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Network planning of repetitive processes in housing construction industry

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Summary

The paper describes a special network planning technique for repetitive building processes, used in the "BAS" system.

For the practical users, the engineers in contractor firms, the input and output aspects of this system are most interesting. The emphasis is therefore put on these parts.

The network drawings and EDP-input with this technique are simplified by using several levels of subnetworks. Very often we will find repetitive processes in the housing construction industry, and therefore a subnetwork of a special type can be used several times. Such a subnet describes the structure of a process, and different sets of quantities and time estimates can refer to the same type of subnetwork. Since it is only necessary to define the content of the subnetworks once, the planner can consentrate in analyzing the cycles of work rather than drawing the same network structures a number of times.

The linkage between subnetworks is achieved by dependencies of special types, which are explained in detail in the paper.

The main output from the calculation is a type of GANTT-diagram. This "Bar chart" tells in a compact form the gangs who are planned to be working, the kind of jobs and their locations on the site, the calendar time the different jobs are going to be performed, and, lastly, the necessary number of workers occupied during the time span of the plan. The linkage between the networkdrawing and the output is established in the use of location codes and job descriptions.

The BAS-system approach

Over the last years there has been developed a network planning system at the Norwegian Building Research Institute.

The system is called the BAS system (Bygg- og Anleggsstyring), or CMS (Construction Management System). (The computations and resulting print-outs are done by EDP-programs. These are run on a UNIVAC 1108 (or 1107) computer).

Our clients are mostly small contractors (i.e. 150 - 250 employees). These firms have usually about 5 building projects running simultaneously. In addition to the contractors own labourers about 20 subcontractors are also working on a typical project. The main contractor is usually doing the planning and coordination jobs of both his own and the different subcontractors labour force.

These contractors cannot afford employing network exsperts, and it is of paramount importance that the network planning is easy to understand. The basis for a network plan must be presented in a surveyable way, and the resulting schedule must be easy readable by the foremen on the site.

When developing the BAS system the emphasis was put on several aspects of which the main ones are listed in the following.

a) Repetition of work cycles

A Housing construction project usually contains several repetitive processes or cycles, and the system should be able to take benefit from this fact.

b) Constant gangsizes

In Norway the firms are trying to employ their workers for long periods on the same building site. The system should therefore be able to achieve a resource allocation which would result in acceptable (i.e. small) variations in gangsizes over time and for all trades.

c) Splitting of activities

In practice a gang sometimes stops working on an activity for a time in order to perform a more critical activity.

Splitting of activities should therefore be allowed by the system.

d) Time estimates

The time estimates should be given in manhours for each activity, and the duration of an activity then depends on the number of men available at the time the activity is going to be done. Therefore, the activity duration should be calculated by the computer, and it should also be possible to specify the maximum number of men working on a specific activity.

e) Easy readable output

The foremen on the building sites are usually not theoretically educated people, so it is important that they, and not just the engineers, understand the resulting plan.

The output must therefore be surveyable and easy readable.

Illustration example

In order to show how the planning is done in practice by the BAS-system, we have chosen a housing project which is built near Bergen on the West Coast of Norway. The example, which consists of 48 flats, is only a part of the project, and the original network plan is simplified accordingly.

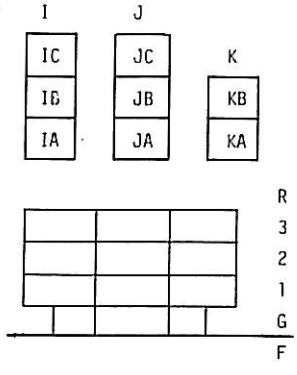
The example refer to three appartment buildings made of concrete. In each building there are laundry and small storage rooms on the groundfloor, and then flats in the other three storeys. Two of the buildings have three entrances, the third one has two.

Location codes

The BAS-system uses location codes for crossreferences between the network drawing, the EDP-printout and the different working locations on the site. Each such code is composed of two characters, see fig. 1.

In this project the first character is a reference to a specific building and the second one to a specific location in this building.

This: JA = Building 12, entrance A
K3 = Building 10,3 floor



I : Building 14
J : " 12
K : " 10
A,B,C: Entrance A, B, C
F : Foundation
G : Groundfloor
1,2,3: 1st, 2nd, 3rd floor
R : Roof

Fig. 1 Location codes

Manpower resources

The splitting of workers into gangs is an important part of the BAS planning procedure. Each gang is given a "name" of maximum 4 characters, see fig. 2.
E.g. ELEC - Electricians
CAR1 - Carpenters, gang no. 1

TYPE	Resource	No. of Men	TYPE	Resource	No. of Men
DOZE	Dozer team	2	ROFR	Roofers	2
LAB	Labourers	2	GLAZ	Glaziers	2
MONT	Mounting crew	3	MAS	Masons	5
CONF	Concr.foundation	6	CAR2	Carpenters, 2	8
TRAC	Tractors	3	TERZ	Terrazzo workers	2
PLUM	Plumbers	5	SMIT	Blacksmith	1
CONG	Concr.groundfloor	8	FLAY	Floor layers	3
ELEC	Electricians	3	PAIN	Painters	5
CONS	Concr.storeys	8	PAPE	Paper hangers	3
SMET	Sheet metal work	4	CLEN	Cleaners	2
CAR1	Carpenters, 1	6	INSP	Inspectors	1

Fig. 2 Resources

For every team a basic gangsize must be specified, and which is the usual number of men within a particular trade working on the site. It is also possible to specify a special gangsize for an activity, i.e. a maximum number of men allocated to work on that activity.

This special gangsize may be greater or less than the basic gangsize, and it overrules the basic gangsize.

Network model

A BAS network is constructed by using up to 5 levels of subnetworks, subnets. The lowest or innermost level of these subnets is called basic nets. The basic nets are built up of basic activities. Each such activity is the smallest division of work done in the planning. Only one gang of a particular resource can perform a basic activity.

All subnets have "names" of 4 alfa-numerical characters. The main network has always the name PROJ. The basic activities have no names, but instead they are referred to by the name of the resource type that will be doing the job.

The repetitive processes, which is typical for the housing industry, will most often result into equal structures of several subnets. This structure is defined (described) only once on the network drawing (and in the EDP-input). By using the same name, this process can be repeated without redefining nets. (There can be different amounts of work connected to subnets of the same type).

In the BAS system three types of dependencies are used:

1. Single predecessor arrow.

   This states that the successor cannot start until the predesessor is finished. This type of dependency is used to connect the activities (i.e. subnets or basic activities) in a subnet to the subnet's frame, and between activities on the same level in the network.

2. Compound predecessor arrow.

   This can only be used between identical types of subnets on the same level. This type of dependency states that a basic activity in the successor subnet cannot start until the corresponding basic activity in the predecessor subnet is finished.

3. Calendar date dependency.

   This states that an activity cannot start before a specified date.

Dependencies of type 1 or 2 might have associated a specific time with them, positive for a planned time gap and negative for an overlap.

Most of the dependencies are internal in a subnet, but there might also be used an "extraordinary dependency", i.e. an arrow that penetrates subnet frames. In fig. 3 the main network is constructed of 3 subnets regarding each of the

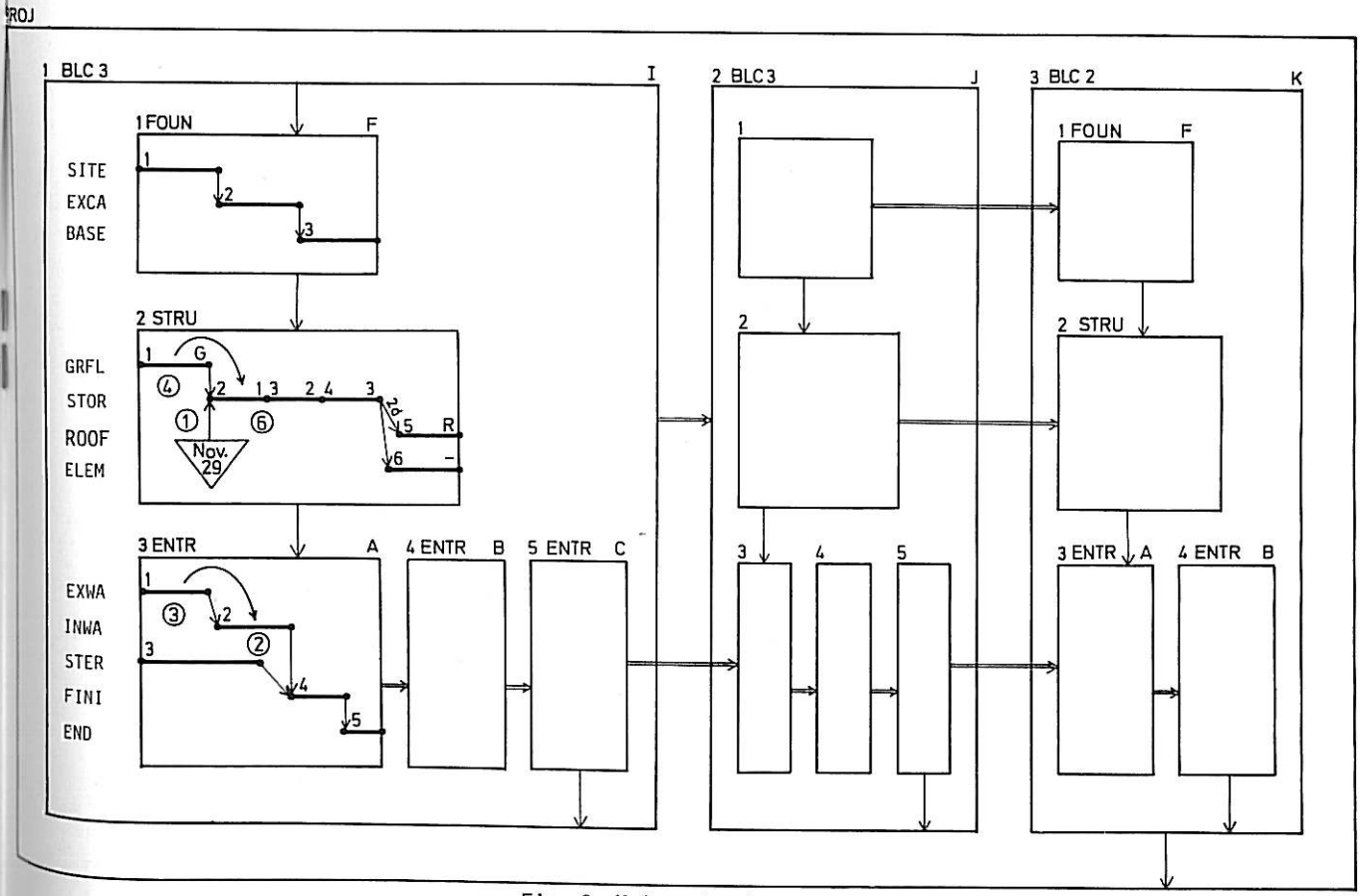


Fig. 3 Main network

buildings I, J and K. As earlier mentioned, building I and J are "identical" and the same subnet, BLC3, is composed of 3 types of subnets: FOUN for foundation works, STRU for structure above ground and ENTR for work connected with the entrances. As the process in each entrance has an identical structure, the same subnet is used for all entrances, i.e. three times.

Each of these three subnets is composed of basic nets.

Thus STRU contains the basic nets GRFL, STOR, ROOF and ELEM. Here STOR is describing the superstructure work for one storey. As the process is similar for 3 storeys, the basic net is used 3 times for onebuilding and 9 times altogether.

In order to have an easy way of reference, all the subnets are given a local number in the subnet (or main network) which they are a part of. Thus STRU is no 2 in BLC3 and ROOF is no 5 in STRU. These local numbers are placed to the left on the subnet frame on the drawing. To the right on the frames the location codes are placed, in order to have cross reference to the site. Thus the first BLC3 has location I, ROOF location R and the three subnets ENTR location A, B and C. In fig. 4A and B all the basic nets are defined. The basic net EXWA for external walls etc. contains 5 basic activities. As in other subnets, the basic activities in the basic net are given a local number placed to the left above the activity. Underneath no 1 there is put 27% -2, telling that 27% of the total work for the carpenters, CAR1, in EXWA is allocated to this basic activity, and that maximum 2 men may be doing this job. Activity 1 and 5 are start connected and no 4 and 5 are end connected to the subnet frame (type 1).

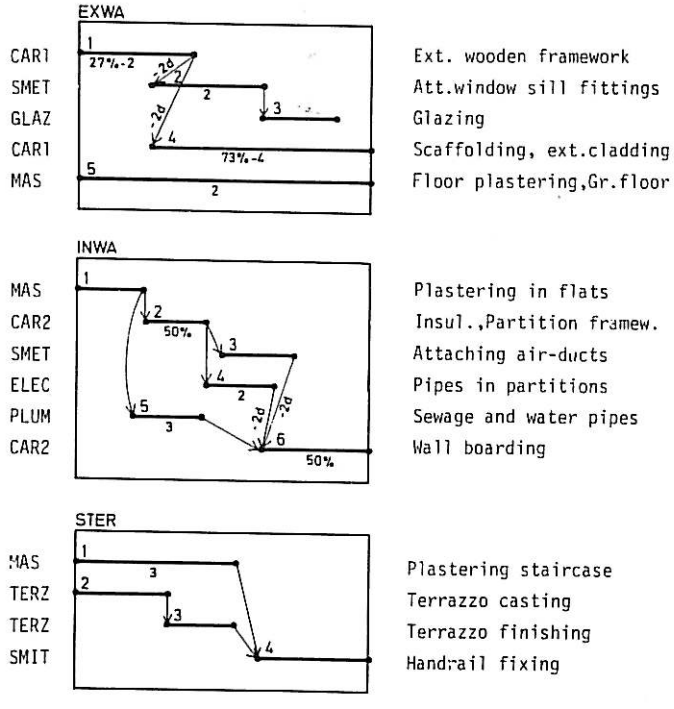


Fig. 4A Basic networks

Between no 1 and 2 there is an overlap of 2 days on a dependency type 1. Here the activities no 2 and 5 seem to be a loose end (i.e. not connected to other activities), but in specifying ENTR (fig. 3) there is an extraordinary dependency from no 3 in EXWA to no 2 in INWA and a connection is established. In fig. 3 there is a "double" arrow between the subnets ENTR for entrances A and B. The result of this compound predecessor arrow is that the carpenters, CAR1, may start erecting external wooden framework in entrance B immediately after having finished this work in entrance A.

In STRU, fig. 3, there is also specified a date dependency for the basic activity no 1 in STOR first floor in building I.

Time estimates

The time estimates are given in manhours of work and referred to resource (gang) and basic net. If the same resource performs more than one basic activity on a basic net, there must be a percent distribution within the net. In the basic net EXWA (fig.4A), 27% of the carpenter's work is allocated to basic activity no 1 and the rest 27% to no 4.

The amount of work may not be the same for all basic nets of a special type, and the BAS system therefore allows up to 9 different sets of time estimates to be associated to each basic net.

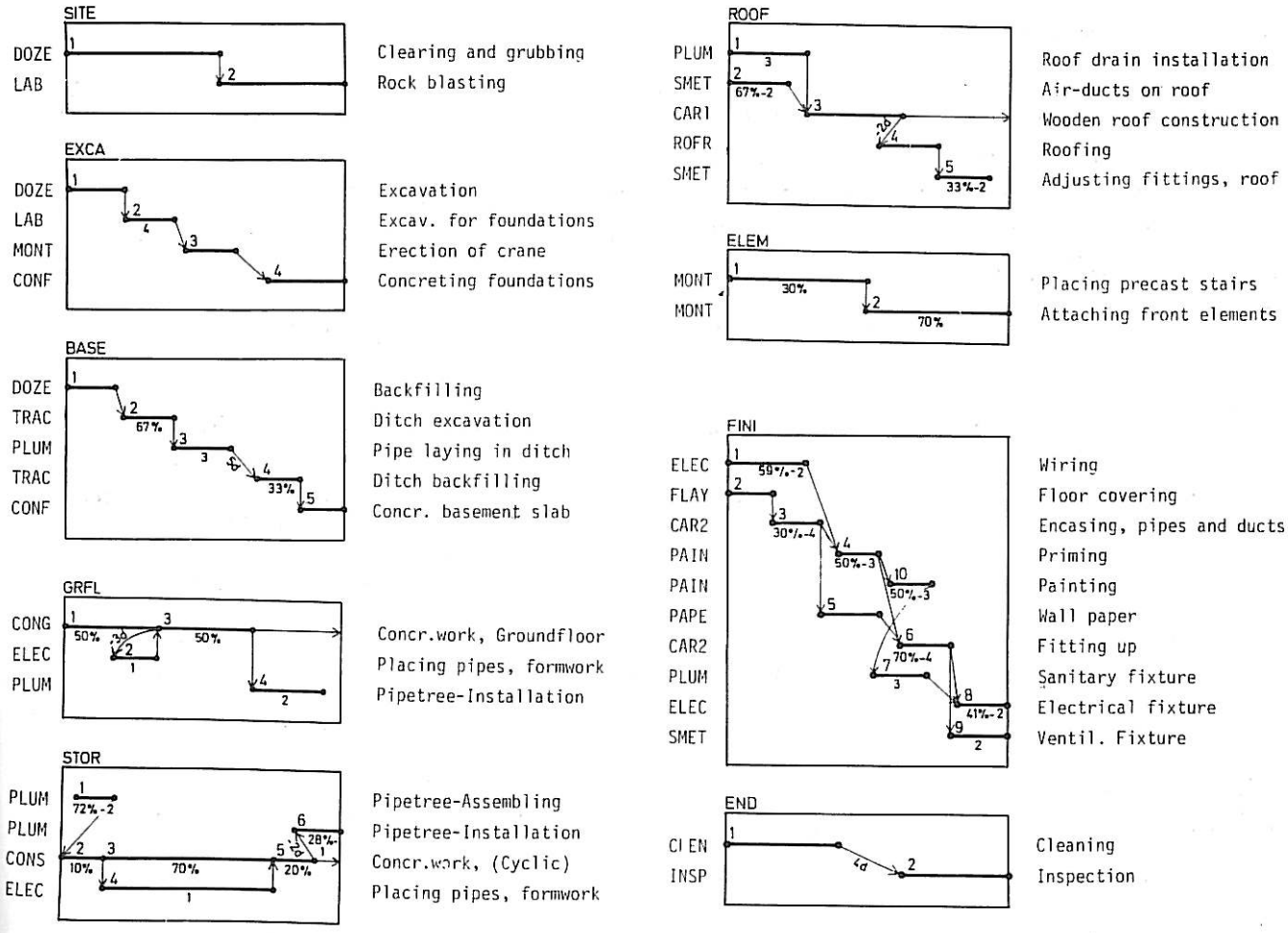


Fig. 4B Basic networks

Output

The main type of output from the EDP-program is shown in fig. 5 and is a cut from the complete resource allocation printout.

This "Bar chart" has much in common with the manual planning schedules used in Norway, and that is an advantage when introduced to the contractors.

On top of the plan there is a heading and a calendar with all Monday dates printed out. All Saturdays, Sundays and holydays are marked with a dot (.). These dot columns separate the weeks. At the left hand side the gangs are listed, e.g. Carpenters, 1, Roofers etc.

To the right of this text there is printed for every day the number of men planned to be working or rather the number of man-days done by the gang.

Under the resource line the different types of work to be done by the gang are listed . These texts correspond entirely with the describing texts for the basic activities, fig. 4A and B.

To the right of this job description there are location codes on the different dates when the activity is planned to be performed.

Thus the carpenters, gang no 1, is planned to be working on the roof of the first building (IR) until Jan. 24. Then erection of ext. wooden framework (see fig. 4A, basic net EXWA) in entrance A, building 14 (IA). On Jan. 28 this is finished and the similar work starts in entrance B (IB).

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NORGES BYGGFORSKNINGSINSTITUTT
BAS-SYSTEMET
R E S S U R S D I S P O N E R I N G
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PROSJEKT      : WESTHOME, FIELD B            PROSJEKT START      : SEPT, 13,,1971

OPPDRAGSGIVER: NORW,BUILD,RESEARCH-INST      OPPDRAGSGIVERS REF,: ILL, INTERNET 72

*****************************************************************************************************************************
                              JAN          JAN          JAN          FEB          FEB          FEB          FEB
                              17           24           31           7            14           21           28
*****************************************************************************************************************************
CONCR,GROUNDFLOOR    MANN    , 8 8 8 8 8 , , 8 8 4 0 0 , , 0 0 0 0 0 , , 0 0 0 0 0 , , 0 0 0 0 0 , , 0 0 0 0 0 , , 0 0 0 0 0
  CONCR,WORK ,GROUNDFLOOR    ,KGKGKGKGKG , ,KGKGKG      , ,          , ,          , ,          , ,          , ,

ELECTRICIANS         MANN    , 1 0 0 1 1 , , 1 1 0 0 0 , , 1 1 1 1 0 , , 0 0 1 2 3 , , 1 0 2 3 3 , , 3 1 1 3 3 , , 3 2 2 2 1
  PLACING PIPES, FORMWORK    ,KG  J2J2J2 , ,J2J2    J3 , ,J3J3J3J3  , ,  K1K1K1K1 , ,  K2K2      , ,K2K2  K3K3 , ,K3K3
  PIPES IN PARTITIONS        ,           , ,          , ,          , ,       IAIA , ,IA    IBIB , ,      ICIC , ,
  WIRING                     ,           , ,          , ,          , ,          , ,    IAIAIA , ,IAIAIBIB  , ,IBICICICIC
  ELECTRICAL FIXTURE         ,           , ,          , ,          , ,          , ,          , ,          , ,

CONCR,STOREYS        MANN    , 8 8 8 8 8 , , 8 8 8 8 8 , , 8 8 8 8 8 , , 8 8 8 8 8 , , 8 8 8 8 8 , , 3 5 8 8 8 , , 8 8 5 0 0
  CONCR,WORK,(CYCLIC)        ,J1J1J2J2J2 , ,J2J2J2J2J3 , ,J3J3J3J3J3 , ,J3K1K1K1K1 , ,K1K2K2K2K2 , ,K2K2K3K3K3 , ,K3K3K3
                             ,           , ,          , ,          , ,          , ,          , ,          , ,
SHEET METAL WORK,    MANN    , 0 0 0 0 0 , , 0 0 2 2 2 , , 2 2 2 1 2 , , 2 3 0 3 4 , , 4 3 0 3 4 , , 3 0 0 2 4 , , 4 2 2 2 3
  AIR-DUCTS ON ROOF          ,           , ,          , ,          , ,       JR , ,  JR        , ,          , ,          KR
  ATT,WINDOW SILL FITTINGS   ,           , ,    IAIAIA , ,IBIBIBIBIC , ,ICIC     , ,          , ,          , ,JAJAJAJBJB
  ATTACHING AIR-DUCTS        ,           , ,          , ,          , ,       IAIA , ,IAIA  IBIB , ,IB    ICIC , ,IC
  VENTIL, FIXTURE            ,           , ,          , ,          , ,          , ,          , ,          , ,
  ADJUSTING FITTINGS,ROOF    ,           , ,          , ,          , ,  IRIR      , ,          , ,          , ,

CARPENTERS,1         MANN    , 6 6 6 6 6 , , 3 2 6 6 6 , , 6 6 6 6 6 , , 6 4 4 4 4 , , 4 2 6 6 6 , , 6 6 6 2 4 , , 6 6 6 6 6
  WOODEN ROOF CONSTRUCTION   ,IRIRIRIRIR , ,IR        , ,          , ,          , ,    JRJRJR , ,JRJRJR    , ,
  EXT, WOODEN FRAMEWORK      ,           , ,IAIAIAIAIB , ,IBIBICICIC , ,IC       , ,          , ,      JAJA , ,JAJBJBJBJC
  SCAFFOLDING,EXT,CLADDING   ,           , ,    IAIAIA , ,IAIAIBIBIB , ,IBIBICICIC , ,ICIC      , ,       JA , ,JAJAJAJAJB

ROOFERS              MANN    , 0 0 0 2 2 , , 2 2 2 2 2 , , 2 2 2 2 2 , , 2 1 0 0 0 , , 0 0 0 0 0 , , 0 2 2 2 2 , , 2 2 2 2 2
  ROOFING                    ,     IRIR , ,IRIRIRIRIR , ,IRIRIRIRIR , ,IRIR       , ,          , ,  JRJRJRJR , ,JRJRJRJRJR

GLAZIERS             MANN    , 0 0 0 0 0 , , 0 0 0 0 0 , , 1 2 2 1 2 , , 2 0 2 2 1 , , 0 0 0 0 0 , , 0 0 0 0 0 , , 0 0 0 0 2
  GLAZING                    ,           , ,          , ,IAIAIAIBIB , ,IB  ICICIC , ,          , ,          , ,       JAJA

MASONS               MANN    , 0 0 0 0 0 , , 5 5 5 5 5 , , 5 4 5 5 5 , , 5 1 5 5 5 , , 2 2 5 5 5 , , 0 0 0 5 5 , , 5 5 5 5 5
  FLOORPLASTERING,GR,FLOOR   ,           , ,IAIAIBIBIC , ,ICIC      , ,          , ,          , ,       JAJA , ,JBJBJCJC
  PLASTERING IN FLATS        ,           , ,          , ,    IAIAIA , ,IA  IBIBIB , ,IBICICICIC , ,          , ,          JA
  PLASTERING STAIRCASE       ,           , ,IAIAIBIBIB , ,ICICIC    , ,ICIC      , ,          , ,       JAJA , ,JBJBJBJC
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Fig. 5 Bar chart" printout

The bar chart may be printed out for a period of about one year. The EDP-sheets sheets are then cut and glued together to a complete schedule. This is then reduced by Xerox to a linear scale of about 70% on a transparent paper. Using this reduced copy one can easy get the necessary number of copies for all parts which are involved in the project.

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