studies and naturally the work methods changed a lot during this period of time, e.g., due to continuous improvement, new tools or technological changes. But these method changes were not updated in the standard times.

5.2 Specific needs for action by applying MoTDM

In order to define and establish new TDM processes the MoTDM practically applied. MoTDM's attributes represent a guideline for the assembly planning project to ensure a comprehensive view on relevant aspects in TDM. The current and target characteristics are appointed in a number of expert meetings with external support. Subsequently the utilisation of MoTDM presents how the company met the challenges to establish an actual planning and continuous improvement fundament.

The company used time studies to determine times, yet the studies were performed too seldomly. This led to a calculation of offers on the level of 'run and setup times' because more detailed data was not available. In the future time categories will be determined on the level of influential and non-influential working times. As the fundament for standard times working times will be determined by PMTS in specific by MTM for single and job shop production (MEK). This prospective approach is accompanied by other methods to determine time. Up to now, only stop watches were used as time determination tools. Time determination will be put on a solid basis in the future by applying MTM, work sampling, time studies and building standard data.

Time determination trainings had already been performed and first experiences were gathered in practical application during the new assembly project. The TDM-related basic knowledge of employees from offer calculation, work scheduling, production planning and assembly was re-established and is continuously enhanced in practical application.

Time determination has to be agreed with the workers council for assembly, manufacturing and logistics. Decentralised spreadsheet solutions have already been changed to a centralised TDM IT system. Time data is already managed in a centralised database instead of on local computers. Within this context also the organisational assignment of TDM is going to be centralised on the site instead of continuing with local responsibilities. The application purpose of time data was restricted to calculate offers. The first step to extend the application areas of time data was to use them for challenges in work system design, as shown by the assembly project. Further enlargement will proceed to product design and leadership-related issues.

Figure 5 Morphology of TDM including the characteristics of the case study

Attributes	Characteristics							
	General aspects							
Type of production	single-unit production	◆● job-shop production	series production	mass production				
Organisational assignment of TDM	◆ local	decentralised in production areas	● central on site	central in company				
Competence in TDM	◆ basic knowledge (novice)	● practical application (competent)	expertise in training (expert)					
Agreement	required with several instances (e.g. with works council and management)	required with one instance ●(e.g. with works council)	◆ not required					
Time unit	● TMU	MOD	HM	s	◆ min	◆ h	day	shift
Level of time category (Human)	level I (e.g. order time)	◆ level II (e.g. setup and run time)	level III (e.g. basic, rest, allowance time)	level IV (e.g. working, waiting, personal or contingency allowance time)	● level V (e.g. influential or non-influential working time)			
Level of time category (Machine)	level I (e.g. holding time)	level II (e.g. machine setup and machine run time)	level III (e.g. machine-basic, machine-allowance time)	level IV (e.g. effective time, machine ancillary time, machine idle time)	level V (e.g. influential effective time, machine ancillary time)			
Transferability of time data	◆ area-specific	● company-specific	industry-specific	● industry-neutral				
Currentness of time data	◆ not up-to-date	● up-to-date						
Review of currentness of time data	non periodical with every change of work methods	non periodical with large changes of work methods	periodical					
	Determination							
Area of determination	◆● production	◆● assembly	● maintenance	logistics				
PEP phase	pre-SOP	post-SOP						
Controllability of manual task	fully influential (manual task)	partially influential (mechanised)	non-influential (automated)					
Extent of work content	hours (large)	◆ minutes (middle)	● seconds (small)					
Type of time	actual time	target time						
Methods to determine time	◆● time study	self-recording	inquiry	● predetermined motion time systems	● standard data building blocks			
	calcualtion/simulation	comparing and estimating	● work sampling	registering by devices				
Determination tools	(stop) watch & paper	special time determination devices	universal devices with TDM-software	data collection	video analysis and motion capturing	process planning tools/simulation tools		
Determination speed ratio	<10:1	10:1 – 1:1	1:1 – 1:10	1:10 – 1:50	1:50 – 1:100	>1:100		
	Pre-processing							
Type of time	target time	standard time	standard data					
Category of process building blocks	product-neutral	◆ product-related	● application-related					
Influencing factors	quantitative	qualitative						
Reference to added value	primary (value adding)	secondary (non value adding)						
Time data presentation	catalogue/table	chart	(time) formula					
	Application							
Level of time data application	strategic	tactical	operational					
Application purpose	● design-oriented (e.g. workplace design)	◆● order-oriented (e.g. order monitoring)	employee-oriented (e.g. remuneration)	● leadership-oriented (e.g. investment planning)	● product-oriented (e.g. product design)			
Accuracy requirement	< 5%	>5-10%	>10-15%	>15-20%	>20%			
	Administration							
Data storage	◆ decentralised on single PC's	decentralised in production areas	● central on site	central in a concern/company				
Administration system	◆ spread sheets, etc.	IT systems in planning (CAP, CAM, Dig.Mnfct.)	IT systems in production (PDL/MDL, MES, PPC/ERP)	● TDM IT systems				
Level of integration	not at all	interfaces	full					

◆ Current characteristics ● Target characteristics

Legend:

CAM	Computer Aided Manufacturing	min	Minutes
CAP	Computer Aided Planning	MOD	Mode
Dig. Mnfct.	Digital Manufacturing	PDL	Plant Data Logging
ERP	Enterprise Resource Planning	PPC	Production Planning and Control
h	Hours	TDM	Time Data Management
HM	One-hundredth of a minute	TMU	Time Measurement Unit
MDL	Machine Data Logging	s	Seconds
MES	Manufacturing Execution Systems	SOP	Start of Production

5.3 Results and consequences

As a consequence of applying MoTDM a wider and more modern view on time data and TDM was achieved. The extent of observed work content decreased by applying MEK compared to time studies. The accuracy of the recorded work methods increased, thus, creating more transparency and reproducibility of work methods in order to improve work systems. Especially a prospective approach in time determination met the challenges arising from the high demand in order to calculate offers accurately based on actual time data and work methods. Time data is going to be utilised to facilitate a new order control and capacity planning. This case study indicates clearly that MoTDM provides a comprehensive framework for companies in order to approach TDM-related issues.

6 Conclusions and outlook

The developed MoTDM represents a unique, comprehensive and independent overview of TDM issues in manufacturing companies. For the first time it provides a solid scientific fundament in TDM. The benefit of MoTDM is a simple yet efficient and practically applicable capturing of different attributes and their typical characteristics.

From a managerial point of view, MoTDM assists a manufacturing company to obtain quick and solid insight to the current situation of their TDM as well as to detect opportunities for designing the target status of their time data-relevant processes. Both lead to transparency in TDM-related processes of a company and provide the basis to identify needs for action in (re-)designing TDM.

To summarise the paper, MoTDM provides various advantages. From a research point of view, it provides a solid, systematic, company- and time determination method-independent view on TDM. From management's practical view, it is the advantage of gaining a valid time fundament for planning, controlling and decision making tasks. Hence, applicators are enabled to critically consider TDM within a company in order to define needs for action or fields for improvement.

Yet the MoTDM raises no claim to completeness concerning the attributes and is currently applicable only in manufacturing companies. It also provides the first approach to develop a maturity model for TDM or to develop holistic TDM audits. This will contribute to a solid fundament to support systematic improvement processes and to assess the effectiveness of realised actions of improvement considering TDM.

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References

Almström, P. and Kinnander, A. (2011) 'The productivity potential assessment method: assessing and benchmarking the improvement potential in manufacturing systems at shop-floor level', *Int. J. of Productivity and Performance Management*, Vol. 60, No. 7, pp.758–770.

Al-Tahat, M., Al-Refaie, A. and Al-Dwairi, A. (2012) 'Performance evaluation and analysis of a JIT-Kanban production system with sampling inspection', *Int. J. of Industrial and Systems Engineering*, Vol. 11, No. 3, pp.225–249.

Azadeh, A., Izadbakhsh, H.R., Mohammadhosseinzad, M. and Raissifard, M.R. (2011) 'A hybrid computer simulation-genetic algorithm for scheduling optimisation of cargo trains with time and queue limitations', *Int. J. of Industrial and Systems Engineering*, Vol. 8, No. 2, pp.157–174.

Barnes, R.M. (1980) *Motion and Time Study*, John Wiley & Sons, New York.

Becks, C. (1998) 'MTM – Werkzeug zur Gestaltung und Quantifizierung von Montageprozessen', in Herbert Utz (Hrsg): *Moderne Methoden zur Montageplanung: Schlüssel für eine effiziente Produktion*, Seminarbericht 36, pp.2-1–2.24, Institut für Werkzeugmaschinen und Betriebswissenschaft, München.

Bokranz, R. and Landau, K. (2006) *Produktivitätsmanagement von Arbeitssystemen*, Schäffer-Poeschel Verlag, Stuttgart.

Bokranz, R. and Landau, K. (2012) *Handbuch Industrial Engineering: Produktivitätsmanagement mit MTM*, Schäffer-Poeschel Verlag, Stuttgart.

Boothroyd, G., Dewhurst, P. and Knight, W.A. (2011) *Product Design for Manufacture and Assembly*, 3rd ed., CRC Press, Taylor & Francis Group, Boca Raton, FL.

Carey, P., Farell, J., Hui, M. and Sullivan, B. (Eds.) (2007) *Heyde's MODAPTS – A Language of Work*, Heyde Dynamics, Brisbane.

Chryssolouris, G. (2006) *Manufacturing Systems: Theory and Practice*, 2nd ed., Springer, New York.

Desai, A. and Mital, A. (2011) 'Simplifying the product maintenance process by building ease of maintenance into the design', *Int. J. of Industrial and Systems Engineering*, Vol. 9, No. 4, pp.434–454.

Deuse, J. (2010) 'MTM – Die Prozesssprache für ein modernes Industrial Engineering', in Britzke, B. (Hrsg.): *MTM in einer globalisierten Wirtschaft – Arbeitsprozesse systematisch gestalten und optimieren*, pp.65–80, FinanzBuchVerlag, München.

Deuse, J., Wischniewski, S. and Fischer, H. (2006) 'Renaissance des Industrial Engineering – Methoden für die Umsetzung Ganzheitlicher Produktionssysteme', *werkstattstechnik* online 96, Vol. 1, No. 2, pp.57–60.

DMTMV (2012) [online] https://www.dmtm.com/index/index.php? (accessed 12 July 2012).

Dombrowski, U., Crespo, I. and Zahn, T. (2010) 'Adaptive configuration of a lean production system in small and medium-sized enterprises', *Production Engineering*, Vol. 2010, No. 4, pp.341–348.

Dreyfus, S.E. and Dreyfus, H.L. (1980) *A Five-Stage Model of the Mental Activities Involved in Directed Skill Acquisition*, Research report, University of California, Berkley.

Duanmu, J. and Taaffe, K. (2012) 'Production capabilities using takt times, requirements analysis and simulation', *Int. J. of Industrial and Systems Engineering*, Vol. 10, No. 2, pp.197–216.

Erohin, O., Kuhlang, P., Schallow, J. and Deuse, J. (2012) 'Intelligent utilisation of digital databases for assembly time determination early phases of product emergence', *Proceedings of 45th CIRP Conference on Manufacturing Systems, Procedia CIRP*, Athens, Greece, Vol. 3, pp.S.424–S.429.

Esfandyari, A., Osman, M.R., Ismail, N. and Tahriri, F. (2011) 'Application of value stream mapping using simulation to decrease production lead time', *Int. J. of Industrial and Systems Engineering*, Vol. 8, No. 2, pp.230–250.

Eversheim, W. (1996) *Betriebshütte Produktion und Management*, 7.Auflage, Springer Verlag, Berlin.

Groover, M.P. (2007) *Work Systems and the Methods, Measurement and Management of Work*, Pearson Prentice Hall, Upper Saddle River, NJ.

Gurumurthy, A. and Kodali, R. (2011) 'Simulation model for the design of lean manufacturing systems – a case study', *International Journal of Productivity and Quality Management*, Vol. 4, Nos. 5–6, pp.691–714.

Hammer, W. (1997) *Wörterbuch der Arbeitswissenschaft – Begriffe und Definitionen*, Hanser, München.

Heinz, K. (1995) 'Die Zukunft der Zeitwirtschaft – Die Zeitwirtschaft der Zukunft', in *Produktivitätsfaktor Zeitwirtschaft. Proceedings Fachtagung*, 18–19 Oktober, Dortmund, pp.2–11.

Heinz, K. and Olbrich, R. (1989) *Zeitdatenermittlung in indirekten Bereichen*, Verlag TÜV, Rheinland.

Heinz, K. and Olbrich, R. (1994) *Planzeitermittlung*, Hanser, München.

Hinrichsen, S. (2009) *Arbeitsrationalisierung mittels Methoden des Industrial Engineerings in Dienstleitungsbetrieben*, Shaker Verlag, Aachen.

ifaa (2012) *ifaa-Trendbarometer*, Survey, July [online] http://www.arbeitswissenschaft.net (accessed 17 July 2012).

Jain, V., Wadhwa, S. and Deshmukh, S.G. (2006) 'Modelling and analysis of supply chain dynamics: a high intelligent time (HIT) Petri net based approach', *Int. J. of Industrial and Systems Engineering*, Vol. 1, Nos. 1/2, pp.59–86.

Jiao, J. and Tseng, M. (1999) 'A pragmatic approach to product costing based on standard time estimation', *International Journal of Operations & Production Management*, Vol. 19, No. 7, pp.738–755.

Kanawaty, G. (Ed.) (1992) *Introduction to Work Study*, 4th ed., International Labour Office – ILO, Geneva, Switzerland.

Kuhlang, P. and Sihn, W. (2012) 'Industrial Engineering – Moderne Sichtweise des systematischen Produktivitätsmanagements', *WINGbusiness*, Vol. 2012, No. 2, pp.9–14.

Kuhlang, P., Edtmayr, T. and Sihn, W. (2011) 'Methodical approach to increase productivity and reduce lead time in assembly and production-logistic processes', *CIRP Journal of Manufacturing Science and Technology*, Vol. 4, No. 1, pp.24–32.

Landau, K. (2007) *Lexikon Arbeitsgestaltung – Best Practice im Arbeitsprozess*, Universum Verlag, Wiesbaden.

Lotter, B. and Wiendahl, H-P. (2006) *Montage in der industriellen Produktion*, Springer, Heidelberg.

Maynard, H.B., Stegemerten, G.J. and Schwab, J.L. (1948) *Methods – Time Measurement*, McGraw Hill, New York.

Meyers, F.E. and Stewart, J.R. (2002) *Motion and Time Study for Lean Manufacturing*, 3rd ed., Pearson Prentice Hall, Upper Saddle River, NJ.

Nakayama, S., Nakayama, K. and Nakayama, H. (2002) 'A study on setting standard time using work achievement quotient', *International Journal of Production Research*, Vol. 40, No. 15, pp.3945–3953.

Niebel, B.W. (1993) *Motion and Time Study*, 9th ed., IRWIN, Boston, MA.

Niebel, B.W. and Freivalds, A. (2003) *Methods, Standards and Work Design*, 11th ed., McGraw-Hill, Boston, MA.

Ohm, P. (1997) *Integratives Zeitdatenmanagement – Konzept und EDV-Werkzeuge*, Praxiswissen Verlag, Dortmund.

Olbrich, R. (1993) *Aufbau einer Zeitwirtschaft*, Bachem, Köln.

Peter, K. and Lanza, G. (2011) 'Company-specific quantitative evaluation of lean production methods', *Production Engineering*, Vol. 2011, No. 5, pp.81–87.

Petzelt, D. (2010) *Konzept zur rechnergestützten Bestimmung von Sollzeiten in der Montageplanung*, Shaker Verlag, Aachen.

Picker, C. (2006) *Prospektive Zeitbestimmung für nicht wertschöpfende Montagetätigkeiten*, Dortmund, Univ., Fakultät Maschinenbau, Diss.

Quick, J.H., Duncan, J.H. and Malcolm Jr., J.A. (1965) *Das Work-Factor-Buch*, Carl Hanser, München.

REFA (2002) *Ausgewählte Methoden zur prozessorientierten Arbeitsorganisation*, REFA, Bundesverband.

REFA (1997) *Datenermittlung – Methodenlehre der Betriebsorganisation*, Teil 2, Carl Hanser Verlag, München.

Sackermann, R. (2009) *Eine wissensbasierte Methode zur Zeitermittlung in der Einzel- und Kleinserienfertigung*, Shaker Verlag, Aachen.

Sakamoto, S. (2010) *Beyond World-Class Productivity – Industrial Engineering Practice and Theory*, Springer Verlag, London.

Schaub, K., Caragnano, G., Britzke, B. and Bruder, R. (2012) 'The European assembly worksheet', *Theoretical Issues in Ergonomics Science*, iFirst, Vol. 1, No. 23, pp.1–23.

Soroush, H.M. (2012) 'Solving the single machine scheduling problem with general job-dependent past-sequence-dependent setup times and learning effects', *European Journal of Industrial Engineering*, Vol. 6, No. 5, pp.596–628.

Stowasser, S. (2010) 'Produktivität und Industrial Engineering', *Methodisches Produktivitätsmanagement – Umsetzung und Perspektiven*, angewandte Arbeitswissenschaft Zeitschrift für Unternehmenspraxis, ifaa, Jahrgang, Vol. 47, No. 204, pp.7–20.

Tschich, H. (2000) *Entwicklung eines durchgängigen Modells für Zeitdaten mit anwendungsorientierter Genauigkeit*, Dortmund, Universität, Fakultät Maschinenbau, Diss.

Vainio, F., Maier, M., Knuutila, T., Alhoniemi, E., Johnsson, M. and Nevalainen, O.S. (2010) 'Estimating printed circuit board assembly times using neural networks', *International Journal of Production Research*, Vol. 48, No. 8, pp.2201–2218.

Wiendahl, H-P. (1996) 'Produktionsplanung und -steuerung', in Eversheim, W. (Hrsg.): *Betriebshütte Produktion und Management*, 7.Auflage, Springer Verlag, Berlin.

Wiendahl, H-P. (2010) *Betriebsorganisation für Ingenieure*, 7. aktualisierte Auflage, Carl Hanser Verlag, München.

Zandin, K.B. (2003) *MOST Work Measurement System*, 3rd ed., Revised and expanded, Taylor & Francis Group, Boca Raton, FL.

Zülch, G. (1996) 'Arbeitswirtschaft', in Eversheim, W. (Hrsg.): *Betriebshütte Produktion und Management*, 7. Auflage, Springer Verlag, Berlin.

Notes

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