THE AUTOMATION OF PROJECT RESOURCE SCHEDULING USING SITE LAYOUT MAPPING

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ABSTRACT

This paper describes the implementation of and experience with a construction scheduling procedure incorporating knowledge based techniques. The system works from a site layout drawing and whilst the process can be operated almost 'automatically' experience so far indicates that it is necessary to be able to use the system in its 'manual' mode as a decision support tool for project planners.

INTRODUCTION

Resource scheduling has theoretically been a weapon in the armoury of the construction project planner for a long time. It has been investigated extensively and these investigations have been reviewed in many learned articles. (refs 2,3,5). The techniques developed split into two main types: those based on mathematical programming and those based on heuristic methods. The mathematical ones require an enormous amount of computer power in order to process even modest projects and therefore the heuristic methods are the only ones that have made any real progress into practice.

All the project resource scheduling techniques available commercially in the United Kingdom are based on a project being modelled in terms of a network of some form. Whilst this is suitable for many projects it is not always the ideal choice and indeed in some situations it is not at all practical. Furthermore, the methods, whilst aiming to give 'better than average' schedules have very little basis in reality and disregard many important factors which influence construction costs and hence plans.

Work on one such factor, site layout, has lead to the development of a non-network based model which can be used for construction scheduling. The basis of this model was described by Mawdesley and Sirajuddin (1,4) and incorporates not only site layout but also several knowledge bases allowing individual users to tailor the system to their own methods and requirements.

The construction site to be scheduled is divided into a number of equal sized rectangular vertical prisms the horizontal dimensions of which represent the smallest size of a resource (usually taken as 0.5m). The finished work in each prism is input from a CAD or similar package. The system then uses three knowledge bases and inference engines to determine what work must actually be carried out in order to produce the finished work in each prism and also the order in which that work must be carried out. The ability of the system to achieve this has been tested and reported (1). This paper concentrates on the methods used to produce a schedule from this information.

The work has been carried out on a 4Mbyte Atari computer using the GEM operating system and using Prospero Pro-Pascal. Several small knowledge bases are used. They are all rule based and the inference engines all use a form of forward chaining. Standard shells were considered but not used because of the amount of other programming which was necessary and the particular interfaces which were required.

The paper is divided into sections describing the operation of resources, the resource model, the actual scheduling procedure and its reports and an example of its use on a small project. A discussion on the practicality of the work and future directions is included at the end.

OPERATION OF RESOURCES

The ability of any scheduler to produce realistic schedules will be limited by its ability to model the operation of a resource. In this system, a resource is modelled as a complex entity which in addition to the productivity attributes normally used in scheduling also has features which describe its size and manoeuvrability. In particular, each resource has the following characteristics which must be provided by the planner, see figure 1 :

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                         RESOURCE EDITING FORM
WORK TO BE SCHEDULED (START,END ELV.) : EXCV_WORK(000.00,-60.00)
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
RESOURCE CODE : EXCV1        TOTAL AVAILABLE : 03       TOTAL USED : 01
                           CURRENT AVAILABLE : 02      TO BE USED : 01
TITLE : CATERPILLAR EXCAVATOR - MODEL 225________________
WORK TYPE 1   : SLOP_EXCV  OUTPUT 1 : 80.00__  MATERIAL 1 : SOIL______
WORK TYPE 2   : EXCV_WORK  OUTPUT 2 : 120.00_  MATERIAL 2 : SOIL______
WORK TYPE 3   : GNRL_EXCV  OUTPUT 3 : 100.00_  MATERIAL 3 : SOIL______
WORK TYPE 4   : ----_----  OUTPUT 4 : 0000.00  MATERIAL 4 : ----------
RESOURCE DIM. IN CM (L,W,H)                 = 0000,0000,0000
MANOEUVRE AREA DIM. IN CM (L,W,H)           = 0000,0000,0000
SAFETY BUFFER DISTANCE IN CM                = 0000
OPTIMUM WORKING AREA DIM. IN CM (L,W,H)     = 0000,0000,0000
RESOURCE COST PER DAY                       = 0000.00
WORKING SHAPE 1 : ----------             WORKING SHAPE 2 : ----------

[ DELETE ]  [ SAVE ]  [ CLEAR ]  [ EXIT ]
[ DISPLAY PREVIOUS ]  [ DISPLAY NEXT ]  [ USE THIS RESOURCE ]
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FIGURE 1: A dialogue form showing the resource data needed for the scheduling operation

Resource Code: A five character code which is used throughout the program operations to recognise the resource.

Total and current available resource: This is the total number of the resource available when the project starts and the total resource at the beginning of each scheduling cycle. This may be set to a very large number to produce a 'fastest time' schedule.

Total used and to be used resource: The total used is the difference between the total available and the current available. "To be used" resource is a user defined number of gangs that he want to use in a particular scheduling cycle.

Title: The resource description. As an example, a resource for erecting formwork may be defined at this field as a "two carpenter and one foreman gang".

Work type: A 9 character word describing the work which the resource can execute. One resource is allowed to work on up to four different types of work.

Output:: The production rate of the resource on the work type being considered.

Resource area: The area occupied by the resource. Some resources such as cranes occupy definite areas and are usually placed adjacent to the area on which they are working. The size of the area which the resource occupies can be defined in this field. Other resources such as labour gangs often work within the area on which the type of work actually exists. In this case, the resource area can be defined as on grid square.

Manoeuvre area: The area needed for the resource to turn a round.
Safety buffer area: Resources often require some area around the actual working area to act as a safety buffer between them and other work. The size of this buffer can be defined in this field.

Optimum working area: Resources working on one type of work can work at different amounts of that work at one time but the productivity of the resource may be affected by the size of the task being undertaken. This field allows the user to specify the working area that gives the most efficient production of the resource on the particular work type.

Resource Cost: The cost of the resource per unit time.

Working shape: The shape of the work which a resource can undertake most efficiently may vary. This field allows the user to suggest the best shape of working area for a resource.

When resources are used in the scheduling process described below, the following items are considered:

1. The Resource Pools: A resource pool is the supply of resources which are idle and available for allocation to tasks. In this model, two resource pools exist in every project. One is located off the project site and the other on the project site. The "ON SITE" resource pool starts empty, and whenever a resource finishes work it stays in this pool before it moves to the "OFF SITE" pool. The amount of time that a resource is allowed to stay in this pool without being used is a matter for the planner and it will affect the cost of the project since resources in this pool will be paid for by the site whilst those in the "OFF SITE" pool will not. In the initial model, a resource is moved to the "OFF SITE" pool after one cycle in the "ON SITE" pool. This will result in a less resource congested site. When work is to be scheduled, the program first checks the "ON SITE" pool and then the "OFF SITE" pool.

2. The Spatial Concept of a Resource in Operation: The volume needed by each resource is taken into account throughout the scheduling process. This is recognised in two forms:

   i) The volume occupied by the physical part of the resource and the manoeuvres volume required.
   ii) A buffer volume is added to the above volume to represent a safety zone for resource operation.

   A resource volume cannot overlap any other resource volume or its safety buffer volume, but two safety buffer zones can overlap each other since no resources occupy this volume permanently.

3. The Resource Optimum Working Area: Any resource must have a minimum and a maximum work area in which it can operate. For example, one does not use a scraper to excavate a one meter square nor a labourer with a shovel for the major excavation of a road project. The optimum area lies somewhere between these impractical limits and is to some extent a matter of experience rather than fact. The choice of optimum working area will affect the amount of work tackled at one time and will therefore determine the durations of the scheduling cycles; it will also determine the amount of 'overlap' allowed between consecutive activities.

4. Checking Performed on the Resource and the Safety Buffer: When an area of the project is assigned to be scheduled, resource pools are scanned for a resource that can carry out this particular type of work. In the manual scheduler, the user will choose the resource to be used from those displayed by the program. Several checks are done before the resource is displayed to the user:

   4.1 The ON SITE resource pool followed by the OFF SITE resource pool will be checked for availability of resources to do this type of work.

   4.2 The area of work is checked with the optimum working area that the resource can operate on.

   4.3 The safety buffer area of the resource is checked so that no other resource or work in progress violates it. This safety buffer is applied both to the resource and to the area of work since the resource may be positioned in the work area or adjacent to it.

   4.4 The resource and safety buffer area is checked to ensure that it falls within the site.

   If any of the above checks fail, the user will be given a chance to re-select or re-position the resource in the site or to define a new safety buffer in place of the one defined by the resource.

SCHEDULING PROCEDURE

As described in the Introduction, the scheduling procedure is based on the pencil model described by Sirajuddin and Mawdesley (1). The process generates the work required over all the site and can be represented in several forms. An example of the work generated and contained in one pencil is shown in figure 2.

By considering all the grid squares together, the system can recognise what work is available for scheduling at any time on all parts of the site. An example of such a view of the 'instantaneous work available' is shown in figure 3.

At this stage the scheduling procedure is required to select a resource and an area of work for it to do OR to select an area of work and a resource to do it. These two methods might be considered to model different approaches to project planning and may give different schedules. At present only the latter technique is implemented in the 'Manual' scheduler the steps of which are described here:

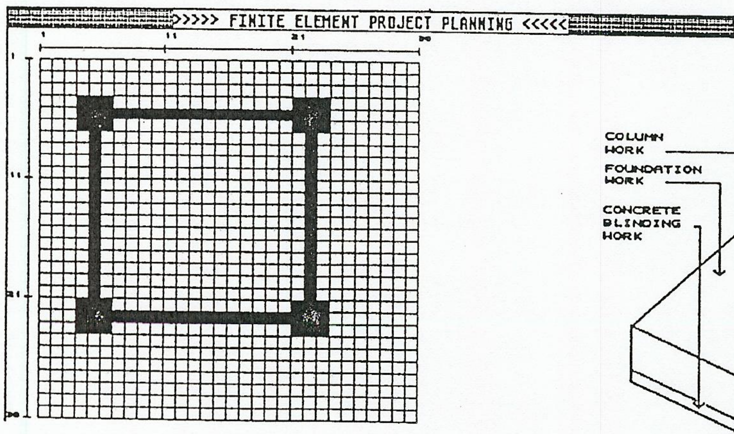
1. The user highlights a group of pencils which represents a work area that he wants to schedule. Two possible situations exist:

   CASE 1 All pencils have one type of work

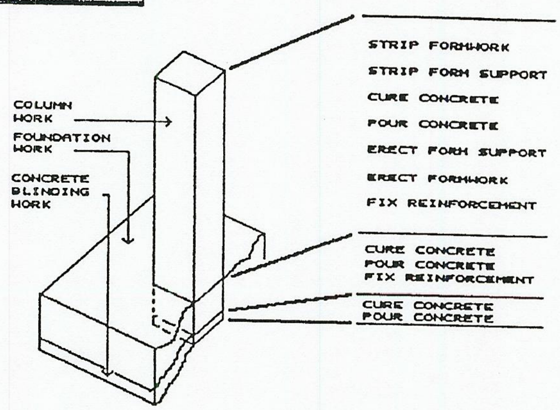
   CASE 2 More than one type of work exists in the pencils. In this case, the work types must be related to each other and be able to be executed by same resource type (an example of this might be excavation work and slope excavation work).

The user can schedule more than one work area to start at one time. Each work area is saved in a different list which will be called CYCLE.

The checking in point 4.1 and 4.2 will be performed at this stage.



The Site



Original and Extra work

FIGURE 2: An example of a simple site showing a grid and the automatically generated extra work.

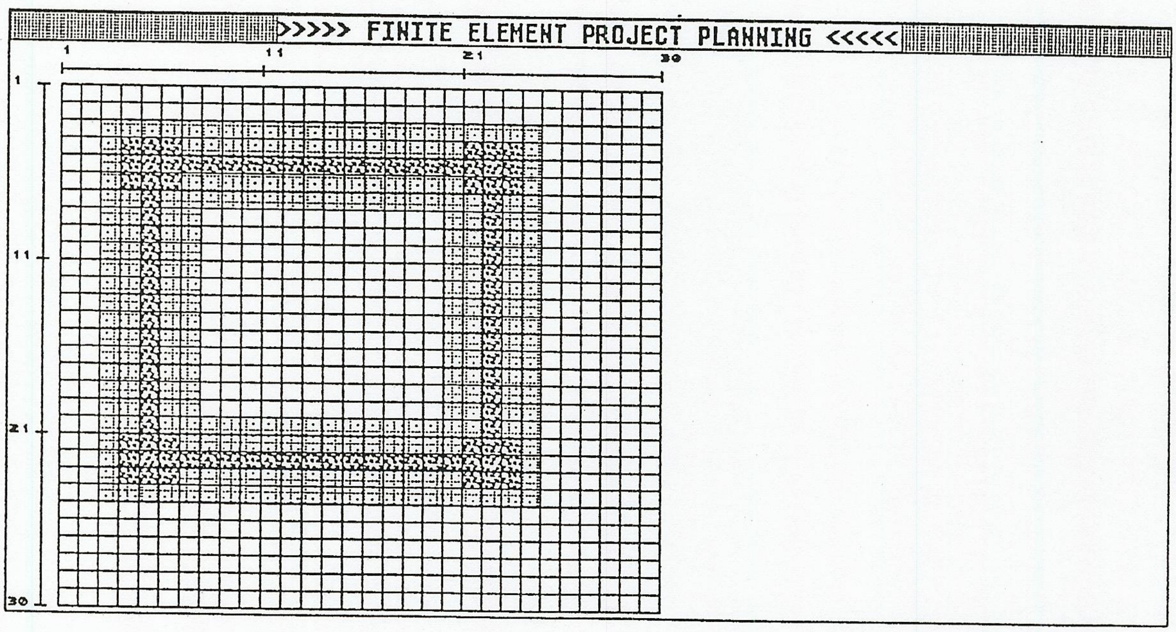


FIGURE 3: A computer generate plan of the site showing the positions of particular work types (here Reinforcement and Scaffolding).

2. All the resources that can operate in the work type in the CYCLE are displayed to the user (step 2 to 5 are repeated for each CYCLE). If CASE 2 is followed in grouping the pencils in step 1, the program will learn from a knowledge base if the different work type can be constructed together and if so, the CYCLE will be given a general work type code which will be embedded in the rule. A sample of such rule is given below:

IF	slop _ excv
OR	excv _ work
OR	excv _ fill
THEN	gnrl _ excv.

Several of the work types in the condition part can exist in any CYCLE and will be replaced by the work type in the conclusion part.

This formation will give the user a powerful tool by which he can follow a MICRO scheduling operation (to schedule just one type of work at a time) or a MACRO scheduling operation. The user will pick the resource and the number of gangs that he wants using the form shown earlier in Figure 1.

3. Using the manoeuvre area dimension in Figure 1 and the grid size of the project site the program will display a sketch of the pencils that the resource need to occupy and ask the user to position the resource in the site as shown in figure 4. Checking point 4.3 and 4.4 are done at this stage.

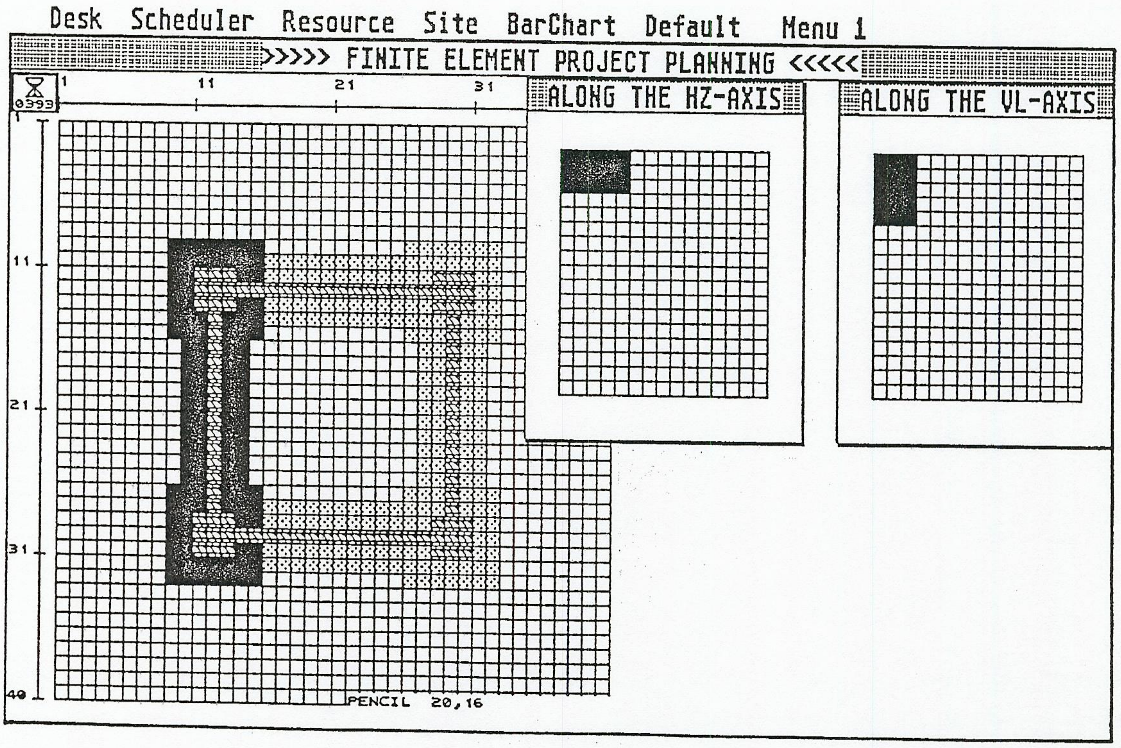


FIGURE 4: Resource allocation tool showing work to be done and resources ready to be positioned

4. The estimation model will calculate the volume of the work from the grouped pencils and estimate the start time, end time, and the cost needed to do the work.. A clock that shows the time in the project is constantly displayed to the user. This clock is used to set the start time and end time of each CYCLE.

5. Each CYCLE is saved in a list called IN PROGRESS WORK until all the CYCLES of this round is finished. The list is organised in order of end time of the work.

6. The program will take the first work in the IN PROGRESS WORK list and schedule it. The duration left of this work will be added to the clock of the project which will represent the time of the project.

7. At this point, the user will be able to schedule another work area by going back to step 1.

If the user did not schedule any other work, he may ask the program to 'fire' another area of work from the IN PROGRESS LIST until the list is exhausted. Every time an area of work is fired, the resource will be freed and added to the ON SITE resource pool in which it can be used in next CYCLE. The project site will be updated at the end of each scheduling phase. The next work in the pencils that has been scheduled will be displayed on the screen for the user to highlight until all works in the pencils are scheduled.

At any time during the process, the user can decide to 'undo' one or more steps of the schedule to improve plan.

SCHEDULING REPORTS

The results of the scheduling procedure are presented in terms of barcharts, two types of which have been developed.

1. Work Type Barchart: This demonstrates the sequence of operations throughout project life as shown in Figure 5.
2. Resource Type Barchart: This displays the usage of each resource in the life of the project as shown in Figure 6.

Each of these charts is available at any time throughout the progress of the scheduling allowing the user to make informed decisions on future steps in the process.

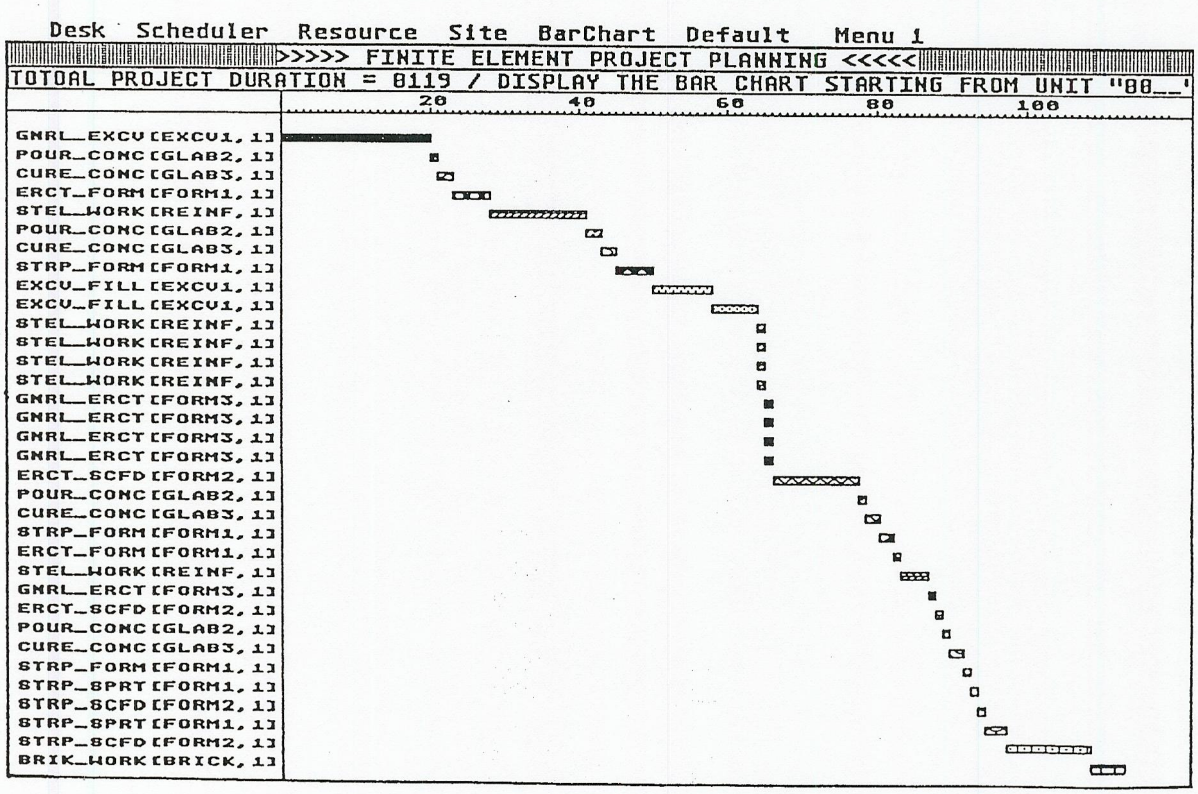


FIGURE 5: Activity barchart.

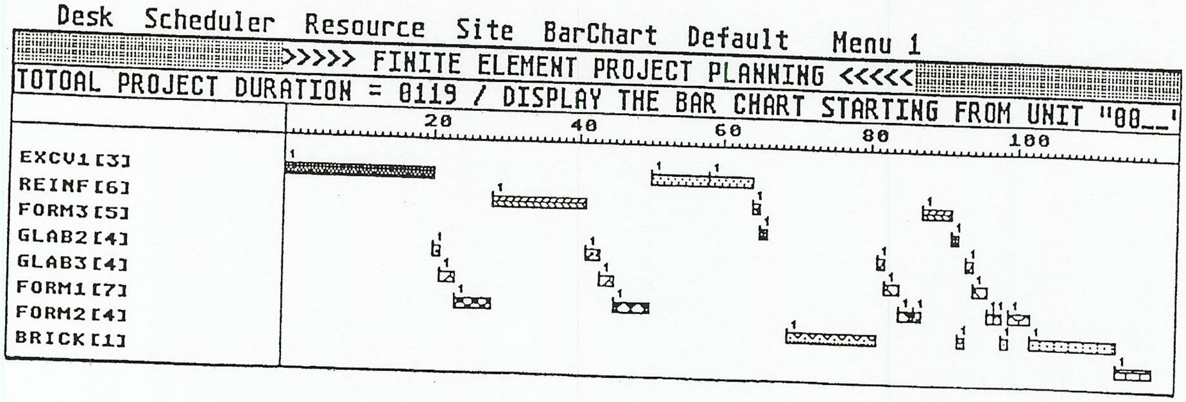


FIGURE 6: Resource utilization barchart

EXAMPLE RESULTS

The 'goodness' of any schedule is very difficult to determine and is a topic of some research in Artificial Intelligence. Figures 5 and 6 illustrate the results of the process applied to the project shown in figure 2. It can be seen that the process results in a feasible solution although, as with many plans, the efficiency of the result might be questioned.

CONCLUSIONS AND FUTURE WORK

It has been shown that the scheduling method can be used to assist project planners to produce feasible schedules. However, there is considerable work to be done to produce a totally automated scheduler which would take into account such features as site access, and temporary site layout. In order to achieve these aims, much greater computer power will be required and it is felt that there may be a possibility for the use of parallel processing in this area.

REFERENCES

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