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METHODS AND TECHNIQUES IN WORK TIME STRUCTURE DETERMINING: THEORY AND PRACTICE IN AIRCRAFT INDUSTRY

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ABSTRACT:
For the two most important known methods and techniques of determining and quantification of the **c**lassic **w**ork **t**ime **s**tructure **cWTS**, **W**ork **D**ay **F**igure **WDF** and **R**atio **D**elay **S**tudy **RDS** or **W**ork **S**ampling **M**ethod **WSM**, the theoretical hypothesis of the most important characteristics is represented, the same as procedures in four phases, along with their comparison.
The project of application procedures for the methods and techniques **WDF** and **RSD/ WSM** has been done in the individual research and in comparison of the results of methods with the object of research from the business system and the aircraft industry processes, along with the belonging conclusions and state improvement suggestions.
KEYWORDS:
work time structure, **WDF**, **RSD/ WSM**, aircraft industry

1. INTRODUCTION

One of the basic business and production indicators is the duration time of some events. The most frequent criteria of the time determining is work time, qualitatively shown in different forms and belonging elements.

With the immanent, famous and permanently used measure, with event duration shown in the standard or time normative with different forms (formulas, tables, figures, diagrams, nomographs), the most frequent qualitative and quantitative work time measure is the **WTS**, represented for the classic and alternative kinds, along with the subkinds and structure types.

The most important, well-known, theoretically established and continually used, the methods and techniques of determining and quantification are **WDF**, as well as **RSD/ WSM**, **[1,2, 3].** For both methods, the theoretical hypothesis and the most important characteristics are represented, along with procedures characteristics in four phases with the subphases and elements, along with their comparison.

The application of the mentioned theory is represented in the research, along with the objects of this research from the business system and aircraft industry processes, including comparison of the results of both methods, where the belonging conclusions, along with the state improvement, have been given.

2. THEORETICAL HYPOTHESIS OF WORK TIME STRUCTURE

2.1 Basic characteristics

The **Definition of the notion WTS** frequently isn't even given, or isn't given explicitely, but is, frequently, expressed implicitely, by means of two groups of work time/ day characteristics, and those are: the content of some theoretical characteristics and the dominant quotations of method existence and application technique.

About the previous, starting definitions witness also the works of some of the most familiar researchers of the Work study area, of which, for instance, one has been shown:

"During work (shift), the workers spend the time on different jobs, on the pause, on the delays that appear for different causes, etc. Research of the **WTS** is a necessity, because of different purposes, of which the most important are... (four purposes are shown)... For the previous purposes to be realized, all forms of spendings have to be classified according to the same-typed groups (categories), in harmony with same objective characteristics, to systematize them and then also analyze it", **[4].**

By including the changes into the previous one, his own suggested definition was given, with the following form and content:

"The **WTS** represents the belonging individual kind, subkind or the type, or their combination, structure projecting with established permanent or changeable work time (static part of the structure), expresses in a time or percentile amount, for the chosen (non)activity of the worker and/ or the equipment, expressed by means of the corresponding components ratio of the physical and mental/ mind acting in the prevalent material modification and/ or in the prevalent information/ administration modification, along with adequate individual form, or their combination, the usage (elements of technology, dynamics, etc.) of the available equipment capacity and/ or time worker fund for the belonging type of projecting structure (dynamic part of the structure) in the conditions of the existence of watched systems and processes without significant deviations, and all because of the accomplishment of the proposed aims and purposes. The results of the individual and/ or interactive influences of the mentioned factors are expressed for periods of the basic calender or business/ work terminal unit. Measuring unit is one working shift and/ or one work day, where the sum of average componential proportion of structure amount to 100%, and the sum of time amounts are duration time of work shift and/ or work day. Situation of more work shifts in one work day is solved theoretically and practically in more differrent ways and different than situation with one shift as a starting and basic measure to more, most often four, shifts and different alternative forms, taking into consideration the mathematical-statistical, physiological, sociological, psychological, economic and other requested and realized hypothesis and conditions, **[5].**

2.2. Kinds, subkinds and types of WTS

Different types of business have as a consequence different organizational structure, where different projecting models of work time realizing (of work shift or work day) determine different models of the **WTS**.

According to the different characteristic it can assimilate, **WTS** can be classified according to different characteristics it can assimilate, **[6, 7].**

In the mentioned **WTS** appear, most often applied, **c**lassic forms named **cWTS**, and which differ in several characteristics: number of shifts in one working day, shift duration time, (non)existence of **p**rescribed **r**ests **PR** and their position in the duration time dynamics, their structure and duration, along with the way and form of their use.

Along with the classic structure, there are **a**lternative forms named **aWTS**, which are usually made of the **t**ypical structure and named **tWTS**, the notion of **s**liding work time and named **sWTS**, the **f**lexible work time and named **fWTS**, and also work at **h**ome structure and named **hWTS**.

3. THEORETICAL HYPOTHESIS OF WTS METHODS AND TECHNIQUES

The methods and techniques, that are most frequently used for **WTS** determining, are:

1. **W**ork **D**ay **F**igure **WDF**
2. **R**atio **D**elay **S**tudy **RDS,** or rather, **W**ork **S**ampling **M**ethod **WSM**

3.1. Basic characteristics of WDF and RSD/ WSM, [3,4,5]

Method WDF

Definition: WDF is a method of duration time measuring of individual activities in order they appear during the entire shift.

Technology: Work place and/ or worker do individual activities, and time analyst, who spends his entire shift beside mentioned entities, follows, notes down and measures the duration time of the entities by means of a chronometer/ stopwatch, a watch or some similar instrument for time measuring, using the flux method without the performance rating, and writes the results down into the measuring list.

Method RSD/ WSM

Definition: RSD/WSM is a method of mathematical-statistical overseeing the phenomena by means of their frequency, which is based on the sampling theory by counting from the two-layered discontinued groups, for which the random variable can recieve only integer values, [1].

Mathematical-statistical basis: The result of the phenomena overseeing, mathematically defined, belongs to the discontinued random variable, whose belonging integer values do discontinual series of numbers.

A typical represent of the discontinued distribution is the binomn distribution.

Its probability function of the distribution is designed by the expression:

$$P(x) = \frac{n!}{x!(n-x)!} \cdot p^x \cdot q^{n-x} \quad (1)$$

which is followed from the binom development $(p+q)^n$, with a necessary condition

$$p + q = 1 \quad (2)$$

where are:

P(x) – probability of research phenomena where in the sample of **n** events, appeared research layer non-work **p** exactly **x** times,

n - sample amount (number of work places, machines and/ or workers),

p - proportion of non-work,

q - proportion of work,

x - number of events for research activity.

3.2. A WTS project measuring procedures for both methods

A **WTS** project measuring procedures for both methods is equal on the level of list or number of composed phases of procedures. Aforementioned phases are:

Phase 1. Prepairing of the measuring

Phase 2. Measuring

Phase 3. Data processing and results analysis

Phase 4. Report about measuring procedure project.

Phase 1. Prepairing of the measuring

Phase 1. embraces the following list and tasks description:

1) determining of the measuring goal (aim) and purpose,

2) education of time analyst,

3) a choice of measuring objects,

4) informing all important participants about the measuring,

5) previous list making and description of activities for **WTS**,

6) space-time plan for determining the research event or activity,

7) making the time analyst list.

Phase 2. WTS measuring

Measuring differs for aforementioned methods depending on the reasonable and justified differences for the technology and technique characteristics of the cited measuring methods. Basic characteristics of the technologies and techniques of the previous ones are:

1) **WDF**: exhibited in the previous definition;

2) **RSD/ WSM**: on the basis of determining rounds schedule, time analyst goes around the work places and/or known ways, stopping in front of the entity, where he establishes the (non)activity and where he observes in the measuring list, following the already familiar procedure.

Measuring is usually performed in two phases:

a) experimental measuring

Basic subgoals and subtasks for both methods are: checking, and if necessary, correcting the determining elements for the preparation of measuring; the time analyst and the objects of the measuring getting aquianted and used to each other; the technology and technique realization on the sample, more or less than those ones used for the main measuring, learning and practicing of the time analyst as much as possible; the last element determining of the representative sample amount for the main measuring is significantly different for the individual method, beside the following characteristics for:

- **WDF**: A cited notation and activity, nor realization of it, doesn't exist, because the correlation between the depending variable/result and independent variable model or affecting factors is not determined. In practice, only the dirrection/recommendation about the sufficient or "representative" sample amount for the main measuring exists, but it is an amount of measuring for a period of 15 to 20 days,
- **RSD/WSM**: universal model of correlation between the depending variable/result and undepending variable is based on the stohastic approach and in the deterministic mode is exhibited by formulas or in some graphic forms;

b) the main measuring

After achieved experimental measuring, the main measuring starts, which establishes the real and existing in the production, but considering where it is, among the others, it has to embrace and satisfy the adequate conditions in relation to prepairing and experimental measuring.

Phase 3. Data processing and results analysis

Basic entitities: work place/ machine and manual or machine-manual work place and/ or operator/ worker on work place to the highest aggregation level; time level from one hour until whole period of measuring , (in)activity from individual to layers and cumulative work time and system WTS, technological and organizational wholeness, etc.

Basic division **WTS** consists of summary, the following levels and belonging entities, with exact number or span of adequate mode and name of basic or starting element of **WTS**-activity:

1. level - the whole or wholesome **WTS**;
2. level - layer: work **W** observations, q% and Non-work **Nw** or Losses **LG** observations, p%;
3. level- group: work **W**, planned losses **LP**, unplanned losses **LU**, Nondiscipline **NO**, Not work in the shift **NWIS**,
4. level- subgroup:work, memos, prepairing of the place and conditions, waiting and missing for material, information, documentation etc.;
5. level- activity: preparatory-finishing work, ..., official talking, ..., tools and dies maintenance, ..., ;

Data, gained by measuring with both methods, can be processed and analysed on basis of more number of data processing and analysing models, given by the adequate combinations of previously cited basic entities.

Phase 4. Report about measuring procedure project

A report for every project with measuring procedures for both methods could, by recommendation, consist of the following parts: the most important part about results and causes of it; preposition of the most important activity for state improvement, the most frequent part divided on short-term, middle-term and long-term activities; content of project with more details for the first of three phases, with important details shown in the described mode and complemented with graphics shown in mode named formulas, tables, diagrams, figures and nomograms; various backgrounds used in project, by example, documentation about firm characteristics, catalogues, etc., but also attachments of measuring lists and other backgrounds prepared for and led in measuring procedure project.

4. APPLICATION OF WDF AND RSD/ WSM

Phase 1. Preparation of measuring

The following list and summary description of tasks is accepted:

1) determining of the aim - The aim was determining of the **classic WTS** with both methods and determining of priority losses, beside the possible comparison for both methods. Purpose is finding improvement activities for solving the noticed problems;

2) education of time analyst - Acknowledgement about technological processes in production is acquired from specialistic literature, from previous own practical experience and of actual cognition of machines. Acknowledgement and initial skills about technology and technique of measuring are acquired on consultations with mentor of the adequate project;

3) selection of measuring objects - For measuring, there are selected operators/ workers on grinding machines in organizational unit Machine tooling of business system and process in aircraft industry:

- **WDF**: one operator/ worker on one grinding machine is selected;
- **RSD/ WSM**: it is twelve operators/ workers on twelve ginding machines;

4) informing operators/ workers and other participants about the measuring - One day before measuring, time analyst went on rounds across the production shop with a person for connection, and in this way, the acquainted operators/ workers, work on selected work places for the measuring. Person for connection informed persons from the leading and managing structure. During aforementioned rounds and talks with the operators, time analyst prompt performs important part of informing the operator/ worker about the measuring, beside realization of measuring for tasks of the time analyst, but not at the request of the firm;

5) making of the list and description activity - By observing work places in selected organizational unit and by observing of overseeing activities is made by the list activities, at first , for the method **RSD/ WSM**. The same list is later simultaneously used for the method **WDF**;

6) determining of the rounds schedule for **RSD/ WSM** - As it would be determined, the rounds plan for **RSD/ WSM** made some experimental rounds beside the measured belonging time, where by calculating and encircling of the results, theoretically are given five rounds per one hour.

7) making of the time analyst list - The time analyst list, which is used, is made on the basis of the previous samples of time analyst lists.

Phase 2. Measuring of WTS

1) experimental measuring

WDF: because of limitations in the chosen firm, the experimental measuring for the method **WDF** was possible to be conducted on the adequate day and data only in one part of whole shift. Experimental measuring is achieved, as the main too, on such way that the start of the activity is observed by a watch, and duration time for the activity by a chronometer/ stopwatch. For measuring of the activity duration time, there are selected minutes and seconds as time units, which are later needed for analysis, are all transfered in minutes.

RSD/ WSM: because of limitations, the same as for **WDF**, experimental measuring for **RSD/ WSM** is realized by the regular technology and technique in one part of the whole shift in the same day and data the same as for **WDF**.

During conducting the experimental measuring for **RSD/ WSM,** there are noted some problems, which extended the duration time for one round, but because of it, it would not be possible in the main measuring to realize the previously calculated five rounds per hour. Because of this reason, it decreased the theoretical number of rounds to the realistic three rounds per hour in the main measuring;

2) the main measuring

WDF: the main measuring is performed in the period of three days, of which in the first two days the operator performed the final tooling on the similar repetitional parts, while in the last, the third, day, the measuring is performed on the new workpiece, on the final tooling in grinding of workpiece with great dimensions, and that is the reason of considerable changing of the time tooling in relation to the first day.

RDS/ WSM: measuring is performed in the subsection Grinding, subdepartment Machine tooling.

Measuring for both of methods is performed in the period of three days during march in 2008. During measuring with both methods, some new activities in relation to those, which are predicted by the previously prepaired list of activity, have not happened.

Phase 3. Data processing and results of analysis

Because of adequate limitations, but because of the possibility of comparison of the same models for both methods, the following models of processing analysis are selected:

- groups of activities for work place,
- individual activities for work place,
- complementary coefficient of additional time K_c.

1. Groups of activities for work place

1) WDF

The results of duration time and proportions for groups of activities for one selected work place are shown analitically in TABLE 1., while the proportions in percents graphically for the same selected work place are shown on figure 1.

Table 1. Groups of activities for the chosen machine/ WDR

Groups of activities	Time duration min	Proportion %
Work	866	64
Planned lossed	329,3	24,33
Unplanned losses	157,7	11,67

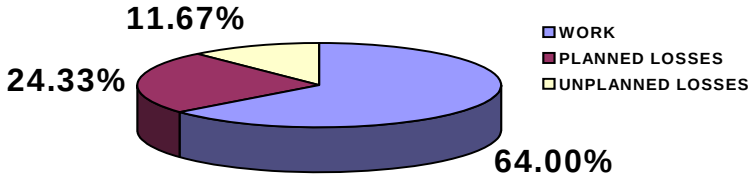

Figure 1. Proportion for groups of activities for chosen machine/ **WDR**

2) RSD/ WSM

Results for groups of activities for all ten grinding machines, on the basis of data from the time analyst lists, and those are shown analitically in TABLE 2., while the proportion in percents is shown graphically for the same selected work place on figure 2.

Table 2. Groups of activites for 10 machines/ RSD- WSM

Groups of activities	Quantity observations	Proportion %
Work	565	68.23
Planned losses	154	18.59
Unplanned losses	109	13.18

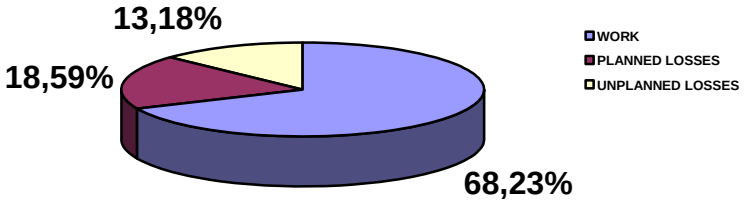

Figure 2. Proportion for groups of activities for 10 machines/ **RSD- WMS**

2. Individual activities for work place

Data processing and analysis of results are done, analogous to those for groups of activities, for individual activities by applying both methods. Because of limititations in this paper, results are not shown in a table and a diagram, but only by description.

1) WDF

a) Work 64%: technological work 24,58%; auxilary work 21,34% (questioned exactness of older machines, more frequent searches, control dimensions of the workpiece); preparatory-finishing work 18,07%,

b) Planned losses 24,33%: taking and putting back tools 13,37%; work place and work conditions maintenance 4,66%: physiological activities 3,4% (including going out to eat in a restorant or prepairing food by self in the auxilary kitchen of the workshop); giving of the data 2,89%;
c) Unplanned losses 11,67%: waiting on documentation 4,69% (reason is the fact that the worker is not in possibility to call in the projecting part of the firm and says that the fact is, that he is free to continue work and to get new work order and waiting for new tasks, but, opposite this, has to go out alone over series of locations in the projecting part, or the supervisor has achieved the mentioned work for him); waiting on the material and parts 3,26%; waiting on control 3%; waiting on new task 0,74%;

2) RSD/ WSM

a) Work 68,23%: technological work 48,79%; auxilary work 15,33% (questioned exactness of older machines, more frequent searches, control dimensions of the workpiece); preparatory-finishing work 4,2%;
b) Planned losses 18.59%: taking and putting back tools 5,55%; official talking 3,5% (additional verbal manual/instructions from supervisor to worker);
c) Unplanned losses 13,18%: waiting on control 4,83%; waiting on material and parts 3,98%; waiting on documentation 3%; the reason of such percent for waiting on control and documentation is the fact that the workers have to go out alone on other locations, where are individuals responsible for the determined control and the documentation, because the overloaded controlor cannot.

For both of methods groups of activities Nondiscipline **NO** and No work in shift **NWIS** have not appeared during the measuring.

3. Complementary coefficient of additional time K_c

Complementary coefficient of additional time is calculated by formula:

$$Kd = \frac{\sum GP}{\sum R + \sum GN + \sum NE} \cdot 100(\%) \qquad (3)$$

where is:

$\sum R$ - number of work observations,

$\sum GP$ - number of planned losses observations,

$\sum GN$ - number of unplanned losses observations,

$\sum NE$ - number of undisciplined observations;

1) **WDF**

By substituting data for groups of activities $\sum R$ =866; $\sum GP$ =329,3; $\sum GN$ = 157,7; $\sum NE$ =0 from the adequate table in (3), a relatively great amount K_c = 32,16% is calculated.

2) **RSD/ WSM**

By substituting data for groups of activities $\sum R$ =565; $\sum GP$ =154; $\sum GN$ = 109; $\sum NE$ =0 from the adequate table in (3), a relatively great amount K_c = 23% is calculated.

5. CONCLUSION AND PREPOSITION
(or: Phase 4. Report about the measuring procedure project)

5.1. Conclusion

1) preparation of measuring is performed carefully and sistematically by checking all needed elements for both methods,
2) because of the time limitations existing in the firm, experimental measuring is performed by combinating the duration of one work day, while the main measuring has duration of three work days for each of both methods,
3) work proportion is not essentially different, according to both methods and there is a span from 64 to 68%, whereas there exist more significant, different proportions for the belonging work composing elements, caused by changes in the production plan,

4) complementary, losses are in the span from 32 to 36% for both methods, whereas the proportions of the planned losses are greater than the participation of unplanned losses,
5) planned losses have different participations for both methods, with different number of priority activities with different belonging numerical values,
6) unplanned losses have similar proportions, with a few identical priority activities of waiting with similar proportions,
7) groups **NO** and **NWIS** have not appeared during the measuring.

5.2. Preposition of activities for decrease of determined losses

1) On the basis of previously determined results, it exhibits that the preposition of the following activities would be possible to affect work and non-work, with aim of enhancing the capacity effectivness and the representative sample amount,
2) because of the increased proportion of going out for documentation, for transport and montage parts , going to work in the other workshop, the decreasement of task quantity for the worker is needed,
3) it is possible to diminish the greater auxilary and preparatory- finishing times by purchasing new machines. For this, a financial investment is needed, but in the long-term work, the aforementioned can pay off itself, because of the diminishing expenses for the maintenance and general repair of old equipment.

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