MONITORING PROGRESSION IN CONSTRUCTION
- A Case Study At Slovain-Hungarian Railway Line Construction -

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Abstract

To gain abilities for tracking and assessing progress of construction processes under progression it is necessary to construct schedules reflecting predicted progression of tasks to be performed accurately. These schedules may assume either even or uneven progression – depending on the manners of tasks to be managed. Progression measures can be settled according to the characteristics of monitored processes – using job specific indices within the two main types of jobs. The arcticle introduces practical experiences of the above principles in case of constructing Slovain-Hungarian railway line connection.

Key words : construction management, monitoring, network techniques

INTRODUCTION

For to discuss the problem as an essence we can summarize: „The schedule is set for to get a baseline to measure any variances against". To measure variances in progression it is necessary to have at first a pre-set time estimate and to track actual progression of processes time by time. On following sheets we take an overview of ways of constructing time estimates and of their information feedback systems needed for to full-fill jobs of these kinds.

1. EXPECTATIONS ON TIME ESTIMATES FOR TO SERVE MONITORING PURPOSES

When planning construction processes nearly in all cases of works of high significe it is necessary to prepare time estimates of performance, to prepare forecast of financial resources associating, and to estimaste likely needs in some highlighted characteristic resources. These estimates can be prepared either as pre-set schedules or as dinamic (network) models of the project depending on complexity of jobs to be performed.
How deep the structure of works is broken down is determined by aims of application, while (time)units of schedules are set basically in accordance of time-range scanned. One of most preferred expextations against time estimates is accuracy that necessiates planning processes deep in details. Details can be limited by sources and characteristics of information available or by the extent of the schedule targeted. An extended schedule or a WBS uselessly deep in details can reduce its functionality and it gets difficult to keep in hand or simply to look it over.

1.1 Characteristics of Work Breakdown Structure

1.1.1 Units of measurement

When composing processes complexity of an item within the WBS is set according to the structure to be constructed with deep consideration of destination of Schedule to be prepared.
For to estimate and later to track progression selecting appropriate well defined and calculable or sensible units of measurement has great significance.

Main types of units applicable at individual processes:

- ✍ Most characteristic value of a process is its volume (quantity) in a natural unit. This characteristic is fundamental at estimating and at tracking progression based on bills of quantities of works to be or have been completed. As samples for units of this kind we can mention: m^3 for embankment, m^3 or m^2 for gravel layer, etc.

- ✍ Work in shifts or in working hours can be used to quantify jobs of high complexity with output measurable in no single natural unit. Work as unit of a job can serve well in cases typically with less need in machine power but necessiating more professions or skills to cooperate. Jobs of this kind can be let's say: finishing works, landscaping or water-shed management.

- ✍ Currency (financial resources) scheduled or expended can be used to quantify jobs typically with significant needs in machine power and with manyfold output measurable in no single natural unit. In these cases having no better common measures cash-flows can be used for tracking progression.

When planning efforts are generally driven to set natural units for tracking progression due to their most accurate manner with least possibilities of subjective judgements. Comparision of estimates and actual performances at jobs measured in units of work bear less accuracy due to more subjective factors in estimating and in surveying them. Quantifying jobs in currency is considered to be the least accurate due to evidential diversity of costs (and/or cash-flows) of needed resources. Information on cash-flows in these cases may significantly differ from actual technical-technological progression. Cost of an item in the WBS may consist of costs of used material and of value added by the contractor. Jobs with high material costs but with less labour-costs when measured in currency may reflect progression „in" or even „before" schedule while at delay of jobs with more significant live-labour may be not or not in real proportion reflected in a cash-flow. Cash indicatrix offers the more possibilities for manipulating reports and accounts on progression.

1.1.2 Characteristics of performances

According to variations of performances in time processes can be characterized as:

- ✍ Flow of performance of a job is considered to be **proportional** in cases when progression of job can be estimated assuming constant intensity in time. Studying distribution of performance data along a time scale a conclusion emerges that assuming proportional performances serves well at time estimates of small- or

middle-range projects when WBS is broken down deep to so called „work packages" or simple „jobs".

- Flow of preformance of a job is better considered to be **roll-up** typed in cases when significant potentional changes can be forecasted in intensity of progression during performance. It is also necessary to consider jobs of roll-up type at time estimates consisting of (broken down to) sub-projects where master schedule is resulted in ways of aggregation of individual schedules of sub-projects. In these cases resource charts likely show uneven characteristics in time. Typical situations of better assume roll-up typed jobs:
  - Structure (object or building) divided into more segments (or phases);
  - Master schedule highlighting performances of more sub-contractors or of more contributors.

2. MONITORING PROGRESSION

2.1 On-site information as reported progression

In accordance of considerations above when tracking progression time by time it gets necessary to define data sets measured or calculated, such as:

- Quantities (volumes) completed - at jobs measured in natural units;
- Work completed - at jobs measured (estimated) in work units;
- Percent of completion (estimated) - at jobs progression of which is scheduled in percentage;
- Cash expended.

2.2 Indices of progression

2.2.1 Progression indicatrix at jobs of proportional type

Progression of a jobs of proportional type can be best evaluated in percentage of finished works (measured either in natural or in derived units). Indicatrix can be derived as quantity completed over quantity planned.

2.2.2 Progression indices at jobs of roll-up type

In case of jobs of uneven intensity (roll-up typed) to use a single indicatrix may drive us misunderstanding the real situation so it is suggested to define more characteristics for to get picture of progression of higher fidelity. Such characteristics (measured either in natural or in derived units) can be:

- Rate of completion in examined (actual) period scheduled;
- Actual rate of completion in examined (actual) period reported;
- Performance (output) in examined (actual) period scheduled;
- Actual performance (output) in examined (actual) period reported;

Having these characteristics more indices can be derived off them reflecting progression from more views of management. Indices typically figured in percentage can be such as:

- Comparing scheduled rate and reported rate of completion may reflect an overall view of the project to evaluate midle- and longrange run of progression. With indices of this kind changes (delays or variances) of strategic level can be highlighted.

- Comparing scheduled and actual outputs in reviewed period helps to evaluate actual performance and promotes highlighting factual or likely reasons behind any variances (such as weather extremities, lack of resources, difficulties in co-operation, etc.).

- Comparing indices of these kinds of concurrent jobs may reflect performances and in-time deliveries of individual sub-contractors. This way their mutual cooperation and their disciplines in full-filling time-expectations also can be highlighted.

3. INFORMATION SYSTEM OF MONITORING

3.1 Preparing data for monitoring purposes

One of the most significant factor in vitality of any monitoring system is how much extra efforts are necessiated for monitoring purposes. It is intended to use as many in-use figures, measures and indices as can be originated from other evident book-keeping, accounting or contractual obligations of (sub-)contractors allocated by laws and/or regulations. Lot of data of these kinds without any or with slight modifications should be useful for monitoring purposes too. For to achieve this it is fundamental to construct a Work Breakdown Structure with items and with units in it fitting both accounting and scheduling purposes.
It seems to be evident that data structure of schedules and of accounting systems should be in close relation with each other, or at least those could be referred to (derived or aggregated from) each other. As one of the aims it should be kept in mind even in preliminary planning- and also in tendering (contracting) phase of the project. Introducing a proper timely surveying and accounting system for deliveries fitting WBS of Schedules too may result in no need for extra efforts to prepare redundant sets of data for monitoring purposes.

3.2 Flow of information

At preparing periodical (say monthly) reports on progression data sets should be arranged in ways to provide multi-purpose processing. Up to date telecommunication and information technology provide capabilities to manage secure data transfer via public online information streams either in ways of e-mail packages. Considering the most popular or the most wide-spread software applications in Hungary some spreadsheet applications (e.g. MS Excel) may be suggested for use with help of which structured multi-purpose data processing capabilities are available. Using developed data processing applications automated production of reports, charts and indices on progression may effectively assist comprehensive evaluation of actual conditions of the project being monitored.

4. REPRESENTING CONCLUSIONS OF MONITORING

4.1 Displaying progression within schedule representations

It seems to be evident to display progression in an optional graphical output of a computer application developed to manage time estimates. Tending to be a standard they give accesses to indicate progression e.g. within a bar-chart called Gantt-Diagram. This tool is highly applicable to display progression of jobs of proportional type.
To display progression of jobs of roll-up type built-in optional outputs may not be sufficient. Some applications provide accesses to handle bar-charts as graphics. So further „graphical" details on progression (such as texts, data series, pictures) can be added to the basic output sheets for to highlight further easy-to-read information and to make representation more vital.

4.2 Progression curves and indices

Due to the fact that extended data sets are generally processed using computer applications it is evident to use optional outputs (charts and curves) of the application being used. Using up to date spreadsheet applications it is rather dependent on the fantasy of the user than on the capability of the application how to display indices and tendencies characterizing progression of the project being monitored.

5. MONITORING PROGRESSION AT PROJECT OF ZALALÖVÖ – STATE BORDER RAILWAY LINE CONSTRCUTION

The project aiming to construct Zalalövö – Hungarian State Border Railway Line Connection was one of the biggest railway development project within the last fifty years in Hungary. Jobs of preliminary planning, managing and monitoring was performed in coordination of a special sub-organization within the Hungarian Railway Company (MÁV) called Project Office of Highlighted Investments (KBPI).

Due to strictly limited extent of this paper and not aiming to introduce the project itself deep in details paper deals with knowledge relevant to demonstrate disciplines entitled in the headline only.

5.1 Sectioning the project

Sub-structural works of the railway line to be constructed was devided into six packages (tenders) by MÁV KBPI even in preliminary planning pahes of the project. Packages differing significantly in technical-technological content, in volume and in complexity were contracted individually.

Most complex one of the six packages (sections) was Section N^{o} 6 further divided into 14 sub-sections including significant amount of earthworks, retaining walls, culverts, multi-level crossings and other engineering objects. Works in Section N^{o} 4 included also significant amount of earthworks and structural works together with a 300 m long tunnel that was one of the rarest structure to be built in Hungary. Section N^{o} 3 and section N^{o} 5 included viaducts of different lengths among which there was a 1400 m long viaduct crossing river Zala and becoming one of the longest ones of its kind in

Central Europe. Section N° 1 and section N° 2 included typically significant amount of earthworks together with several smaller culverts and frame bridges crossing several seasonal water flows and agricultural dust access roads.

Great variety of jobs, differing complexitiy of packages and manifold skills and expertises needed together with numerous contributors collaborating to complete project successfully generated emphasized demands on advanced monitoring tools either considering individual packages (contracts) or the overall project itself.

5.2 Work Breakdown Structure

In preliminary planning phase experts of MÁV KBPI prepared a preliminary time estimate for the overall project. They identified sections to be contracted individually also specifying jobs to be performed within each. They carefully identified items and milestones for accounting that got be obligatory to refer to by the contractors both in tendering pase and during the performance. The breakdown structure of these items was constructed to fit the work breakdown structure of the preliminary schedules too. The constructed breakdown structure was also the structure of the obligatory monthly reports on progression.

As result of carefully elaborated tender documents and preliminary estimates later contractors had to prepare no more data than was needed for general accounting purposes during the performance. (At most they had to make some aggregations - in the worst case.)
This way experts of MÁV KBPI provided a monitoring system driving progression reports of individual contributors and those of sub-contractors to overall views and reports of high fidelity for to track real conditions of the project.

5.3 Information system of monitoring

According to complexity of the project it was necessary to build up two levels of information system. Namely:

- Level of individual sections (Level of coordinations), broken down to jobs of sub-sections
- Level of overall project (Master level), broken down to aggregated jobs of sections

5.3.1 Information system of section N° 4 and of section N° 6

Sections N° 4 and N° 6 contractor of which was EGÚT Corporation were including complex jobs manifold both in space and in technology. For to plan and to track progression with expected accuracy section N° 6 had to be divided into 14 sub-sections while section N° 4 consisted of 3 sub-sections. Detailed schedule (time estimates using network techniques) of jobs of these two sections included some 600 items identified and arranged by sub-sections for cooperation purposes and in strict relation with items of accounting specified in tender documentations.
Due to WBS being deep in details jobs identified in the network model (schedule) were assumed to be proportional. A sheet of detailed schedule – prepared using MS Project – is presented in picture N° 1 attached.

Data to read at individual jobs in the bar-chart are:

- Performance scheduled: wide bar in red or in blue highlighting date of early schedules and indicating floats if any;
- Progression reported:
  - thin bar in blue indicating performances in periods preceeding;
  - thin bar in red indicating performance reported actually;
  - figure left to the bar indicating completion reported actually in percentage (completed amounts against planned ones);
  - figures right to the bar indicating actual performance:
    - for jobs measured in percentage: performance reported actually;
    - for jobs measured in natural units (m, m^2, m^3, pcs, etc.):
      - left to the sign '/': performance reported actually (volume and unit)
      - right to the sign '/': completion reported actually (volume and unit)

Cummulative monthly figures of progression arranged by sections were processed using a spreadsheet application a sheet of which is presented in picture N° 2 attached. The contractor EGÚT Corp. reported figures of surveyed progression in way of full-filling proper column of the sheet and sent it via e-mail to the experts charged with preparing monthly reports of the overall project and with updating time estimates for that if necessary.

5.3.2 Links between reports of individual sections and those of the overall project

On level of sections (e.g. at sections N° 4 and at section N° 6) information on actual performances had been collected sub-section by sub-section and job by job. Data sets for higher level reports had to be derived or aggregated off these data. For to evaluate progression of performance on higher (Master) level of reports derived and aggregated figures of scheduled progression also had to be prepared even in preliminary planning phase of the project. For to aggregate monthly data of progression either scheduled or reported also a spreadsheet application had been applied, output figures of which had been used at preparing and at updating estimates of the Master Schedule.

At preparing estimates (schedules) of progression on this higher level of aggregation – as matter of fact – individual items of reports had been assumed to be of roll-up type.

5.3.3 Information system on Master Level

It is one of the top interests of the Client to get real view of progression during performance of the project. In accordance with considerations above data sets of reports were collected on coordination level of sectioned project while progression reports for Master Level were based on data derived or aggregated off the lower level reports.
At sections N° 1, 2, 3 and 5 lower level reports were prepared by the contractors while for higher level they reported their aggregated data arranged by jobs section by section. At section N° 4 and N° 6 lower level information were reported to the Client while the job of processing these data into forms of lover and upper level reports was assigned to a special team of the Client superwising (collecting and integrating) all reports.
Picture N° 2 attached presents a sheet of data collection containing acquired information on monthly progression at sections N° 1, 2, 3 and 5 together with derived

and aggregated ones of sections N° 4 and N° 6. Figures presented in cells of the sheet in different colors are to be read as:

- Cummulative monthly figures of progression scheduled indicated in gray fields;
- Cummulative monthly figures of actual progression reported in white fields.

For to satisfy their reporting obligation on monthly progression contractors had to full-fill actual columns of the sheet and to send it via e-mail to the experts of the Client. Of course surveys and other documentations of performances had to be managed on usual ways out of the monthly monitoring system.

5.4 Representing conclusions of Monitoring

Easy-to-read data sets of concluded progression were transformed into two main forms of representations. Numeric information – as feedback – presented directly in the time estimates (Master Schedule) and individual sheets of bar-charts – as highest level information – rather for financial consideration.

5.4.1 Master Schedule

Master Schedule broken down to jobs arranged by sections (Picture N° 3 attached) read information about the items (job) such as:

- figure of the overall volume of job planned;
- upper bar at job:
  - figures in red frame: monthly progression scheduled;
- lower bar at job:
  - figures in blue field: monthly progression reported in preceeding periods;
  - figure in red field: monthly performance (progression) reported actually;
- righ to the lower bar at job:
  - variance of progression (reported less scheduled) in units of job;
  - variance of progression (reported less scheduled) in percent.

5.4.2 Bar-charts

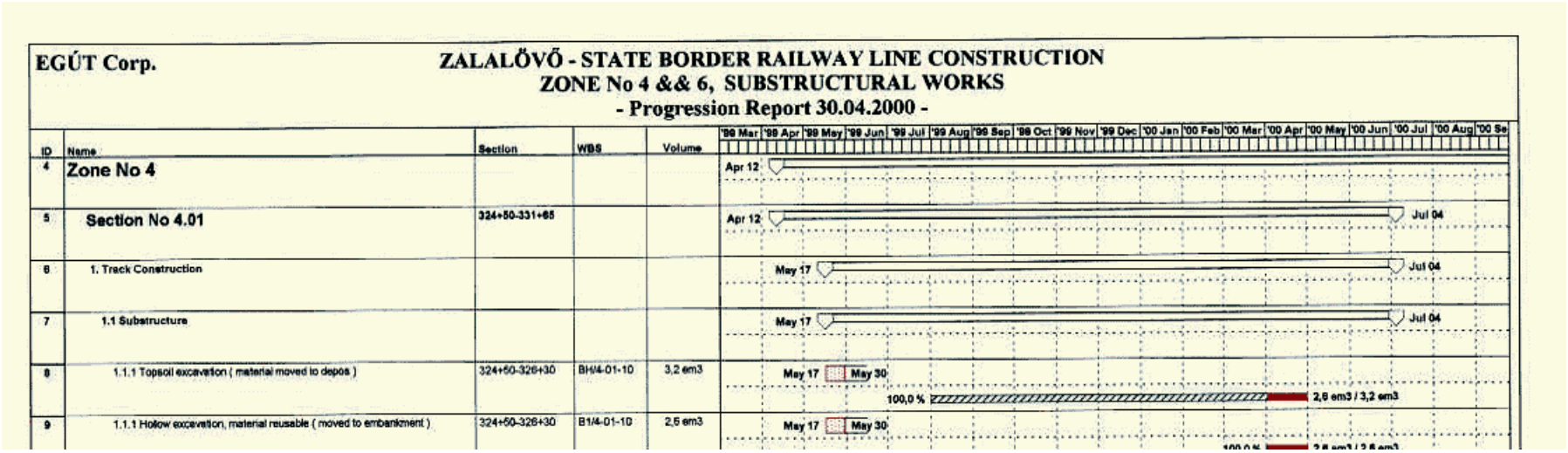
Bar-chart reports broken down to jobs section by section were used to report progression for rather financial considerations. (The project was partly financed by international sources.)

Monthly Bar-chart of an individual section highlighted information such as:

- jobs listed on the left
- horizontal axis of progression (indicated in percent within the range of 0-120 %);
- bars at job:
  - bar in blue: cummulative progression scheduled;
  - bar in yellow: cummulative progression reported;
  - bar in red: performance reported actually.

An example sheet of bar-charts is presented in Picture N° 4 attached.

Picture N^{o} 1: Detail of a Section's Schedule



EGÚT Corp.

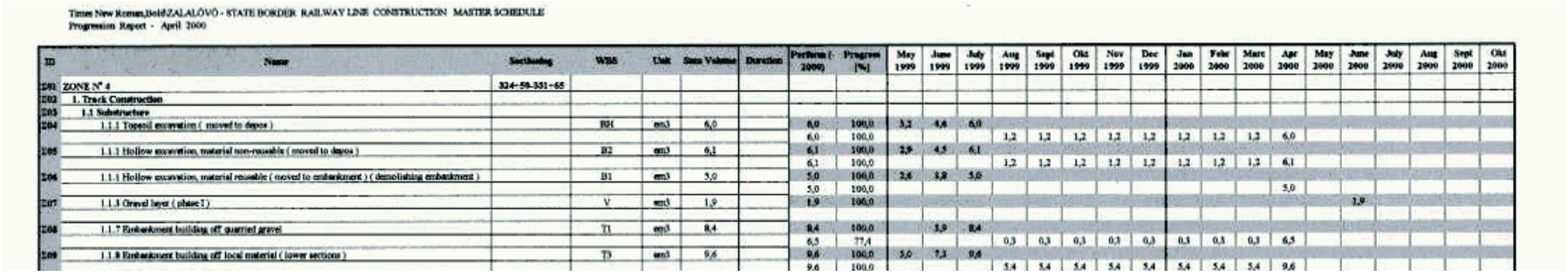
ZALALÖVŐ - STATE BORDER RAILWAY LINE CONSTRUCTION
ZONE No 4 && 6, SUBSTRUCTURAL WORKS
- Progression Report 30.04.2000 -

ID	Name	Section	WBS	Volume
4	Zone No 4			
5	Section No 4.01	324+50-331+65		
6	1. Track Construction			
7	1.1 Substructure			
8	1.1.1 Topsoil excavation (material moved to depos)	324+50-326+30	BH/4-01-10	3,2 em3
9	1.1.1 Hollow excavation, material reusable (moved to embankment)	324+50-326+30	B1/4-01-10	2,6 em3

'99 Mar | '99 Apr | '99 May | '99 Jun | '99 Jul | '99 Aug | '99 Sep | '99 Oct | '99 Nov | '99 Dec | '00 Jan | '00 Feb | '00 Mar | '00 Apr | '00 May | '00 Jun | '00 Jul | '00 Aug | '00 Se

Apr 12
Apr 12 — Jul 04
May 17 — Jul 04
May 17 — Jul 04
May 17 — May 30
100,0 % — 2,6 em3 / 3,2 em3
May 17 — May 30

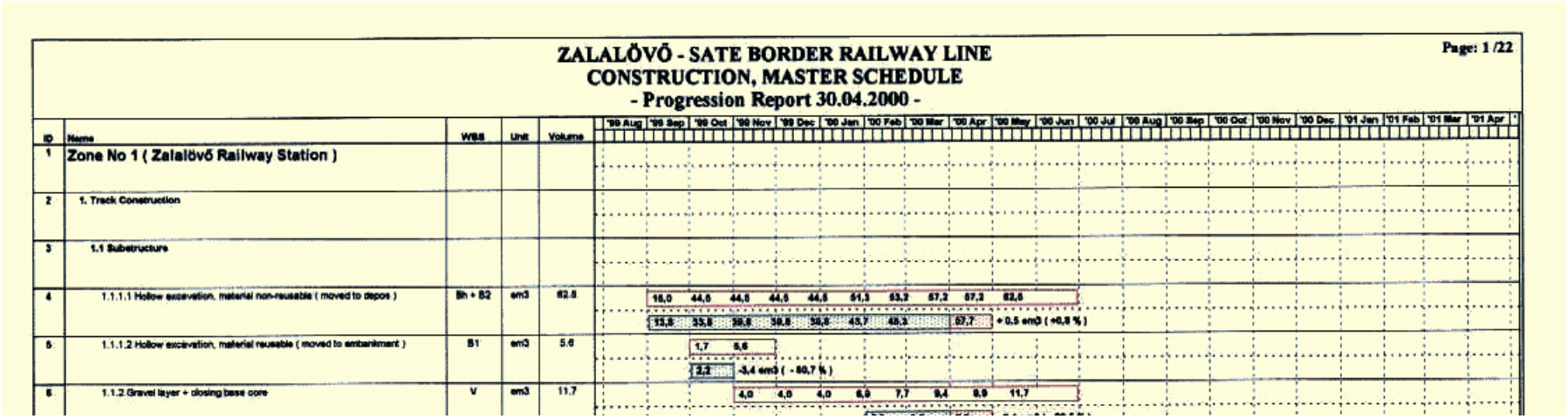
Picture N^{o} 2: Detail of a Sheet for Data Collection



Times New Roman,Bold|ZALALÖVŐ - STATE BORDER RAILWAY LINE CONSTRUCTION MASTER SCHEDULE
Progression Report - April 2000

ID	Name	Sectioning	WBS	Unit	Sum Volume	Duration	Perform (2000)	Progress [%]	May 1999	June 1999	July 1999	Aug 1999	Sept 1999	Okt 1999	Nov 1999	Dec 1999	Jan 2000	Febr 2000	Marc 2000	Apr 2000	May 2000	June 2000	July 2000	Aug 2000	Sept 2000	Okt 2000
001	ZONE N° 4	324+50-331+65																							
002	1. Track Construction																								
003	1.1 Substructure																								
004	1.1.1 Topsoil excavation (moved to depos)		BH	em3	6,0		6,0	100,0	3,2	4,4	6,0														
							6,0	100,0				1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	6,0					
005	1.1.1 Hollow excavation, material non-reusable (moved to depos)		B2	em3	6,1		6,1	100,0	2,9	4,5	6,1														
							6,1	100,0				1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	6,1					
006	1.1.1 Hollow excavation, material reusable (moved to embankment) (demolishing embankment)		B1	em3	5,0		5,0	100,0	2,6	3,8	5,0														
							5,0	100,0												5,0					
007	1.1.3 Gravel layer (phase I)		V	em3	1,9		1,9	100,0														1,9			
008	1.1.7 Embankment building off quarried gravel		T1	em3	8,4		8,4	100,0		3,9	8,4														
							6,5	77,4				0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	6,5					
009	1.1.8 Embankment building off local material (lower sections)		T3	em3	9,6		9,6	100,0	5,0	7,3	9,6														
							9,6	100,0				5,4	5,4	5,4	5,4	5,4	5,4	5,4	5,4	9,6					

Picture N^{o} 3: Detail of Master Schedule



ZALALÖVŐ - SATE BORDER RAILWAY LINE
CONSTRUCTION, MASTER SCHEDULE
- Progression Report 30.04.2000 -

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ID	Name	WBS	Unit	Volume
1	Zone No 1 (Zalalövő Railway Station)			
2	1. Track Consetruction			
3	1.1 Subetructure			
4	1.1.1.1 Hollow excavation, material non-reusable (moved to depos)	Bh + B2	em3	82.8
5	1.1.1.2 Hollow excavation, material reusable (moved to embankment)	B1	em3	5.6
6	1.1.2 Gravel layer + closing base core	V	em3	11.7

Picture N^{o} 4: Detail of a Monthly Bar-Chart Report on Progression