Software for Time-Scheduling of Construction Processes

Logiciel pour le contrôle des délais dans la construction

Software für die Terminkontrolle in Bauprojekten

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SUMMARY
Project and construction management PC-software can be created either by developing new software or by reducing mainframe software to PC size. The article presents a new program for calculating non-rhythmical assembly lines in construction as well as a PC version of matured program package for time scheduling network calculation and presentation.

RÉSUMÉ
Le logiciel de micro-ordinateur pour la gestion de projet et de la construction peut être une nouvelle création ou une adaptation de programmes existant pour les gros ordinateurs. L'article présente un nouveau programme pour le calcul de chaînes de montage arythmiques dans la construction ainsi qu'une version pour micro-ordinateur d'un programme ayant fait ses preuves dans la planification et le contrôle des délais.

ZUSAMMENFASSUNG
Die PC-Software für die Leitung von Gesamt- und Bauausführungsprojekten kann entweder neu entwickelt oder durch Reduktion von Grosscomputerprogrammen gewonnen werden. Der Beitrag beschreibt ein neues Programm für die Berechnung von nichtrhythmischen Taktstrassen im Bauwesen sowie die PC-Version eines bewährten Programms für die Terminplanung und -kontrolle.

INITIAL POSITION

According to the international trend, computer aided methods in construction management succeeded also in the construction industry of the German Democratic Republic. Until now only the larger building plants owing efficient mainframe computers have been using extensive project and construction management software.

At present, a wide application of CAD/CAM systems forces its way in all fields of building activities, both in large plants and now in small plants as well. This development is due to the personal computers.

Personal computers enable an autonomous computer aided operating for civil engineers and construction managers. The possibility of direct calculating and optimizing the parameters of the construction processes in an interactive screen dialogue and of direct printing and drawing the technological documents automatically has overcome former obstacles.

In consequence of this development the call for personal computer software has increased rapidly. The scientific institutions and the R&D departments of the GDR construction industry face massive challenges for construction managment PC programs. The programs for time scheduling and control of construction processes play an importat role within this software. They are able to rationalize the techonological preparation on the one hand and on the other hand they economize time and resource demand.

The research team which deals with "Methods for Preparation of Investment and Building Processes" at the Leipzig University of Technology therefore took the problem of personal computer application in project and construction management in its program. The intention is to promote a further joining of our academic work with practice and to get at the same time fundamentals and examples for the training of our students in the up-to-date methods of civil engineering.

HARDWARE

Since early 80's the GDR construction industry uses mostly the "Bürocomputer A 51" (Office-Computer) made by ROBOTRON, Dresden, This personal computer will be mostly used also in the following years in our country (Fig. 0).

It is a 8-bit computer, including a central unit with 64 K-Byte, numerous connecting units and offers the possibility to be linked with other computers. The normal configuration contains a 31 cm display screen (alphanumeric), 3 to 4 floppy-drive systems, the standardized QWERTY-keyboard, and a serial printer with 132 or 210 characters respectively. A paper tape equipment, several magnetic tape systems, and a remote data transmission device may be connected. Furthermore, it is possible to link the central unit with an interactive graphics systems (which consists of graphic display, matrix printer and terminal graphic plotter). Presently, the work of our research team is concentrated particularly on using the above mentioned type of personal computer for the time scheduling software development.

As in a numer of other countries the production of 16 bit personal computers started in the GDR only recently. Theses PC's are in possession of a remarkably higher memory storage capacity than the "Bürocomputer". Similar hardware configurations are used world-wide.

Nevertheless, the PC software development is mainly done on the small 8 bit computers for the moment. This fact causes some difficulties in respect to the size of the program moduli and demandes for economic use of character-and-word processing in dialogue. But these difficulties are accepted in order to enable as widely and as fast as possible the use of the programs presented in this paper in practice and teaching. On the other hand, experiences concerning modularizing and preparing the future software development for 16 and 32 bit computers are being collected.

Fig. 0

TWO WAYS

Today, project and construction management PC software is created in two ways, which was also showed by the 1985 INTERNET World Congress in Rotterdam. These two ways are

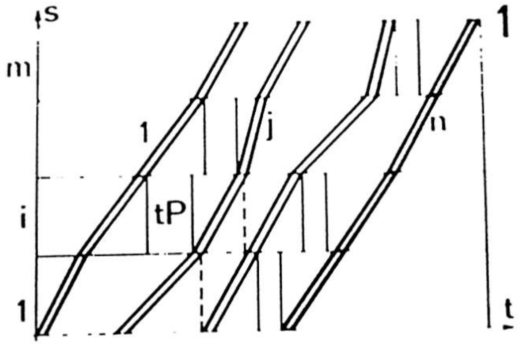
- reducing the mainframe software or
- completely new programming on base of special models and algorithm.

Both these ways are useful and commonly practiced and result in similar programs. PC software on the basis of mainframe computer programs as a modul often completes whole "families" of program systems. They have smaller dimensions, e.g. fewer activities or fewer types of resources in network programs. But they use the same philosophy as their mainframe computer programs, dividing them into separate moduli. Newly programmed PC software often goes its own way. The system philosophy is adapted to the reduced dimension and is in most cases particularly convenient for operator-system interaction.

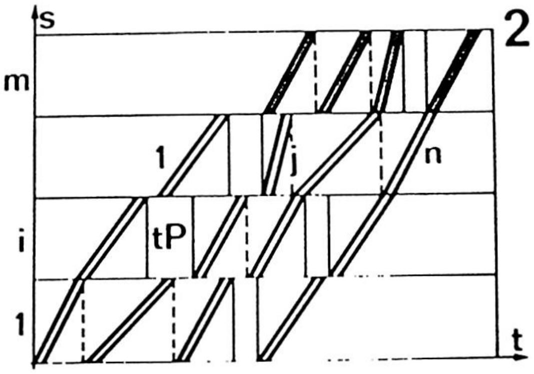
Our PC programs are also created using these two different ways. The "BC-LEINET" is the youngest child of a matured program package, the program "BC-ZYKL" has been newly developed.

THE PROGRAM "BC-ZYKL"

This PC program takes as its basis the classic algorithm of calculation of nonrhythmical assembly lines in construction (Fig. 1 upper part). Using the "Cyclogram Technique" this algorithm calculates minimum start-to-start distances, start-and-finish dates and minimum total time of construction. This is the normal case of serial new buildings, e.g. in the 20 year program of the GDR the "Housing Development Plan" from 1971 to 1990.



$$D_{KT} = \sum_{j=1}^{n-1} \max_{1\leq\mu\leq m} \left(\sum_{i=1}^{\mu} D_{ij} + tP_{\mu j} - \sum_{i=1}^{\mu-1} D_{i,j+1} \right) + \sum_{i=1}^{m} D_{in}$$



$$D_{KO} = \sum_{i=1}^{m-1} \max_{1\leq\nu\leq n} \left(\sum_{j=1}^{\nu} D_{ij} + tP_{i\nu} - \sum_{j=1}^{\nu-1} D_{i+1,j} \right) + \sum_{j=1}^{n} D_{mj}$$

Fig. 1: Cyclograms of nonrhythmical processes

A new variant of this algorithm is shown in the lower part of figure 1. I introduced this algorithm during the last IABSE Congress in Vancouver B.C., in 1984, by a poster. Our research team replaced in this algorithm the continuous employment of the partial production capacities within each subassembly line by continuity of the sequent different partial processes within each building segment. This model is needed for time scheduling of reconstruction processes, where the disruption of the function of the building in question must be minimized (e.g. in case of a hospital).

MATRIX FUER D UND tP

J / I	1 D	1 tP	2 D	2 tP	3 D	3 tP	4 D	4 tP	5 D	5 tP	6 D	6 tP	7 D	7 tP	8 D	8 tP
1	0	0	4	0	6	3	0	0	2	0	3	0	2	0	0	0
2	3	0	3	0	0	0	3	0	0	0	4	0	2	0	1	0
3	0	0	1	0	0	0	2	0	0	0	3	0	2	0	1	0
4	4	0	3	0	4	3	0	0	1	0	6	0	2	0	2	0
5	3	0	2	0	4	3	0	0	2	0	4	0	2	0	0	0
6	0	0	1	0	0	0	3	3	0	0	7	0	2	0	0	0

Fig. 2: Matrix of durations and technological disruptions

The program BC-ZYKL realizes both variants. The input data consists of the tact durations, the technological disruptions, the number and sequence of the buildings, resp. segements, and subassembly lines. These data are arranged as a m-n-matrix (fig. 2) and may be read-in either through the numerical keyboard or through a file on floppy disk. The subroutine R-ZYKL calculates the following outputs:

1) For all n subassemly lines
   - Start-and-finish dates
   - Actual and minimum operating time
   - Waiting time (absolutely and relatively)

2) For all m buildings, resp. segments
   - Start-and-finish dates
   - Actual and minimum construction time
   - Organizational disruptions (absolutely and relatively)

3) For the whole process
   - Total construction time
   - Total operating time of the subcapacities
   - Total share of waiting time, resp. organizational disruptions (as a quality mark of the time scheduling)

The following figures will illustrate these results by means of an example with 6 different buildings and 8 subassembly lines for both variants of continuity:

BEGINNABSTAENDE

von TTS \ nach TTS	2	3	4	5	6	7	8
1	-1						
2		5	9				
3				14			
4					0		
5					2		
6						17	
7							6

Fig. 3: Minimal start-to-start distances

Fig. 3 and 4 show the minimized start-to-start distances and the start-and-finish dates in case of continuous employment of the partial production capacities, that means new building erection processes. Fig. 5 shows the accessory bar graph. It is a quasigraphic one, the capital letters represent the type of resources.

TERMINE UND DAUER DER TEILTAKTSTRASZEN

TTS	AT	ET	D
1	1	11	10
2	0	14	14
3	5	19	14
4	9	17	8
5	19	24	5
6	21	48	27
7	38	50	12
8	44	48	4

Fig. 4: Start and finish dates of subassembly lines

Zeichenerklaerung: A = TTS 1, B = TTS 2 usw., *=techn. Pause

```
----------------------------------------------------------------------------
     0   4   8  12  16  20  24  28  32  36  40  44  48  52  56  60  64  68  72

0 1 | BBBB CCCCCC***     EEFF               GG
    |  . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
0 2 |  AAABBB  DDD           FFFF             GG  H
    |  . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
0 3 |        B    DD             FFF            GG H
    |  . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
0 4 |     AAAABBBCCCC***   E        FFFFFF        GGHH
    |  . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
0 5 |         AAABB  CCCC***EE            FFFF      GG
    |  . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
0 6 |              BDDD***                    FFFFFFFFGG
    |  . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
     0   4   8  12  16  20  24  28  32  36  40  44  48  52  56  60  64  68  72
----------------------------------------------------------------------------
```

Fig. 5: Bar graph of continuous subassembly lines

Zeichenerklaerung: A = TTS 1, B = TTS 2 usw., *=techn. Pause

```
----------------------------------------------------------------------------
     0   4   8  12  16  20  24  28  32  36  40  44  48  52  56  60  64  68  72

0 1 | BBBBCCCCCC***EEFFFGG
    |  . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
0 2 |          AAABBBBDDDFFFFGGH
    |  . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
0 3 |                    BDDFFFGGH
    |  . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
0 4 |                 AAAABBBCCCC***EFFFFFFFGGHH
    |  . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
0 5 |                        AAABBCCCC***EEFFFFGG
    |  . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
0 6 |                                   BDDD***FFFFFFFGG
    |  . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
     0   4   8  12  16  20  24  28  32  36  40  44  48  52  56  60  64  68  72
----------------------------------------------------------------------------
```

Fig. 6: Bar graph of continuous partial processes within each building

Fig. 6 shows the analogue bar graph in case of continuous sequence of the different partial processes within each building, that means reconstruction processes.

Another subroutine summarizes the ressources (Fig. 7). The output is printed as a diagram or histogram of resource allocation plan.

These printouts, lists of processing dates and bargraphs may originally be used for construction management in situ. The input routine of BC-ZYKL makes it possible to change any input data (as durations, sequences, technological disruptions) into an interactive screen dialogue. Therefore this program is suitable for on-line actualizing of time scheduling, as a tool of process control, if the construction manager is equipped with a "Bürocomputer".

The author of this program is Dr. Walter Schlorke, lecturer in our department. BC-ZYKL was programmed for the operating system SCP X, a variant of CP/M. The "Bürocomputer" permits a problem size of 20 buildings and 13 subassembly lines. This will do for the demands of GDR housing firms.

```
AK- SUMMENLINIE FUER TTS-KONTINUITAET
-------------------------------------

AK|    5    10   15   20   25   30   35   40   45   50   55
T |    |    |    |    |    |    |    |    |    |    |    |
--|-------------------------------------------------------
 1|=====
 2|============
 3|============
 4|============
 5|============
 6|=========================
 7|=========================
 8|=========================
 9|=========================
10|================================
11|================================
12|=========================
13|=========================
14|=========================
15|===================
16|===================
17|===================
18|==============
19|==============
20|=====
21|=====
22|=============
23|=============
24|=============
25|=========
26|=========
27|=========
28|=========
29|=========
30|=========
31|=========
32|=========
33|=========
34|=========
35|=========
36|=========
37|=========
38|=========
39|============================
40|============================
41|============================
42|============================
43|============================
44|============================
45|===================================
46|===================================
47|===================================
48|===================================
49|===================
50|===================
----------------------------------------------------------
```

Fig. 7: Ressources histogram

THE PROGRAM "BC-LEINET"

The PP-LEINET (**Lei**pzig-**Net**work) was developed about 15 years ago at the Leipzig University of Technology, by the Department of Mathematics and Data Processing and their partners as a well-matured program package for mainframe computers. As far I know, it is the most advanced network program in the GDR. It started from the MPM model but was then developed beyond it. It enables to use variable durations of the activities, target start-and-finish dates, minimum or maximum distances of the activities, all types of start-and-finish relations, several regimes of work calendars and work shifts. Its standard routines result in complete time scheduling with all types of float, resource allocation time-limited or resource-limited, time-cost optimizing, sequence optimizing and other outputs of mainframe computer PM/CM programs. Of course, batch or dialogue processing is possible. The program package LEINET was developed for ESER-computers (ESER means Integrated System of Computer Technolgoy in the socialist countries); it allows 8000 activities as a maximum and needs a memory storage capacity of 200 to 500 K Byte.

The PC-program BC-LEINET uses the philosophy of this program package, all principle system components and file contents (espacially activity data) are orientated on PP-LEINET. As formerly mentioned, its total system will be divided into separate moduli which are adapted to the size of the "Bürocomputer". The operating system SCP X (CP/M) supports this concept and allows optional extension.

At present we have 5 subroutines:

- NETZCHAR characterization of the network (fig. 8)
- VORGANG data input activity (fig. 9)
- TERMRE calculation of time dates (fig. 10)
- TERMLI output and printing of time data (fig. 11)
- BAGRAF output and printing of bar graphs, for the moment quasigraphically

Furthermore, a calendar file "KALDA" may be read-in through floppy disk.

A new subsoutine RESSUMLI summarizing the resources and printing histograms has been added quite recently. Additional moduli are being developed with the present concentration on resource allocation and time-cost optimization subroutines.

This PC-program can also be used for interactive actualizing all input data. Therefore we intend to extend BC-LEINET as a tool of process control for construction management, as another type of CAM systems.

The author of this program is Dr. Werner Böhr, other staff members and also students take part in the further work. The problem size today is 500 activities per calculation modul. Of course, 16 bit and 32 bit personal computers in this respect are superior to the "Bürocomputer".

APPLICATION

The two PC-programs presented in this paper are planned for practice and teaching application.

BC-ZYKL was originally developed for seminars on "Fundamentals of Building Technolgoy" in the first up to the third term of Civil Engineering studies. Now we have a R&D task for applying this program to some of our housing plants.

```
**********          I N F O R M A T I O N          **********

Netzbezeichnung:  KKWRGB
Laufwerk -NETZ :  2
Kalenderbez.   :  KALRGB1
Laufwerk -KAL  :  2
Ressourcendatei:
Laufwerk -RESS :  2
Netzart        :  objektnetz
Geg. frueh. AT :  191185    Relativtermin:  19
Geg. spaet. ET :  311287    Relativtermin: 791
Anz. der Vorg: :   18
Strukturnummern
   Vorgnr.     :  3000
   Zusmerm.    :  0000
   Ressnr.     :  0000
Letzte Rechnung:  AAAAAAAAAA  *****
Kommentar      :  Kalender KALRGB1 beginnt am 1.11.85,
Kommentar      :  endet am 31.12.87.

F O R T S E T Z U N G:
                        E--->ENDE                   I--->INFORMATION
                        A--->AKTUALISIEREN          S--->SPEICHERN
BITTE IHRE WAHL--->_
```

Fig. 8: Modul NETZCHAR

```
**********     PROGRAMM V O R G A N G  V-1.1 **********
-------------------------------------------------------
**********     I N F O R M A T I O N         **********

Vorgangsnummer:012              Bezeich.:Decke  0.0

Minimaldauer :  240     TERMINE  Geg.frueh. AT :010686
berechn.Dauer:  240              berechneter AT:060686
Maximaldauer :  240              Geg.spaet. ET :

R E S S O U R C E N   ||   V O R L A E U F E R   ||   N A C H F O L G E R
Ress.mummer   Arb.umf || Vorl.nummer   MM VV FFF || Nachf.nummer   MM VV FFF
----------------------||-------------------------||-------------------------
                    0 || 008           1A 10   0 ||
                    0 || 018           1A  0   0 ||
                    0 ||                         ||
                    0 ||                         ||
                    0 ||                         ||

F O R T S E T Z U N G :
                       E--->BEENDEN          I--->INFORMIEREN    P--->PRUEFEN
                       A--->AKTUALISIEREN    S--->SPEICHERN           DER
                       N--->NEUER VORGANG    L--->LOESCHEN            STRUKTUR
BITTE IHRE WAHL--->_
```

Fig. 9: Modul VORGANG

```
***********     PROGRAMM  T E R M R E        V-1-1        ***********
---------------------------------------------------------------------
***********     T E R M I N R E C H N U N G               ***********

Netzbezeichnung:KKWRGB

Laufwerk -NETZ :2

Netzbezeichnung: KKWRGB
Laufwerk -NETZ : 2
Anz. der Vorg. :  18

BEARBEITUNG DIESES NETZES ERWUENSCHT ? (J/N):j

Folgende Arten der TERMINRECHNUNG sind moeglich:
mit Minimaldauer        --->MIN
    Maximaldauer        --->MAX
    gewichteter Dauer   --->GEW
    ENDE                --->E
BITTE IHRE WAHL --->_
```

Fig. 10: Modul TERMRE

```
 Netzname: KKWRGB                  Geg.frueh.AT: 191185 Anzahl der Vorg.:  18
 Netzart : objektnetz              Geg.spaet.ET: 311287
 Datum   : 280286
1   BLNR                                                          BLNR     1
```

VORGANGSNUMMER	BEZEICHNUNG--------	-GFAT-	-FAT--	DAUER	-FET--	TERMINBESTIMMER
002	U-Waende -4.20	191185	191185	230	060786	
007	SBZ -4.20	020186	020186	155	050686	
003	Montage VT -4.20		270186	90	260486	002
008	SZ -4.20	010286	020286	120	010686	007
004	Korr.schutz VT -4.20		130386	30	110486	003
005	Dichtung -4.20		290486	90	270786	002
006	Ruecklage -4.20		170586	90	140886	005

Fig. 11: Modul TERMLI

BC-LEINET, however, came into being by order of the construction industry. Several industrial construction plants are already using it. Its application for seminars in "Design of Construction Processes" will start in April this year.