THE AUTOMATION OF CONSTRUCTION SCHEDULING CONSIDERING VARIABILITY OF WORKING ENVIRONMENT

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Abstract

The duration of building jobs is affected by numbers of different factors what causes that after short period of time schedules, not once, begin to differ from real run of construction. The attainment of stronger stability of the schedules requires to consider variability of factors affecting run of construction within phase of scheduling. This article deals with scheduling methodology which would cover variability of working environment affecting run of construction and possibilities of the automation of scheduling.

KEYWORDS: schedule, working environment

INTRODUCTION

Preparation of construction scheduling is serious task (Jarský, 2000). Construction is being impacted by several factors (Szalayová, 2004) (Lavrinčíková, 2001), which often cause deviation of time schedules from the real process already following shot time. To reach increased stability of time schedules, it is necessary to propose a methodology of time schedules preparation that would encompass the variability of factors influencing such construction process. This kind of methodology, however, is laborious and without automation will hardly be employable in practice.

Definition of construction process duration is one of the key tasks in time scheduling. A construction process duration depends on various factors, whereby some may be defined quite precisely in advance. However, the situation is different in case of work environment that changes along construction and causes differing durations of the processes depending on the particular periods. Because of wide extent of this topic, this article only deals with work environment, especially climatic factors.

The duration of construction process is to be calculated on the basis of its labour content. The labour content is to be defined by standard hour which represents an average value of many measurements over quite a long time. If this average value is accurate, the measurements were performed in over all the year. This way an influence of working environment expressed on results of measurements whereby measured values oscilated around the average value in dependence on particular conditions at which the measurements had been taken (fig. 1). So at favourable working conditions the labour content was lower, while at unfavourable ones has increased.

Work environment can be understood as a set of physical external factors, for example external temperature, humidity, air flow, sun light, noise, immediately impacting the construction process and its duration. The working environment affects all components of construction process like:

- Work process part impacted by human activity and the use of tools,
- Work process part impacted by construction machines and mechanisms (Motyčka, 2007),
- Natural process (Bašková, 2004).

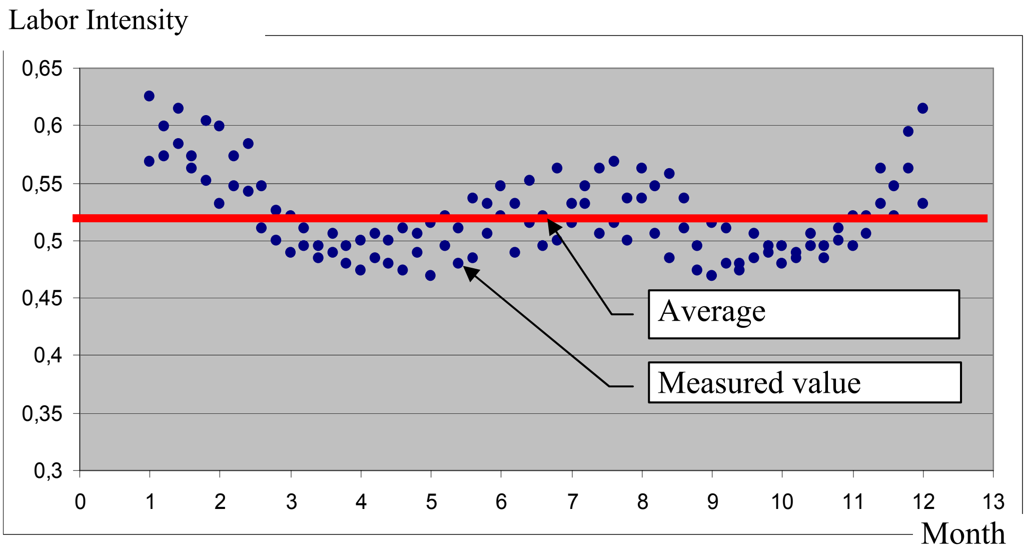

Figure 1: Expected relation between standard labour content and measured values for any construction process

MODELING OF WORKING ENVIRONMENT

If the time schedule reflects the impacts of work environment it is necessary to understand a development of the working environment along the construction. Since most of constructions are performed in exterior unsheltered from climatic conditions and even interior work is significantly impacted by these conditions it is necessary to pay attention to quantification of climatic factors.

In Slovak Republic, climatic factors are characterised through very extensive dynamics of changes depending on geographic position, micro-relief of the given territory and season. Frequent weather variations force us to ask to what extent we are able to predict such changes. Short term, one to three day weather forecasts, just as five to seven day ones are relatively reliable. However, in case of long term forecasts it is hard to speak of any reliability. Therefore, it is necessary to identify different possibilities of climatic factors prediction.

One method for climatic factors forecasting in the course of construction is a replacement of weather forecasts based on knowledge of atmospheric processes by statistical constants processed upon measurements in the past.

Air temperature is a climatic factor often impacting the construction processes. When analysing external air temperature, it is possible to follow temperature variations during the year (mean monthly values) and day (daily temperature development). The graph in Fig. 2 depicts development of average monthly temperatures in the region of Hurbanovo in years 1871 to 2002.

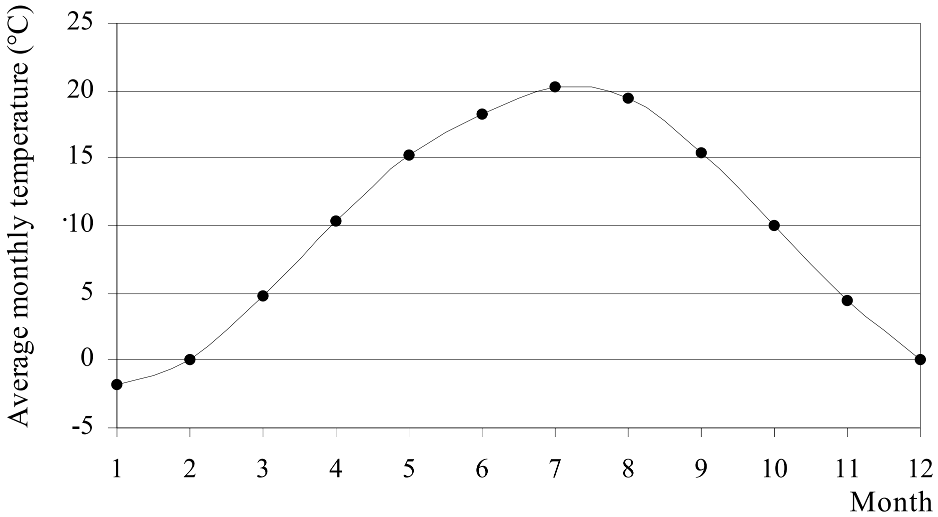

Figure 2: Average monthly temperatures around Hurbanovo

Similarly, other work environment factors may be modeled. Some, like air flow and atmospheric precipitation may be modeled for the respective seasons of the year using relative calculations.

MODELING OF DURATION OF A CONSTRUCTION PROCESS

Generally, work environment factors may impact the process duration as follows:

- Process duration changes continuously,
- Process duration changes abruptly,
- Process cannot be performed.

Continuous change of process duration may be caused by concrete hardening rate depending on environment temperature. External temperature defines the period after which the structure may be demoulded and also impacts the timing of other works to be performed on that structure. When planning construction, the duration of such work may be modified through an index.

Work environment factors, and especially temperature, also impact workers. Fig. 3 classifies temperature impact on worker efficiency in three-tier physical difficulty classification, air humidity and flow are not considered.

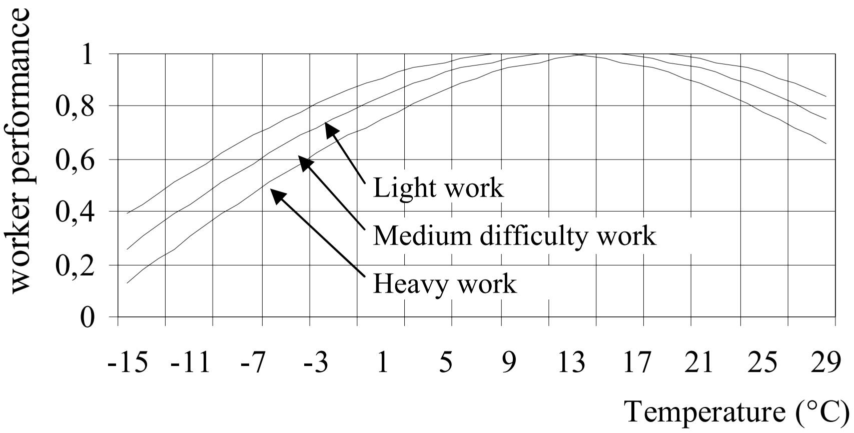

Figure 3: Temperature impact on worker performance

Fig. 4 depicts the progress of labour intensity within a year with regards to monolithic ceiling structures concreting, whereby average labour intensity represents 1,065 $Mh.m^{-3}$ and realistic research based labour intesity represents around 20 % of the average value. Thereby, it was assumed that concrete additives will enable concreting in low temperatures.

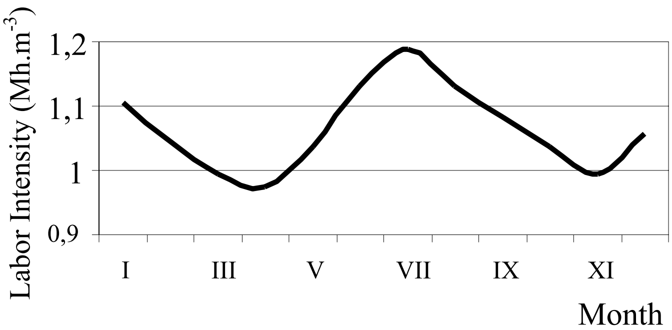

Figure 4: Labour intensity for concreting

Work environment may cause the process duration to change in big steps. This usually takes place in case of extra measures, e.g. heating of constructed structures when concreting in low temperatures (Juríček, 2005). This results in a change of labour intensity. Fig. 5 depicts the development from Fig 4 when considering measures implementation in winter months.

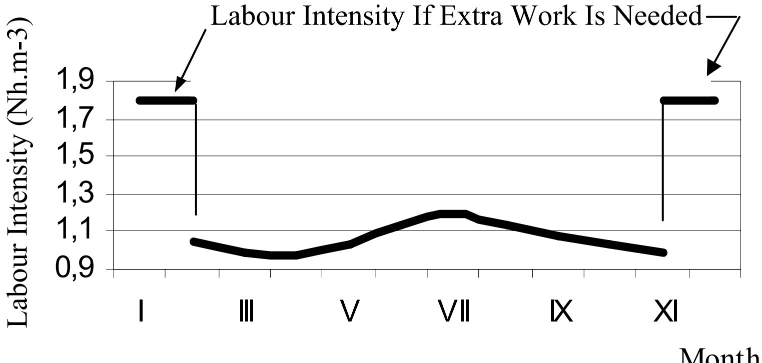

Figure 5: Concreting Labour Intensity

If a process cannot be performed, it needs to be shifted to a period with more favorable climatic conditions.

INPUT DATA SET

Compiling a set of input data is labor intensive. Some input data have general validity and are compiled only once; other data need to be compiled for each project separately based on the assumed project conditions. Therefore, input data may be split into:

- Input data with general validity that may be applied to various locations and projects. These are especially data reflecting the impact of work environment factors on construction process in the entire interval of values the factors may reach in the course of construction.
- Input data with local relevance, such as meteorological phenomena. Average monthly temperatures, average daily development per respective month, frequency, marginal values, etc. count among important factors.
- Input data on the project and construction processes, such a list of construction processes, their labor intensity, allocation of sources including financial sources, mutual links between processes, etc.

CALCULATION OF INDEXES AND DETERMINATION OF PROCESS DURATION

The definition of these indexes starts with the analysis of a process or a set of operations forming a process. The shares of human work, machine work and natural process in the construction process are defined. Then, indexes kPm of work environment impact on construction process duration are defined as follows:

$$k_{Pm} = \sum_{i=1}^{n} p_i k_{zmi} \qquad (-) \qquad (1)$$

where k_{Pm} is the index of work environment impact on a process in month *m* (-),
p_i the share of partial operation i on the duration of the entire construction process (e.g., share of heavy human work, share of machine work, etc.), Σpi=1 (-),
n the number of partial operations in the construction process (-),
k_{zmi} the index of environment impact on partial operation i of the process (e.g. environment impact on the duration of a machine work) in month m. It is calculated from the following formula:

$$k_{zmi} = \prod_{f=1}^{d} k_{fm} \qquad (-) \qquad (2)$$

where k_{fm} is the index reflecting the impact of the relevant environment factor (e.g. impact of temperature, humidity, etc.) on process operation *i* in month *m* (-), *d* the number of work environment factors impacting operation i of the construction process (-).

Labor intensity of selected processes following their adjustment through index k_{zm} is listed in Table 1.

Table 1. Labor intensity of selected construction processes

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Manual excavations – class. 3 in ice-free earth (3,373 Nh.m^{-3})												
	3,43	3,36	3,14	3,11	3,34	3,52	3,75	3,86	3,41	3,11	3,17	3,42
Wall reinforcing (28,283 Nh.t^{-1})												
	31,29	30,26	27,22	25,88	26,75	27,72	29,02	29,68	27,10	25,92	27,67	31,19
Ceiling formwork (0,881 Nh.m^{-2})												
	0,98	0,94	0,85	0,81	0,83	0,86	0,90	0,93	0,84	0,81	0,86	0,97

Fig. 6 shows a graphical comparison of the average standard labor content of timber-work which is commonly used in calculation of construction process duration and standard labor content considering variable ambient temperature at the outside working station.

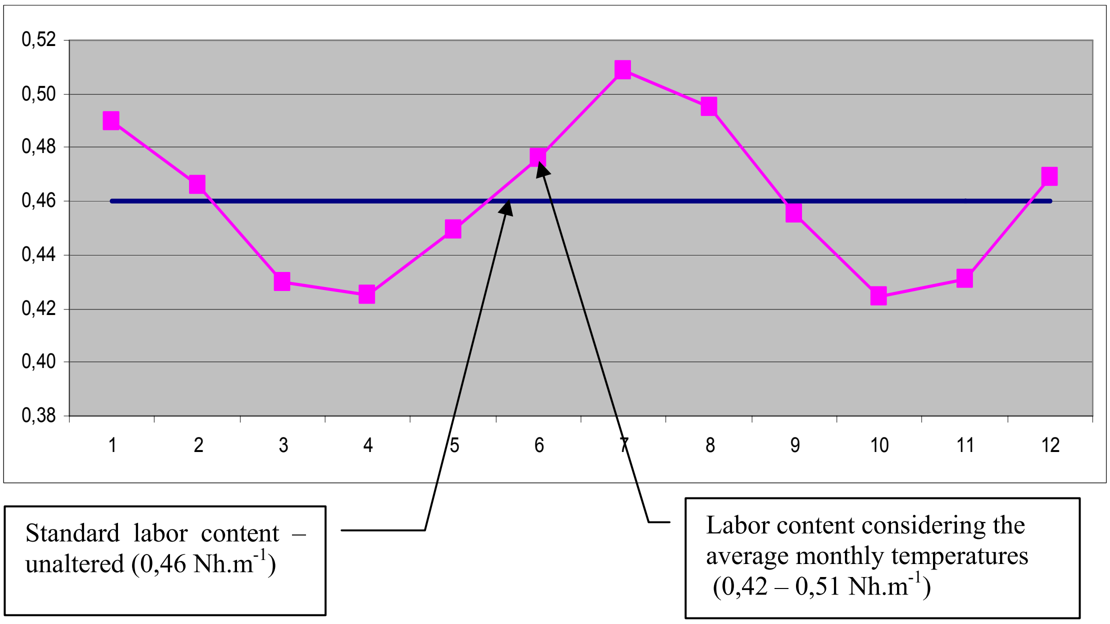

Figure 6: Time standards for timber - works

The process duration is calculated through the application of formula (3).

$$T_p = \frac{q \cdot \frac{N_{\check{c}}}{k_m}}{N_r \cdot t_{hs}} = \frac{T_p^*}{k_m} \qquad \text{(shift)} \qquad (3)$$

where T_p process duration (change),
q number of units (m^3, m^2, $m^{\prime}$, t, ks),
$N_{\check{c}}$ time standard (Mh . mj^{-1}),
k_m index of work environment impact on process duration in a given month (-),
N_r number of workers performing an activity (-),
t_{hs} duration of change (h . $change^{-1}$),
T_p* duration of standard process (change).

AUTOMATION OF CONSTRUCTION SCHEDULING

Before scheduling it´s needed to fix the input data what is time consuming process. Thereafter the construction schedule, by an ordinary way, is to be set. An incorporation of the working environment influence on duration of the construction processes may, however, be automatized. The procedure of the construction schedule modification considering an influence of climatic conditions on duration of construction processes roughly represents the algorytm in fig. 7.

Scheduling begins with with fixing of date of start of the very first process. Subequently, it is to be considered if this process can be performed in given term (under "term" we can understand e.g. month) eventually if an execution requires any special provisions (heating up of fresh concrete, protection of working station against rain, etc.) which would increase the labor content. Duration of the process is to be calculated using formula 3. The process does not need to be completed within a given month, but may continue to the next month. However, work environment factors change in such new month. Therefore, the number of units (m^3, m^2, m´, t, pieces) remaining from the original value is calculated:

$$q_z = q \frac{T_p^r}{T_p} \qquad \text{(shift)} \qquad (4)$$

where q_z is the number of units (m^3, m^2, m´, t, pcs), not implemented yet,
q total number of units (m^3, m^2, m´, t, pcs),
T_p total duration of a process (change),
T_p^r process duration within an interval (change).

Processes are interlinked. Each link may have a time value defining timing of the respective processes. This timing may depend on the work environment. It may represent the dependence of the time value itself, which may change with respect to work environment factors, or it may be the case of definition of conditions to be fulfilled throughout the entire postponement – e.g. minimum temperature, etc. If this condition is not observed, measures (e.g. heating) need to be proposed, or the process performance needs to be shifted to different period.

Following the definition of time value links, another activity is included in the time schedule using the identical procedure.

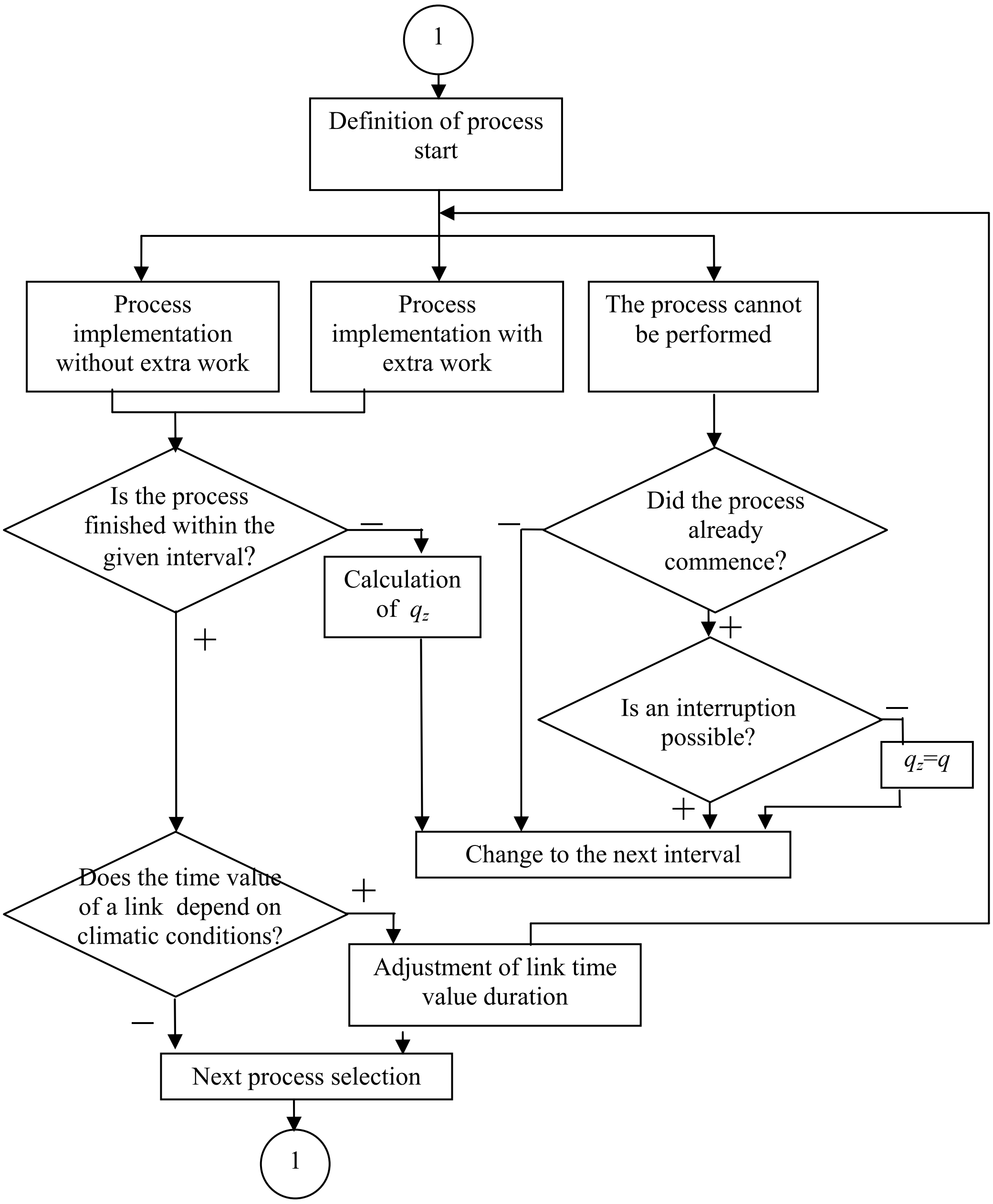

Figure 7: Generation of time schedule reflecting the dynamics of work environment changes

Fig. 8 shows an example of the timber – work (rafters) schedule for four buildings. For comparison, this schedule includes duration of the jobs based on average time standards versus durations modified with regard to influence of the climatic condition if the jobs starts in March or in July.

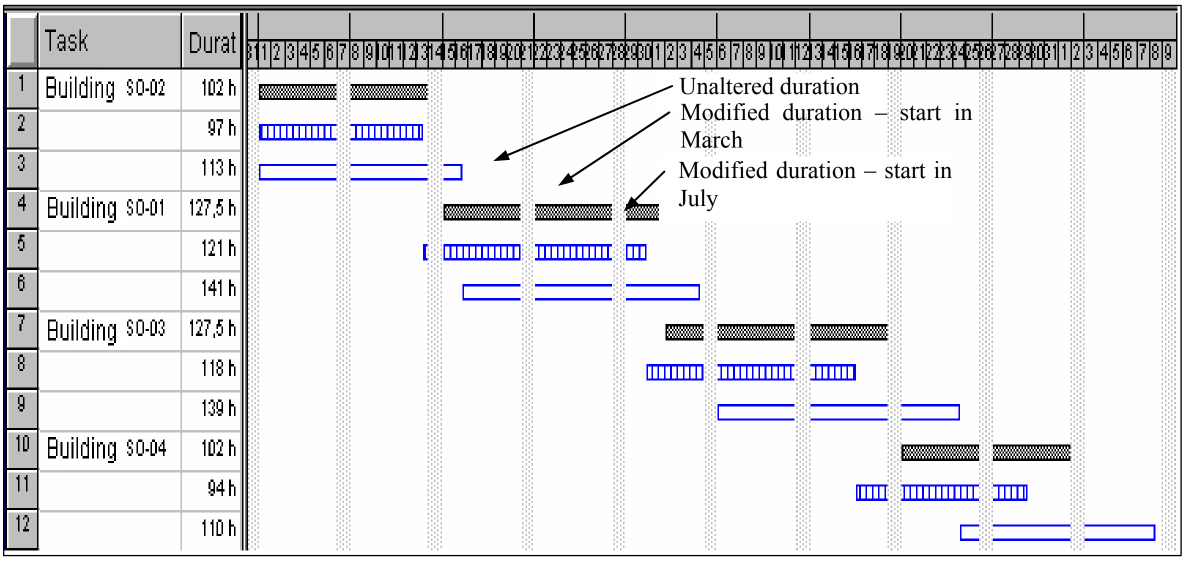

Figure 8: Time table of timber – works

CONCLUSIONS

Time schedules rank among principal construction preparation documents. For them to be precise enough, they have to enable construction management without need of frequent updates. This requires consideреation of the working environment within scheduling. Therefore, it would suffice to deal only with some processes, which are the most important in terms of construction work progress.

By application of scheduling automation, as discussed tereinbefore, woul increase an employability of this methodology in practice.

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