Systemic Analysis

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Automation of building process time structure models

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Summary

A determining element of building management system, which allows modeling of data in time, is a building schedule. In the paper are present the models analyze of building process time structure and elements parameters analyze of these models. The particular network analyze model and its mathematical mechanism are behind software for building scheduling. The mathematical links classifying of network process method allow new view at possibilities of particular software to satisfying requirements, which are risen during a creating and improving building schedule modeling in the pre-manufacturing, manufacturing and realization phase of invested process. For development of new one or improvement already existed software for building schedule automatized modeling is necessary not only clear and entire requirement specifications to software, but also theoretical basis of process network analyses adjusting for the building process conditions.

KEYWORDS: modeling, building schedule, networks analyses methods, software

1. INTRODUCTION

Most of the building companies are aimed about integrated information management system, processed by computers in the all its part. The main principle of this integration is a saving of all primary, processing dates about particular building objects into suitable organized databases and permanent showing of these dates into calendar time. A determining element of building management system, which allows modelling of data in time, is a building schedule. Therefore is necessary to have the building schedule computational processing as the most reliable model of objective building process course models.

2. METHODOLOGY

The methods of network analysis are the main tool for processing of building schedule by computers. Particular methods allow a mathematical project modelling by networks. The medium of building production, in the network, is becoming

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an operation, i. e. building process at the different level of aggregation. A network topology describes a way of mutual activities connection at the model. The classical methods of network analyse have general application, but during their using are rising the building process mathematical modelling inaccuracies, which markedly decrease a quality of final model, i. e. building schedule. (1) (8) (9)

The process relativities have their particularities in building industry. Network topology of building model should represent real technological and organizational relativities of particular building processes. During the time course modelling of building by computers in the network topology is possible to define just these links among processes, which are mathematical defined by particular method of the computer software. Equally, the modelling of internal time, technological and also spatial structure of building processes is possible just in the dimensions, which are provided by particular computer software.

2.1. Time structure models of building process

The various abstract models are used for time structure expression of building process:

- verbal (time structure is defined by parameters description and their time assessment),
- mathematically (time structure is described by mathematical expressions),
- graphic models (time structure is defined by graphical representation).
- Generally, all these three model types are used together and are each other completed for better visualise and understanding and higher informative ability.
- For the graphical visualise of processes time course and their parameters in the building practise are used (4) (7):
- Gantt diagram – line graphic schedule,
- time-spatial graph,
- histogram – cumulative graph of building-up sources using,
- network – arc or node defined network model.

The graphical model of building is always completed by description and mathematical term. Also, the network analyses of building processes and their combinations, which is in generally a mathematical methods summary of projects modelling by networks and is using the combination of all three abstract model types. The network is a base, which is completed by entered or calculated of time parameters, or by description of particular process. The given mathematical mechanism is suitable for assessment of graph elements (nodes, arcs) parameters.

Between individual graphical drawing model ways of building course is always close connection. The outputs, which are obtained by network analyses methods, are mostly graphically interpreted by Gantt diagram. On the second hand is

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common, that this line graphic schedule is completed by graphical drawing of taken mathematical bonds among processes.

2.2. Elements of time course building model

In generally, the elements of time course building model in the building projects are:

- **Particular activities – processes**., which are necessary for achievement of projects goals, an activity is realization of classified element or its parts, which are realized by one capacity unit on one place in continuous time,
- **Process configurations** – configuration of activities, which are focused to the goal achievement, process configuration is ordered group of processes,
- **Milestones** – in advance clearly defined requirements and specifications for project course,
- **Connections and relativities between processes or process and milestone** – mutual technical, technological, organizational and logical connections between activities, processes, process configurations and milestones (when relativity is expressed by mathematically way, that means a bond between processes or process and milestone)

The bond means mathematical expression of mutual relativities between processes, their configurations and milestones. The time bond between two points in time (events) of processes or milestones is expressed by mathematical term. The first point is referred to previous process/milestone „i“, the second point of bond is referred to process/milestone „j“, which follows previous process/milestone.

2.3. Time parameters of building process or milestone

Among the time parameters of building process belong (4) (7):

t_i - process duration i,
tRo_i - process development date i,
tUs_i - process consolidation date i,
tZu_i - process reduction date i,
tPr_i - process technological interval duration i,
tOd_i - defferment process duration i.

Next, among processes time parameters belong terms (non-calendar or calendar), terms of start TZ_i or term of finish TK_i i-process, or its part, or milestone term Tm.

At the network analyses are parameters, which are expressed events terms, neatly classified into the earliest events terms defined by „forward calculation“ and the latest events terms defined by „ahead calculation“, necessary the earliest or the latest term or fixed necessary term:

NT - necessary date (defined by real or relatively calendar date),
ZM_i - the earliest start of activity i date,

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KM_i - the earliest finish of activity *i* date,
ZP_i - the latest start of activity *i* date,
KP_i - the latest finish of activity *i* date.

A time parameters assessment (in the chosen units of measures) of building process can be defined by constant (by estimation, calculation, stochastic, deterministic) or as an average parameter, which is dependent on a valuation of other parameters in particular process or else processes.

2.4. Connections and relativities between processes

During the planning, the particular processes are jointed (organized) in the process configuration so that in the realization time first one makes a building preparedness by its activities necessary for second one. At the same time, they do not destroy a result of own activity each other. The process order in the configuration is defined on the connections base among processes. Between two processes can be:

- **Connection of dependency** – a start of process course is directly relative by previous process finish (or its part).
- **Connection of partial dependency** – production space or process course is influenced by continuance or result product of another process.
- **Connection of independency** – course and result products are irrelevant each other.

The connection of dependency between two processes can rise as a result their technological and organization relativity:

- **Technological relative connection** – is, when previous process make next working queue
- **Organization relative connection** – is, when processes use the same working equipments and labour power.

The terms process relativity and bond between processes are sometimes changed in literature (4) (7) (10). The process relativity is technological or organization matter and is followed from building process structure. The term – "bond between processes" relates with network analyses. It is mathematically expressed mutual technical, technological, organization or logical relativity between activities, processes and their configurations and milestones. During the computer processing of schedules by software, which done on base of network analyses (3) (5) (6) is necessary the process relativity express by mathematical bonds.

2.5. Mathematical bonds in network analyses methods

The base for automated modelling of time project course is always particular network analyses method. During the modelling of building time course by computer is possible to define in the network topology technological or

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organization process relativities only by these mathematical bonds, which are defined in the particular network analyses method and its mathematical mechanism.

2.5.1. Types of bonds in network analysis method

In Types of connection define, which time parameters of two jointed processes/milestones are in the calculation directly considered, specially for „forwards calculation" and also for „aback calculation". Each type of connections is characteristic also way of definition and time assessment of distance.

The mathematical bond between processes/milestones is possible to divide into:

- Simple bonds – these bonds express the connection between one event of previous process and one event of next process. There are connections: finish-start (K–Z), start-start (Z–Z), finish-finish (Z–Z) and the bonds, which are derived from them, such partial start-start ČZ-Z and partial finish-finish ČK-K. The definition of necessary the earliest date (NT) belongs among simple bonds too.
- Double bonds – allow by one mathematical mechanism to express the connection between two events (also one) of previous process and between two events (or one) of next process. They are the mathematical connections of two simple bonds. Their elementary representative is critical approach bond (KP), and it's derived construction-technological (STV) and line (PRV) bond.
- Cyclic bonds – these bonds express a feedback between event of next process/milestone and event of previous process/milestone. That is the bond, which has a given particular maximal possible value of time distance „b" (where $b \neq \infty$). Eventually, it can be a double bond between events of two processes, where first bond has given a maximal possible time distance and second one has a maximal accepted time distance. The elementary representative of cyclic bond is a definition of the latest or stably necessary date (NT). There belongs a stably process connection (PP) without the interruption possibility of working teams (or with given maximal possible interruption) between two processes i. e. finish work of one process and start work of another process.

The cyclic bond can be cause of conflict of dates during the network calculation. The conflict of dates is a situation, when the calculated dates of event activities in the network modelling are in conflict with specific requirements of process time course. The next problem is that an enclosed cycle can generate at mathematical calculation of dates during give a cycle bond, i. e. number of calculation iterations is unlimited and that gives out a logical mistake in network model. It follows necessity of opened cycle using with limited number of calculation iterations.

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2.5.2. *Time parameters of bonds between processes*

Among time parameters of bonds belong (1) (8) (9):

- Minimal (the shortest possible) time distance „a“ of two events,
- Maximal (the longest accepted) time distance „b“ of two events,
- These time parameters of processes/milestones, which value time affects a calculation of events time distance jointed by bond. It can use different or equivalent processes parameters for terms forwards or aback calculation of particular bond type.

A time distance size „a“ also „b“ of two events is express in the particular time measure. For individual connection types have time distance these values:

- minimal time distance „a“:
- $a < 0$, $a = 0$, $a > 0$, when „a“ is not given, a=0
- maximal time distance „b“: $b < 0$, $b = 0$, $b > 0$, when „b“ is not given, $b = \infty$.

The time distance value can be given for each bond type followed:

- defined by particular number (given constant) in time measure,
- defined by mathematical term, where time distance is a function of particular process parameters (previous or next process). When is time distance value derived from particular processes parameters value, mostly is necessary to give out a factor *k* (in % or as an index number). The value of factor *k* can be followed:
  - from time parameters of previous process,
  - from time parameters of next process,
  - from time parameters of previous also next process,
  - as a rate of minimal working queue on the working place a. o.

defined by mathematical term, where time distance is a function of given constant and particular processes parameters (previous or next process).

2.6. Working operation at building time course of modelling

Among working operations, which are necessary to do during the creation, debugger and updating of building schedule belong:

- setting a process bill of quantities,
- definition of process duration,
- definition of process requirements for building sources
- relativity organizational allowance of processes (milestones),
- definition of processes (milestones) starts and finishes necessary dates,
- processes summarization or decomposition,
- processes aggregation and desegregations,
- processes connection are interruption,
- summarization, equalizing or planning of building sources e. i.

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Each of these modelling operations of building schedule demand special approaches. The result model of building schedule is used as documentation for preparation and organization requirements and process management of building product realization. The difficultness of individual operation or possibility of individual operation automated performing during schedule computer processing, is depended on using software ability. The creation of models and documentation can be quicker and higher quality by using an integrated connection inputs and outputs of various systems.

A process position concerning at time axle is depicted following process specific relativity during building schedule processing in Gantt diagram or time spatial graph. The main question for planner is: "When can particular process start concerning already scheduled (realized) processes? " The time parameters changes of any process cause that the schedule can be unrealistic and it is necessary to do it again. According as schedule actualization is able to allow all processes relativity, which was in a previous time model, is dependent of the planner special ability. The implementation of these changes into schedule can by equally complicate as its primary draft.

2.7. Automated modeling of building process time structure

Some computers programs allow mathematical connection of parameters processes calculation, but not allow entry process relativity by mathematical bonds (e. g. MS-Excel). The process position in time is defined by fixed location on time axel. This result model of building schedule has "static" character, e. i. time process parameters are stably definite and the change of them is not possible to automated change in schedule model creation, debugging and using.

The schedule "static" model, which is not set for automated debugging or actualization, is possible to create by each software, which is using the mathematical bond. Its creation is quicker, less complicated and there are necessary less planer specific abilities than in creation of "dynamic" model. There is not so important that using mathematical bond real allows for example internal time structure of building process after any process parameters change. The using bond can have constantly given time distances. The processes relativities are possible to define for example only by simple bond, or by necessary dates. In this case, all processes dates have to be real planned and allow all specific requirements for particular building schedule. In time schedule processing by computers, the mathematical definition of mutual processes time position is using only for recording of source requirement or creation of necessary processes documentation.

When a building model is designed for optimal plan debugging, for plan actualization in time realization or for various building simulation, is necessary to use such software (network analyses method), which allows correct definition of

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mutual processes position in time during any parameters change of model elements. For example, when the software uses bonds with constantly given time distances only, in time of processes parameters changes is necessary rethink given time distance bond value too.

Some software allows the using only limited number of bond types. On the figure 1 is example building schedule, which is made in MS-Project program (3) (5) and processes bonds definitions, where double connections are omitted. In this case, here can start up a necessity of change the time distance value and change of used bond type among processes. The process debugging becomes expertly difficult and slow by this way.

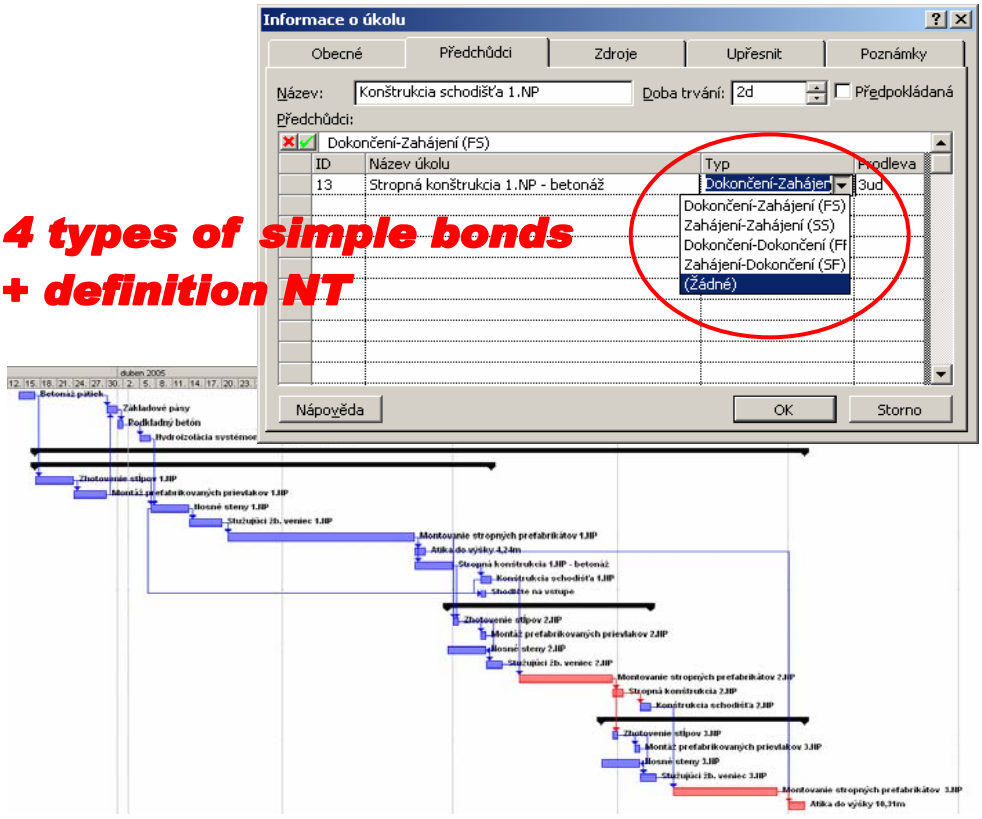

Figure 1: Building schedule and bonds in MS-Project program

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When a computer program allows a definition of mutual technological and organizational relativities among processes by suitable mathematical bonds, the result schedule debugging is not too difficult. On the figure 2 is example of building schedule made by Contec program (6), which for example for the definition technological process relativity uses STV bond. This bond allows consecutive the automated plan debugging without the ignored relation of relativity risk among processes. This program allows in the created schedule by gradual simulations, the revision of different options and finding out the optimal result for previous given limited specification and given criteria.

On the second hand, the software like this can demand the higher requirements at modeller expertness or can have the difficult process parameters entry and their assessment.

A particular network analysis method is behind each computer program for building schedule. The program ability discharge of users requirements, which are made in time of building schedule model creation and debugging in the pre-manufacturing, manufacturing and realization phase of invested process, is depend to mathematical mechanism.

A software development for automation of building process modeling is not in final phase. The completed requests specification at software, which will be a result of real necessity of their users is only first one, but very important step on this way to progress.

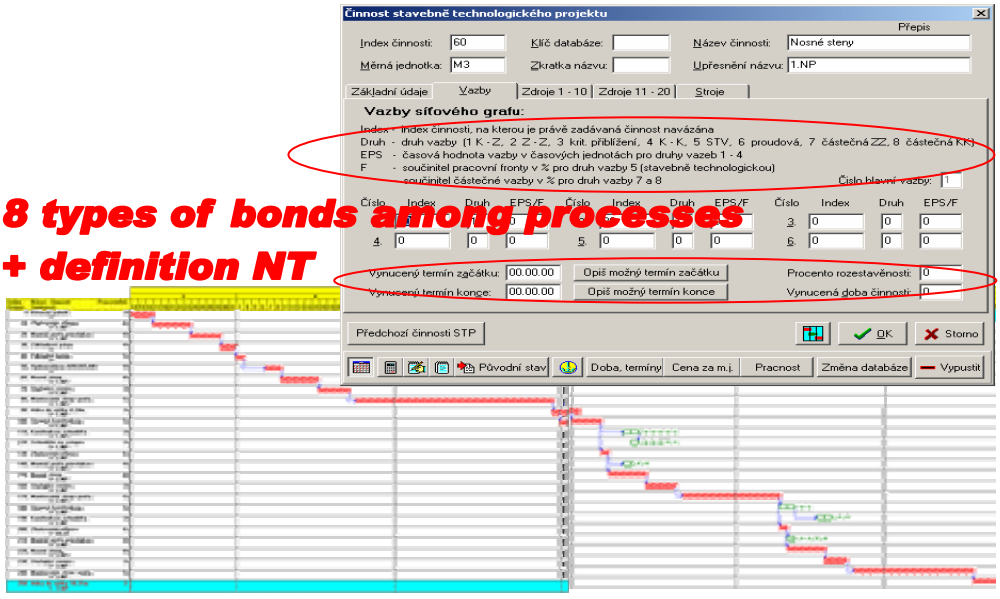

Figure 2: Building schedule and bonds in Contec program

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3. CONCLUSIONS

Nowadays, the difficultness of schedule creation, manually or by computer in particular software background is relatively high. All mathematical schedule models, which are created by particular network analyses methods, do not allow a saving of schedule reality in time of its time parameters changes or different limits (necessary dates or disposable amount for particular sources e. i.). When a computer program, following some of network analyses methods, allows a suitable definition by mathematical connection of mutual technological and organizational relativities among processes, their debugging or implementation of changes into schedule result in time building, it has not to be so difficult.

For automated modelling purposes of building schedule is necessary not only clear and completed request specification at software, but also an adjusting of process network analyses theoretical information at building process condition. The computer programs for creation of building schedule should by make by this way, instead the mathematical connections entry allow directly operation entry among processes. The programs for building schedule modelling should allow an inputs and outputs integration of different individual information systems, as are production plan of constructions, budget, safety and protection health at work. Finally, the programs for building schedule modelling should allow automated debugging of schedule in time building condition change, or more options simulation and creation of schedule for multi-criteria assessment and a selection optimal option.

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