The Reinvention of Time Blocks

Citation for the original published paper (version of record):
Almström, P. (2024). The Reinvention of Time Blocks. Advances in Transdisciplinary Engineering, 52: 431-441. http://dx.doi.org/10.3233/ATDE240186

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Sustainable Production through Advanced Manufacturing, Intelligent Automation and Work Integrated Learning, J. Andersson et al. (Eds.)

doi:10.3233/ATDE240186

The Reinvention of Time Blocks

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Abstract. To estimate a time for future production activities is complex and requires specialist knowledge if the result needs to be accurate. The Parametric Time Block (PTB) concept is proposed as a solution to efficiently and accurately determine time for assembly activities in early development phases. As a part of a design science approach is the concept tested at two case companies. The result of the application is very promising with a dramatic efficiency increase for determining time of a forthcoming product. Several insights regarding both the structuring of PTBs and the design process have been drawn from the cases.

Keywords. Time data management, Predetermined time systems, Productivity

1. Introduction

The strong digitalization trend in the manufacturing industry puts focus on time data used for all types of planning, balancing, cost calculations, and other purposes. The data quality is often in a poor state, but there is a growing realization of the importance of having accurate time bases ([1], [2]). Actual times are not measured or followed up, and there are few companies that are able to set planned times correctly. To determine, use, improve and administrate time bases is called Time Data Management (TDM) [3]. Only companies using a pre-determined time system (PTS) are able to set times for manual work tasks before the production has started. In the future it will be possible to use digital human models to generate accurate times for manual operations in early development phases [4], but we are not there yet. Using a PTS requires a lot of engineering effort and specialized competence, and there is a trade-off between that effort and the gain from being able to set times correctly in the design phase of new production systems [5].

To lower this effort is "Parametric Time Blocks" (PTB) a promising concept. The idea is to aggregate PTS elements or times determined by other methods into larger chunks of time, tailored to a specific company's needs and to set a total time only using a limited number of variables or parameters. Neither the idea of aggregating PTS elements, nor the idea of using variables to speed up the time determination are new. Aggregated activities with assigned time formulas were used at a large scale when piece rate was the dominant salary principle in the manufacturing industry [6]. When the salary changed to fixed monthly salaries in the 1970ies or beginning of 1980ies, the need for correct times for manual operations was considered to be more or less obsolete [7]. Manufacturing companies with large scale manual assembly lines have kept the quality

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of the time bases at decent levels, because of the need to calculate times for the assembly operations to design and balance assembly lines before they exist in reality.

The aim of this article is first to introduce the PTB theory and second to report the result from two tests of the proposed PTB theory and to draw conclusions about changes and refinements of the theory.

2. Research methodology

This study is part of the TIMEBLY (Time Data Management Automation for Manual Assembly) project, financed through the FFI program by Vinnova, Energimyndigheten and Formas. It involves five manufacturing companies, a TDM software company, three universities and two research institutes. The project is driven by the industrial need of finding more efficient and accurate time setting methods to both improve quality and ease of use for Time Data Management.

The research has a design science approach ([8], [9]) where solutions are developed and tested based on the industrial need. The design artifact is in this case the more efficient TDM structure and its design process. The stakeholders that are interested in a more efficient TDM are primarily the engineers and planners that directly handles the TDM today in manufacturing companies. Secondary stakeholders are all functions in the companies that benefit from higher quality of the time bases and faster and more accurate answers on questions about time for different purposes, i.e. calculate offers to customers, making investment decisions, make or buy decisions etc.

The first step in a design process is to establish and understand the problem. The project group involves some of the most experienced TDM professionals in Sweden and it has close ties to the Nordic MTM Association. The involvement of a world leading TDM software company also contributes to the understanding of the problem and the relevance of the research. Present state studies at each of the participating industrial companies in the TIMEBLY project were conducted to further understand the details of the TDM at each company and the challenges they are facing. The present state study was reported in a conference article [10].

The next step in the design process was to develop solutions to the general dilemma of creating and maintaining time bases with sufficient precision while spending less engineering effort and to "break" the traditional trade-off situation between precision and effort mentioned in the introduction. One of the participating companies, a large automotive company, had developed a TDM system some years ago based on the idea of using time blocks. These time blocks are not parametric, but they are rather company tailored aggregation of activities. The use of this new system has been very successful, and the other project participants wanted to learn more about it. This developed into a series of workshops where the project group analyzed the possibilities of developing similar time block based TDM systems at each participating industrial company. We also performed a literature study which revealed that very similar ideas were used to set times for piece rate wages. The literature from the 1950ies and 1960ies helped to form a theory for PTB.

This emerging theory was used and thus tested in the two case studies at Swegon and Volvo Cars, accounted for in this article. The case studies were a part of two master thesis projects at Chalmer University of Technology ([11], [12]). The case studies have resulted in new insights in terms of both confirmation and modifications of the proposed theory. The next step in the design process will be to apply the modified theory at other companies and to refine the theory further and establish a recommended design process for TDM. Ultimately, the mechanisms [13] that will make the TDM design process succeed or fail, must be described, and analyzed.

3. Time Data Management

Time Data Management (TDM) is the determination, application, improvement, and administration of times or time bases for any type of production [3]. To determine time for machine activities is comparably trivial to the determination of time for manual activities. There are many different time determination methods (figure 1) and they can be divided into measuring actual times in running production and planned time for future production. The time bases are used in product development to estimate costs, to get input to make-or-buy decisions or to compare design solutions. The time is used in process planning to make decisions about investment in, for example new assembly lines, to balance the lines and to calculate the amount of required production staff. The time bases are further used in the running production to analyze the difference between planned and actual times to find improvements.

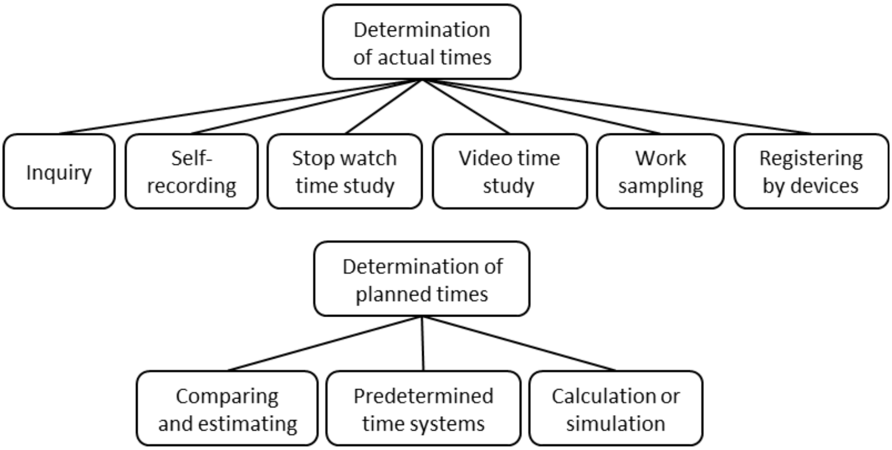

Figure 1. Different time determination methods (from [3]).

The PTS system MTM (Methods Time Measurement) was invented in the 1940ies [7] and there have been several aggregated MTM-based systems developed since then. For example MTM-2 (used today mainly in France) was developed in Sweden in the 1960ies and MTM-UAS was developed in Germany, Austria and Switzerland in the 1970ies. The MTM system used in Sweden today is SAM (Sequential Activity and Method analysis), developed in the 1980ies [7]. The SAM method is just like the other aggregated MTM variants designed by combining MTM-1 elements into larger activities, or blocks. Each element has a standard time and if the same element is repeated, for example a number of steps to cover a distance, the element time can be multiplied by the number of repetitions to get a total time. The purpose of using time blocks today is not for setting salaries but, for example, to set times for early cost estimation and design of new assembly lines.

It is important to determine both planned times and actual times by suitable methods. However, the most fundamental issue is to define the different times that should be used at each company. That can seem like a trivial issue, but it isn't [10]. There are often many different interpretations at every company of for example what value adding time is, or what should be included in a cycle time. If the company measure actual times and can compare that to correctly set planned time, it is possible to systematically analyze the deviations and use that for continuous improvements. With such mature TDM can the company reap all the benefits of having correct and up to date time bases, such as being able to use advanced optimization of production plans or giving correct offers to customers (figure 2).

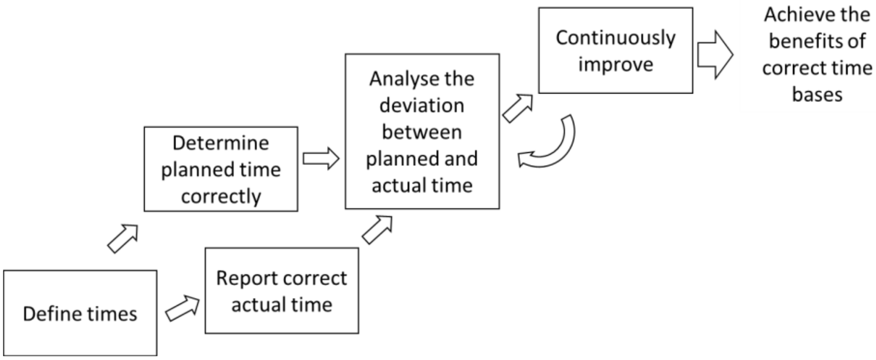

Figure 2. TDM maturity (from [10]).

4. The Parametric Time Blocks concept and theory

The PTB concept is the design artifact and that include both the structure of PTBs with the required information and the design process to develop the PTBs. The intended users of the PTBs and specifically the PTB interfaces are decision makers, planners, salespersons etc., that not necessarily need to understand all the calculations involved to reach a resulting time for a complete operation (such as assembly). They can use the PTB interface to estimate the total time with high precision for an operation that doesn't exist yet.

The PTB structure is based on the combination of generalized activities. It is very important to standardize the definitions of activities and to break down and divide activities in a logical way. All companies use different definition of activity levels and time parameters. In the research project TIMEBLY we have decided to use the term "operation step" to denote an activity at a level between a complete operation (the assembly done at one station on a line) and the smallest level elements.

4.1. Naming of operation steps

To break down activities into smaller activities or the other way around to aggregate small activities into larger, may seem trivial and many companies don't bother to create internal standards for how to do that. However, this does create a lot of confusion and extra work due to lack of clear definitions and differences in syntax used by different individuals. Every company needs to develop an internal standard for how to name activities.

4.2. Division in operation steps

It is important to separate operation steps that are carried out at different frequencies or situations, such as activities that are carried out per cycle, per batch (setup work), or per new product (process planning work). There are also activities that are carried out at regular time intervals such as preventive maintenance, and there are activities that are random, such as disturbance handling.

The following four rules were used in the 1960ies ([14], [6]) to divide complete operations into operation steps. We propose that they are still valid, even though the purpose is very different today.

An operation step should be:

- General - The operation step should be formulated to be generally valid for as many activities as possible.
- Combinable - The operation step should be able to combine with other operation steps without overlap or missing sub-activities.
- Repeatable - The operation step should be possible to multiply by a variable denoting the number of repetitions and result in a correct total time.
- Describing - The operation step should be formulated so it can be used directly in a work instruction.

4.3. The structure of operation steps

Operation steps should be divided into different libraries or databases. The idea that was tested in the cases was to divide into Product based operation steps, Process based operation steps, and Layout dependent operation steps. Product based operation steps are operations steps that are unique for a particular component or a product, there is no point of trying to generalize those. Process based operation steps are the generalized operation steps, typically common activities such as picking a number of screws and attaching them to a product using a power tool. Layout dependent operation steps are movements depending on particular arrangements at a workplace. To take a step is the most obvious movement to keep as a separate operation step.

4.4. Time equations

The time equations are intended to be very simple linear functions or possibly step functions made up of constants and variables. A majority of the equations will be very simple, such as time equals a constant.

4.5. Design of time blocks

Libraries of operation steps are combined to form time blocks. The total time for a time block is simply the sum of the time equations of all operation steps. Since the operation steps are stored in databases, they can be combined to different time blocks for different purposes. Very coarse time blocks can be used in early phases to do make-or-buy decisions, while finer time blocks can be used in running production for planning purposes.

4.6. Example of PTB

The following example will demonstrate the relation between operation steps, time equations and PTB (figure 3). The first step is to identify, define, name and set time for general operation steps. These are put in a database where time equations are stored together with time values for constants. Based on that data base can PTBs be created where the time equation of every operation step are summed in a time equation for the time block. If the time block contains variables it can be called a parametric time block, otherwise it will be a time block with a constant time. The time block is implemented in either a spread sheet software or in a dedicated software. A time block interface can then be programmed to improve the ease of use for the end user of the time information, such as a production planner or a person doing product calculations in early stages.

Operation steps data base

Operation step definition	Time equation	Constants	Constant time	Variables
Assemble first bolt	T=A	A=Time for first bolt	135 TMU	
Assemble consecutive bolts	T=(N-1)*B	B=Time per bolt	55 TMU	N=Number of bolts
Return tool	T=C	C=Return time	40 TMU	

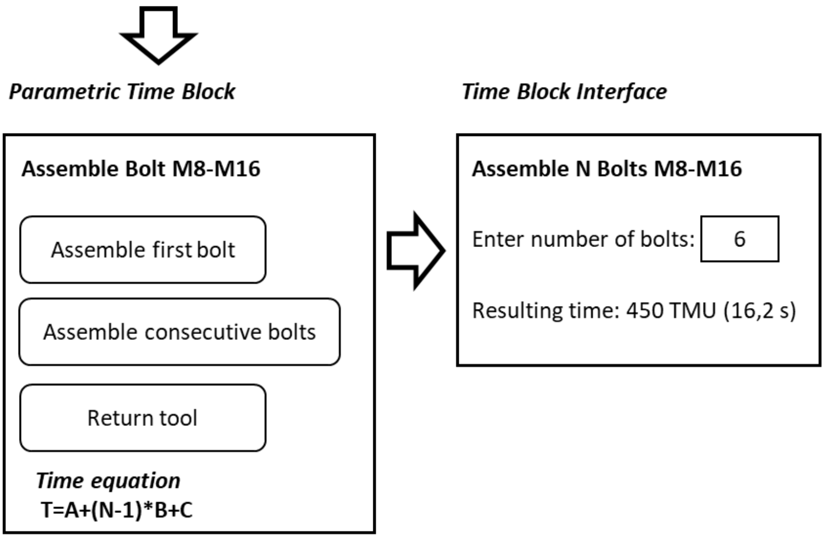

Figure 3. Illustration of the relation between operation steps, time equations and time blocks.

5. Results

In TIMEBLY has PTB been tested in two cases at Volvo Cars and Swegon. A limited part of the products assembled was selected for each of the cases. The subassemblies selected had many variants based on a modular concept at both companies. In both cases could the time blocks be based on existing PTS times. Similar PTB prototypes were developed and implemented in spreadsheets.

5.1. The Swegon case

Swegon produces HVAC units for large commercial buildings. The HVAC units are designed in a modular way, where modules for fans, heat exchangers, filters, etc can be combined to form an almost infinite number of variants. However, in practice does Swegon assemble around 9000 units of about 4000 variants per year where each unit consists of 2 to 8 different modules. The modularization makes it possible to standardize the assembly work by combining a limited number of (several hundreds) assembly activities. Swegon is using SAM, but different engineers have made the SAM analyses over time without clear definitions and rules for creating new operations and therefore is the database messy. It is hard to find commonalities and make the time determination of new assemblies efficient. Swegon therefore wants to start over, and the company sees the PTB concept as a way forward.

All HVAC units have a base frame that is covered by insulated panels. These panels come in many variants due both to different sizes of the modules and what other components that need to be attached to the insides of the panels. Presently, hundreds of different SAM sequences were used to describe the assembly of all panel variants. In this study this amount could be reduced by about 30% by finding commonalities and assign variables in time equations. The time equations were summarized in a spreadsheet with an interface where only a few variables would generate a planned time for the assembly of a complete panel (figure 4).

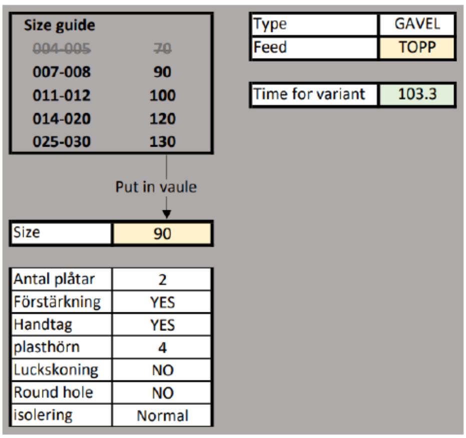

Figure 4. Spreadsheet interface for the PTB developed at Swegon (from [11]).

One validation experiment was carried out where five different products with different options were selected and the time was calculated using the present SAM sequences and the PTB. The result was good, the PTB generated time was 93% of the SAM time on average.

5.2. The Volvo Cars case

Volvo Car's products are assembled on assembly lines that need to handle a large variation of different car models as well as a huge number of variants of different components based on the customer's specification of the car. The cars are assembled to customer order, but the sequence is altered to create a reasonably levelled workload.

The company has several assembly factories around the world. Volvo divides the responsibility of time bases on two organizations. The manufacturing engineering department determines the value adding time based on the bill-of-materials and the assembly sequence, while the non-value adding time is added and owned by each assembly factory. The idea is that the time for value adding activities should be common for all factories while non-value adding time, such as the number of steps needed to get material from a material façade is added depending on the layout and material handling in each factory. Keeping the value adding time updated and standardized is challenging when the factories make continuous improvements, that may involve changing the assembly method that will affect the value adding time.

Volvo use their own variant of SAM called Volvo SAM, with certain rules for the application of the method that have been negotiated between the union and the company. The time unit used is TMU which is defined as 1/100.000 hour or one TMU equals 0.036 s. Volvo has a standardized method for planning the assembly and determining the time bases. The time is gradually refined through the different development stages and the final determination of the planned time using Volvo SAM takes place in the later stages. In earlier stages are estimations based on previous models and assembly lines used together with the known differences.

The assembly of a sub-system called the "tunnel" was used for the case study. The tunnel is the structure between the front seats in the car that the gear shifter is attached to. The tunnel is assembled in a sub-assembly line that feeds the main assembly line with customer specific variants in the right sequence. The line is divided into 7 stations and the cycle time is less than a minute.

The current set of tunnel assembly activities were described in 650 operation steps expressed as SAM sequences. This set was analyzed for commonalities and the rules for operation step division (see the PTB theory above) were applied. The analysis resulted in 33 time blocks consisting of generalized operation steps with time equations containing constants and variables. An example is Attaching clips, where only 4 variables are needed to set a correct time using the PTB (figure 5).

Attaching part X to car with three plastic clips					
Operation Steps	**SAM Steps**	**SAM Code**	**Unit Time**	**Frequency**	**Work Time**
Attach first clip	Take a single part over a distance of > 45cm	GS10	10	1	10
	Take a single part over a distance of <= 10cm	GS10	10	1	10
	Place a single part with precision over a distance of <= 10cm	PP10	25	1	25
Attach second clip	Take a single part over a distance of <= 10cm	GS10	10	1	10
	Take a single part over a distance of <= 10cm	GS10	10	1	10
	Place a single part with precision over a distance of <= 10cm	PP10	25	1	25
Attach third clip	Take a single part over a distance of <= 10cm	GS10	10	1	10
	Take a single part over a distance of <= 10cm	GS10	10	1	10
	Place a single part with precision over a distance of <= 10cm	PP10	25	1	25
Total TMU					**135**

Inputs	Number of clips need to attach	3
	How many clips' distance is in between 10cm to 45cm	0
	How many times both hands need to attach clips	3
	How many times need extra force to attach clips	0
Output	**Total TMU**	**135**

Figure 5. Comparison of present SAM codes to the PTB interface developed for Volvo Cars (from [12]).

Two experiments were carried out. First a validation of the total time for the present tunnel product and a representative mix of variants during a day using the PTB. It turned out that the resulting time was 97% of the time produced by the present use of Volvo SAM. The second experiment was very interesting. The time for a forthcoming model of the tunnel assembly was determined by an experienced time setting engineer at Volvo using Volvo SAM. The engineer's work was timed using a stopwatch. Then the time for the same work was calculated using the PTB and it took only one fourth of the time spent by the engineer for the students to produce a total time. About 80% of the activities for the new model could be covered by the PTB, the remaining 20% had to use the present SAM sequences for determining the time. The result was about 98% accurate to the time determined by the engineer.

6. Comparison and discussion

The approaches of the two case studies were very similar, where the aim was to apply the PTB theory. However, the implementation turned out to be a bit different. The students in the Swegon case had to spend a lot of effort on cleaning the present data to understand commonalities. Therefore, they didn't reach as far as in the Volvo case in terms of reducing the number of operation steps by finding the commonalities that could lead to a generalization. In the Swegon case it was not possible to perform an experiment with a new product since there was no new product in the right development phase available.

The second experiment at Volvo Cars was a big success. Using the PTB took only a fourth of the time when calculating the time for a completely new product. The precision of the analysis using PTB was found to be adequate in both cases with total times only a few percent deviation from the time produced by using the existing PTS. Qualitative assessments at both companies were very positive to the new concept and both companies will continue the development.

The two cases represent two early tests of the design methodology for efficient and effective TDM. There are some important insights that can be drawn from the case studies:

6.1. Naming of operation steps

The Swegon case especially highlights the importance of defining the names of activities carefully. Volvo had a better naming policy with reasonably standardized names for SAM sequences. In the case at Volvo a syntax for structured formulation of operation steps names was proposed.

6.2. Division in operation steps

The four proposed rules for division of operation steps were used in the cases. The General, Combinable and Repeatable rules were no problem and seemed logical to apply. However, the Describing rule turned out to be more challenging. An operation step can be of different size in terms of its time length. Long operation steps require a long name to fully include all that an assembler needs to do to complete the job. That is not practical. Thus, the Describing rule needs to be revised.

6.3. The structure of operation steps

The original idea to divide into Product, Process and Layout, may not be the best. In the Swegon case was four libraries used. The fourth was for activities of different frequency than every cycle, in this case set up activities. The continuing application at other companies has confirmed that another standard structure needs to be proposed to be general enough to cover all companies' needs.

6.4. Time equations

The determination of the time equations went according to plan. At Swegon there were two particular operation steps, assembly of sealing stripes and assembly of insulation, where SAM could not be used as a time determination method. This was because these operations have elements that are random, such as that it's up to the assembler to choose to use left over pieces of insulation or discard them. Instead, stopwatch study of a number of cycles for different variants was used to determine a statistically based average depending on certain variables, such as circumference length of a panel.

6.5. Design of time blocks

Very similar spreadsheet-based implementations were made at both companies. These worked well but can be regarded as demonstrators and not final solutions. Integration is needed with existing software and databases at both companies and for any company considering the design of time blocks.

7. Conclusion

In conclusion shows the PTB concept a great potential for making the time setting process more efficient as well as making time setting possible in early phases by non-specialists. However, there are several pre-conditions that must be fulfilled before the PTBs can be formulated:

- A standardized nomenclature for names of activities and times must be established.
- Standardized work must be implemented, and the standards must be followed up to make sure that they are followed by every operator.
- Decisions must be made for every company about which time-determination methods to use and how detailed the break-down of activities needs to be.
- The activity and the time equations must be structured in databases.

- Layout influences the method and therefore should the layout of stations where the same activities are performed be as similar and standardized as possible.

The time blocks concept is a potential time data management tool that can be used to calculate assembly time with the help of equations. By developing blocks based on operations steps in structured libraries, the time for assembling a complete unit can be calculated. One of the biggest advantages of using time blocks is that they are reusable. When an activity has been timed once, the time block can be used to repeat this in any shop floor area. This saves a significant amount of time and effort compared to traditional time studies and management of time bases. Time blocks are also very accurate, provided that the preexisting data is accurate. Any errors in the equations can be evaluated during the development stage. Another advantage of time blocks is that they are scalable. The size of the blocks can be adjusted to meet the needs of the organization and the differences in their products. However, this study is just one step in the design science process to develop more efficient TDM and to explain the mechanisms that leads to efficiency.

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