Process times in logistic chains – New proposals for classification, measurement, and application

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Abstract - Kurzfassung

More than time analysis in individual machines, time measurements in harvest process chains require a generally recognized, practicable structure of work time classification, for which suggestions are given in this contribution. In addition, a process data acquisition system which, among other features, allows critical points to be analyzed and work time to be documented based on automatically collected data is put up for discussion.

Keywords: Time classification, harvest process chains, process data acquisition, analysis of critical points

Prozesszeiten in logistischen Ketten - neue Vorschläge zur Gliederung, Erfassung und Verwendung

Zeitmessungen an Ernteprozessketten erfordern, mehr noch als bei der Zeitanalyse an Einzelmaschinen, eine allgemein anerkannte, praktikable Struktur der Arbeitszeitgliederung. Der Beitrag enthält entsprechende Vorschläge. Zur Diskussion gestellt wird ferner ein Prozessdatenerfassungssystem, das auf Basis automatisch gewonnener Daten unter anderem eine Schwachstellenanalyse und eine Arbeitszeitdokumentation erlaubt.

Schlüsselwörter: Zeitgliederung, Ernteprozessketten, Schwachstellenanalyse

1 Introduction

Time classification is a means of understanding for the structural division of time spans into qualitatively different, clearly definable partial process times and their classification in a scheme based on certain analytical purposes. In science and the economy, they are used as an aid for exact process analysis, which may include people as well as the means or the object of work in work processes. Only the precise knowledge of the structure and percentage of different time chain elements provides access to the reserves of work and machine capacity. Thus, time classification and measurement are considered the basis of efficiency increase.

If the time required for a logistic chain in plant production is measured, critical points in material flow and machinery use can be identified. For this purpose, time classification must enable time information from several process chain elements (work equipment) to be combined. This also leads to the discovery of deficiencies in the capacity planning of the process elements which work together. Well synchronized process chains have a small percentage of time losses per process chain element and small overall time losses. This requires a comprehensive consideration of the complete logistic chain under time aspects. The limitation of consideration to the percentage of time lost by the key machines does not allow this goal to be met. Due to limited transport, handling, and compression capacities in a silage chain, for example, the high performance potential of the harvesting machine might not be fully exploited.

Time measurements absolutely require a generally recognized, practicable structure of time classification. Only when the classification scheme is generally recognized (even better: *available as a standard*) can reproducibility as a basic necessity of labor science be guaranteed. Today, practicability means that a time classification scheme must provide the possibility of gapless, largely automated time data acquisition in complex process chains which is suitable for various evaluations.

When analyzing the methods of time measurement and evaluation, the authors quickly reached the limits of available time classification systems. Therefore, they suggest a new classification system, which includes a transport-based harvest process chain as an example of application.

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2 Current knowledge

In addition to time classification systems for industrial production as well as the energy and construction sector, independent time classification schemes for agricultural work processes have been available for a long time. They are mainly used for tests of agricultural machinery and work standardization in agriculture. Since all agricultural work processes are machinery-bound, time classification systems are largely tailored for mobile technical work equipment. Among others, the following two time classifications for agricultural work processes are available in Germany:

I Scheme of the KTBL part time method (Jäger 1991)

II TGL 22289 "Time classification in agriculture and forestry" (TGL 22289 1974).

Jäger (1991) described the current knowledge of time requirements for field work in Germany. After reunification, numerous attempts were made to merge the part-time method with the standard TGL 22289, which had been applied in East Germany since 1974 and served as a basis for time analyses in agriculture. Herrmann (1999) also compared the KTBL part time method and the standard TGL 22289. Nevertheless, a modern, standardized tool for work science, work management, and machinery testing is not yet available.

3 Time classification proposal

Sonnen (2006) describes time classification as an interface between the virtual and the real world. Only time classification allows a complex process to be analyzed in detail. Later process comparison or optimization can be carried out based on real time measurements or simulated time data. In the foreseeable future, GPS technology may be available on virtually every mobile agricultural machine. As a result, automatically recorded temporal and spatial information will become available as standard. In combination with available machinery data, which can be supplemented with the aid of additional sensor systems if necessary, automatic process data acquisition becomes possible. In addition to sensor technology, which is used to control the machine, the analysis and minimization of critical points in entire process chains could be possible if the sensor systems are based on a uniform and standardized time classification system. The decentralized digitalization of analogous measurement values with the aid of CAN-BUS systems[1] reduces the number of cables required for the numerous sensors. Partial process times of the individual process elements can then be determined on-line or in a post-process. However, this requires that a time classification scheme with a sufficiently fine structure is available for the gapless measurement of machinery application time and non-productive time. This classification should

- be independent of the kind of machinery and applicable in all agricultural process chains,
- have open ends for simple, purpose-specific, precise determination by means of decimal classification and
- have a responsiveness, which allows for automated process data acquisition and the analysis of critical points.

The standard TGL 22289, which disappeared together with former East Germany, is virtually no longer available even among work scientists. However, literature research confirms the impression that this standard is more suitable than others as a basis for a new time classification system for agricultural process chains, which meets the requirements (Herrmann 1999, Sonnen 2007). In Table 1, the time classes required for harvest process chains are presented, while Table 2 lists the time totals to be determined based on these time classes. The unlimited possibility of expansion at the ramifications of the time classification tree (Fig. 1) proved to be a particular advantage of TGL 22289.

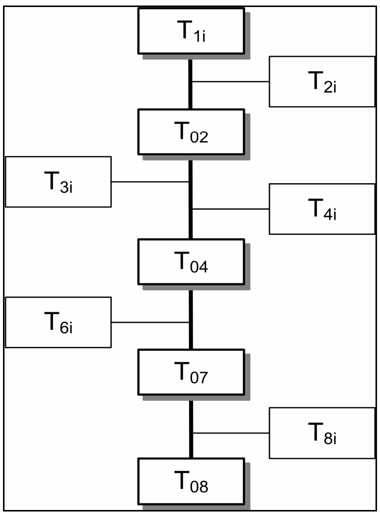

Fig. 1: Adapted time classification tree (basic structure with the names from Tables 1 and 2)

Changes as compared with TGL 22289 mainly result from the goal and the individual responsiveness of analyses used for process optimization or the analysis of critical points. Despite all standardization requirements for research tools, it is undisputed that methods of time measurement and, hence, also time classification systems must always be adapted to specific tasks while a basic structure is retained.

[1] CAN – Controller Area Network

Table 1: Part times of an expanded time classification for harvest process chains

Process part time	Name / Description
T11	**Loading time** in the transport flow
T121	**Loaded drive time field** in the transport flow
T122	**Loaded drive time street/field path** in the transport flow
T13	**Unload time** in the transport flow
T141	**Empty drive time field** in the transport flow
T142	**Empyt drive time street/field path** in the transport flow
T15	**Weigh time** in the transport flow
T21	**Turning and moving time** at the work site
T22	**Drive time** at the work site / the machine does not work as required by the work order
T23	**Time for technological down time** e.g. goods transfer/changing attachment
T31	**Time for care an maintenance** during the acquisition period
T32	**Time for preparation** of the machine for the work
T33	**Time for adjustments**
T41/T42	**Time to remove errors** technical and functional
T43	**Wait time** caused by errors of included process links
T441	**Wait time determined by adaptation** at the work site
T442	**Wait time determined by adaptationt** at the unloading site
T443	**Wait time determined by adaptation** at the weigh location
T611	**Travel time** empty drive from yard to work site incl. traffic delays
T612	**Travel time** empty drive from work site to yard incl. traffic delays
T613	**Travel time** empty drive from warehouse to work site incl. traffic delays
T621	**Travel time** empty drive from work site to work site incl. traffic delays
T622	**Travel time** empty drive from warehouse to work site incl. traffic delays
T7	**Wait time** ecaused by service times of involved process links
T81	**Down time** for organisational reasons
T82	**Down time** due to weather
T83	**Down time** for other reasons

Table 2: Time totals of the expanded time classification for agricultural process chains

Time totals

Process part time	Name	Total
T1	Main time	T1 = T11 + T12 + T13 + T14 + T15
T12	Σ Load drive times	T12 = T121 + T122
T14	Σ Empty drive times	T14 = T141 + T142
T2	Σ Auxiliary times	T2 = T21 + T22 + T23
T3	Σ Service times	T3 = T31 + T32 + T33
T4	Σ Wait times	T4 = T41/T42 + T43 + T44
T44	Σ Wait times	T44 = T441 + T442 + T443
T6	Σ Travel times	T6 = T61 + T62
T61	Σ Travel times	T61 = T611 + T612 + T613
T62	Σ Travel times	T62 = T621 + T622
T8	Σ Down times	T8 = T81 + T82 + T83

Superior time totals

Process part time	Name	Total
T02	Base time	T02 = T1 + T2
T04	Production work time	T04 = T4 + T02 + T3
T07	Use time	T07 = T04 + T6 + T7
T08	Acquisition time frame	T08 = T07 + T8

Due to its letter indexing alone, the KTBL time classification scheme was largely unsuitable for expansion. However, the term “main time”, during which the machine is used for its intended purpose at the work site has become so generally accepted among work scientists that it was taken over under the symbol T1. The time sum T02, which has been extended to include the auxiliary times T2, is now termed basic time (Table 2). The internal classification of the main time T1 for transport cycles is also new as compared with TGL (Fig. 2). This proposal by Schmid (1977) had never been included in the industrial standard.

Other changes in the classification proposal for harvest process chains apply to selected time losses at the levels T2, T4, and T5. In the new version, the partial process time T5, which is listed in TGL 22289 as standing time of the machine due to personal needs of the operator as well as the transport technology-related auxiliary times T24 are not considered because they do not provide any useful information for the analysis of critical points of several machines working together or because their automatic measurement is extraordinarily difficult. Times for the repair of functional and technical failures (T41 and T42) should be measured together as long as these measurements do not include time for machinery testing.

However, the extensions of the classification scheme, which become necessary due to GPS-based precise measurements of the place and the time of use and open up entirely new reserves in process optimization, are particularly important. In his dissertation, Sonnen (2007) discusses them particularly intensively using silage crop harvesting processes as an example. Of course, this system also allows non-networked labour processes, such as soil cultivation, to be classified.

If one assumes that GPS data will be available as standard in harvest process chains in the future, location-dependent partial process times can be added to the time classification scheme. These times are used for the local differentiation of coordination-related waiting times (T44) in order to allow for a detailed analysis of critical points. During silage crop reception or at the vehicle scale, this enables the relevant times to be measured quickly and comfortably.

Based on these insights, the proposal of a time classification scheme for agricultural process chains was developed. Table 1 lists all process times including symbols and short descriptions. Partial process times which can be grouped can be summarized in time totals. Superior time totals are used for the clear classification of the measuring period T08 (Table 2 and Fig. 1).

If time classification is used for the measurement of partial process time and/or the simulation of a selected harvest process chain, the individual partial process time groups must be divided according to the different types of machinery. In the classification overview shown in Fig. 3, the division of the partial process time groups for a harvest process chain for silage crops is considered as an example. Depending on the type of machinery, the module-based time classification overview enables a time classification extract to be created. Additional process-specific partial time explanations help with the clear differentiation of the individual partial process times. Adaptation-related waiting time at the work location (T441) in a harvest process chain for silage crops, for example, is generally caused by incorrect allocation of transport means to the forage harvester in the parallel technique.

The individual time classification modules for time measurement in harvest process chains for silage crops (Fig. 3) show that a division of the main time T1 into partial times for load and empty rides on roads and fields as well as for loading and unloading is un-

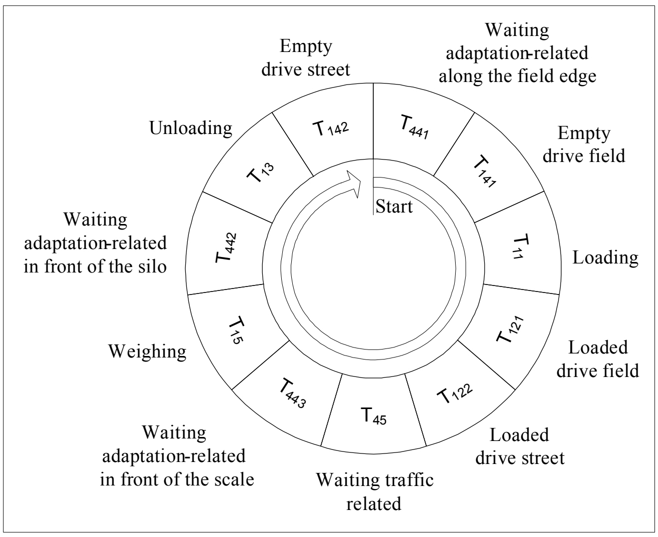

Fig. 2: Cyclically recurring flow of a transport unit

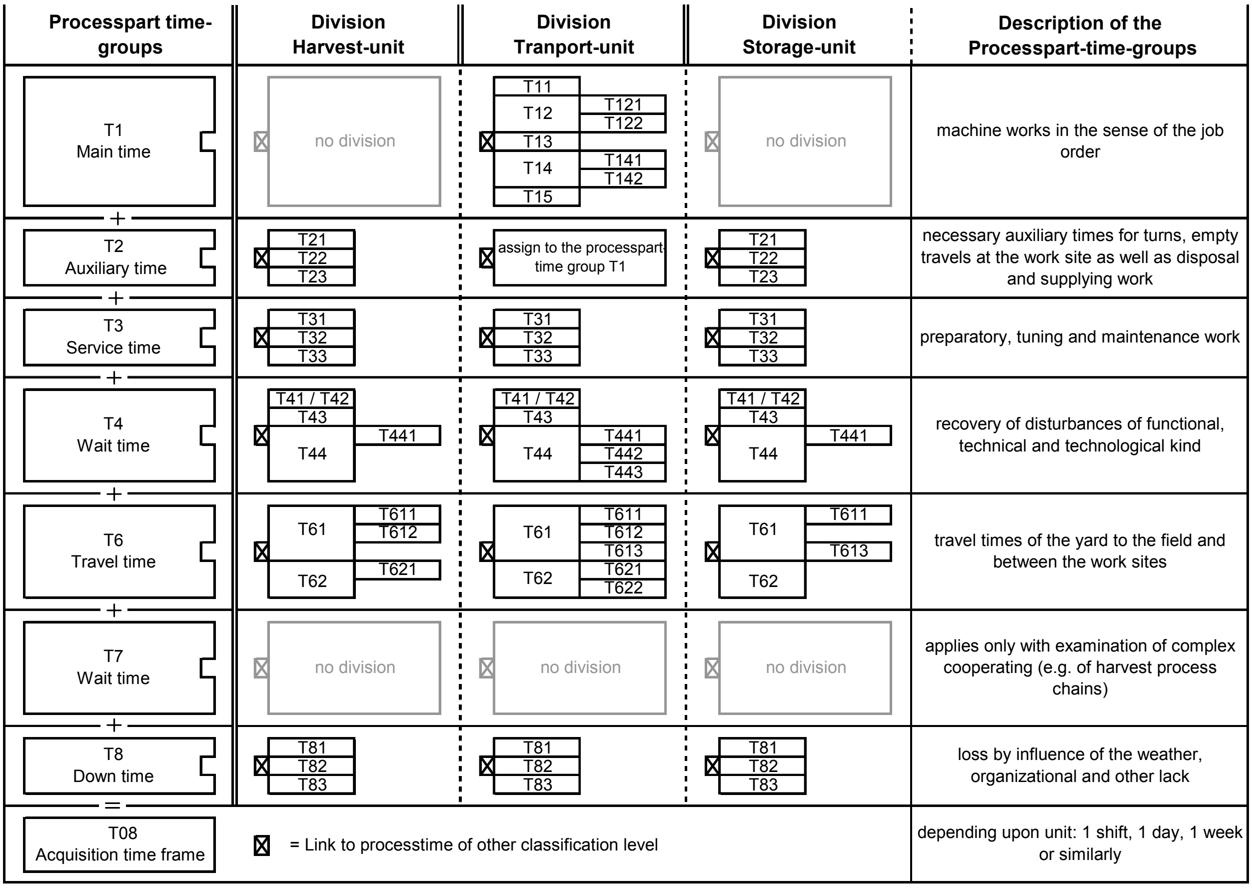

Fig. 3: „Modules“ of the time classification for harvest process chains for silage goods

avoidable. Together with potential weighing times as well as adaptation- and traffic-related waiting times, this leads to a cyclical flow of transport units (Fig. 2) whose duration in relation to pure loading time allows the number of vehicles needed to be derived.

4 Analysis of critical points

In the future, adapted time classification with a sufficiently fine structure will allow the critical points of entire harvest process chains to be analyzed with the aid of intelligent evaluation software, and the available resources (technical, locational, and organizational means) can be used to improve the process chains until they range close to their optimum. If this partially automated optimization does not provide the desired results, computer simulation enables the effects of resources, which have not yet been included to be tested virtually.

On-line process data collection for tractor-based field work has already been tested on the basis of the standardized ISOBUS system and has been evaluated as promising. Similar tests of automatic documentation with the aid of adapted time classification were carried out by Rademacher et al. (2005) for combines. In addition, commercial products for the monitoring of performance parameters and service data are becoming available on the market.

Currently, however, these systems are always oriented towards one single kind of machine, whose types can vary. If standstill or waiting times occur, it is virtually impossible to interpret them such that the requirements are met because the process data of the process elements involved are not recorded simultaneously. Field efficiency, which was introduced by Hunt (2001), is also unable to detect critical points in process design. It only reflects the quality of changes relating to the harvesting machine, which occurred in the process chain at the end of the harvest day.

The analysis of entire harvest process chains therefore requires an automatic process data collection system (APDES) which is independent of the kind of machinery and simultaneously collects machine and GPS data for the determination of partial process times and infrastructure (Fig. 4). If the collection of process data from agricultural harvest process chains is based on uniform, finely structured time classification, the system allows the following points to be verified:

- Standstill and waiting times of the key machine
- Standstill and waiting times of the means of transport and handling
- Percentage of time losses per machine and total time losses in the logistic chain
- Mass flow fluctuations in the logistic chain

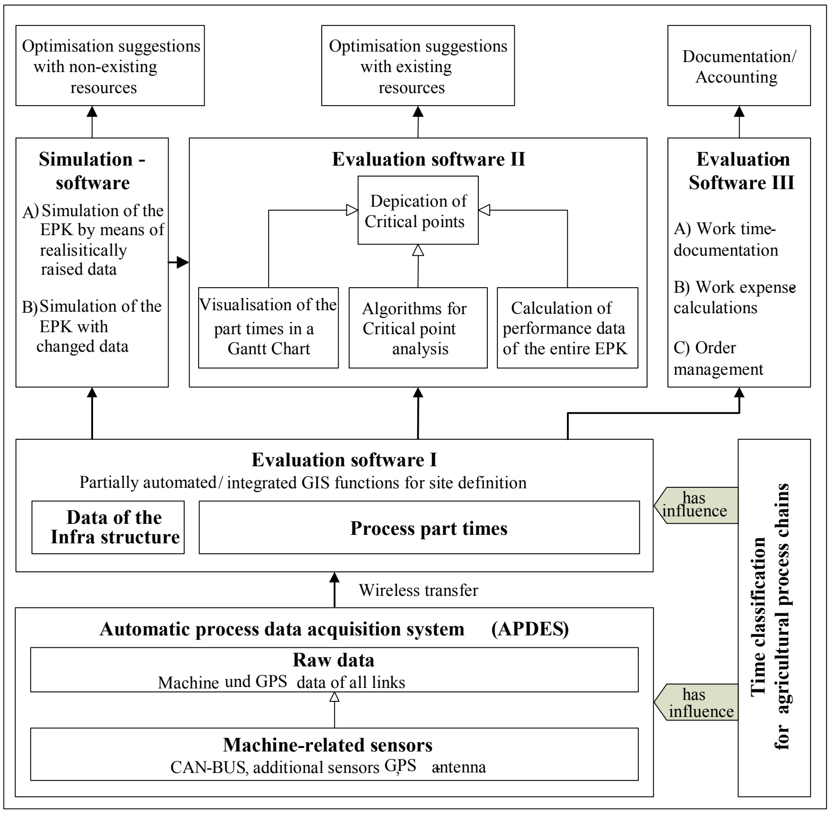

Fig. 4: Automate Process Data Acquisition System (APDES) (Sonnen 2007)

– Degree of exploitation of the installed capacity
– Development of the labour expenses.

If time classification and the measurement method meet the high demands, the analysis of critical points can follow in the post-process after the data have been merged (Sonnen 2007). In the first step, this requires the extraction of the classified partial process times per machine from the recorded data and additional site information about the farm as well as work and storage locations.

Machine data which need to be recorded can often be read out and stored by available CAN-BUS systems without additional work steps. If clear partial process time measurement requires additional machinery data, they must be integrated into the existing machine CAN-BUS in a digital form, if possible. The machinery data can be divided into event-based and continuous data. Event-based data include all status changes, such as the lifting status of a harvesting header. Continuous data, however, are subject to continuous value change, e.g. the mass throughput of a harvesting machine. Data recording is limited to 1 Hz due to the updating rate of the GPS location coordinates. In addition, faster recording frequencies do not promise any additional benefit. Besides the GPS location coordinates, the uniform GPS time serves as a time stamp in the time record. In the future, data structure should have a standardized format so that data can be used beyond the level of the individual manufacturer. For this purpose, the extension of the available agroXML standard is conceivable (KTBL 2007).

At the end of a harvest day or when required, the automatically recorded time logs are transferred to a local PC via a wireless connection (Bluetooth, WLAN, or GSM) to a local PC. Here, machine-related partial process time can be calculated. The necessity of sufficiently precise detection features and evaluation algorithms for clear data assessment must be emphasized. For visualization, the infrastructure used by the machines can be shown on a section of a topographic map with the aid of a commercially available or cost-free internet-based GIS system. Afterwards, this map section is used for the manual specification of the local means and as a basis for a simulation course which might follow.

A simulation model based on real data can provide valuable insights for the analysis of critical points. Uniform, gapless time classification serves as a link between simulation and reality. The automatically recorded machinery data, which are separated according to machinery types, are stored for later analytical steps or specific evaluation algorithms.

A Gantt chart (Fig. 5) allows the partial process times for all machines to be visualized under a uniform time axis and used for an analysis of critical points together with the performance data of the entire harvest process chain.

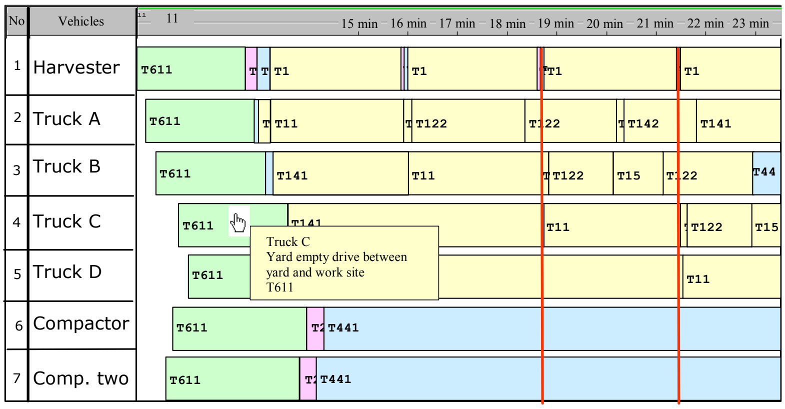

Fig. 5: Gantt chart for the visualization of process part times of multiple machines (Sonnen 2007)

Experts´ knowledge, which can be stored in a data base, enables suggestions for the optimization of the entire harvest process chain under consideration to be derived. In addition, the simulation software also allows scenarios to be tested which cannot be realistically represented using available resources. This may apply to altered mass flows and machine configurations, for example. The following parameters can be used for adjustment in order to optimize processes:

– Transport performance (number of vehicles, capacity utilization, field development, travelled distances, driving speed, weighing time, waiting times…)
– Performance of the harvesting machine (choice, number, working width, driving speed, drive pattern, turning times, waiting times…)
– Silo management (size and form of silos, silage properties, unloading time, distribution technique, compression technique, compression requirements…)

The raw data base which serve as a basis for partial process time acquisition also provides the farmer or contractor with the possibility of automated documentation and tracing of the relevant information. Especially contractors are looking for automated solutions in order to minimize the need for operators to participate in the documentation of work time.

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References

Herrmann A. (1999): Modellierung verfahrenstechnischer Bewertungskriterien bei unterschiedlicher Verknüpfung von Ernte- und Transportarbeitsgängen. Habilitation, Landwirtschaftliche Fakultät, Martin-Luther-Universität Halle-Wittenberg, 204 pp.

Hunt D. (2001): Farm Power and Machinery Management. Iowa State Press, Iowa, 368 pp.

Jäger P. (1991): Zeitbedarf von Feldarbeiten (Teil 1-3). Landtechnik 46 (1/2), 69-71; 46 (3), 123-128; 46 (4), 188-190.

KTBL - Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V (2007): agroXML – Informationstechnik für die zukunftsorientierte Landwirtschaft. KTBL-Schrift 454 , Darmstadt, 180 pp.

Rademacher T. (2005): Effizienter Mähdreschereinsatz - Möglichkeiten zur Kostensenkung im Unternehmen. In: VDI-MEG (ed.), Landtechnik für Profis, VDI-Verlag, Magdeburg, p. 81-93.

Schmid H. (1977): Zeitgliederung für Transport und Umschlag in der Landwirtschaft. Zeitschrift Agrartechnik – Berlin 27 (7), 297-300.

Sonnen J., Tölle R., Frerichs L., Hahn J. (2006): Simulation toolbox for R&D of harvesting machinery and logistic chains. CIGR World Congress Agricultural Engineering for a Better World, Bonn, Germany. 3-7 September 2006, Book of Abstracts, p. 805-806.

Sonnen J. (2007): Simulation von Ernteprozessketten. VDI-MEG 454, HU Berlin, Dissertation, 182 pp.

TGL 22289 (1974): Fachbereichsstandard Zeitgliederung in der Land- und Forstwirtschaft. Begriffe, Kurzzeichen, Erläuterungen.