# SITE LAYOUT AND RESOURCE SCHEDULING - AN APPROACH TO MODELLING MOVEMENT AROUND SITES

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## ABSTRACT

This paper describes the results of experiments carried out in order to model the movement of resources round a construction site. The model developed takes into account the accessess provided, the layout of the facilities on the site, the shape of the structural elements and the shape and size of the resources. The results show that it is possible and practical to produce such a model and to use it for planning even complex projects.

## INTRODUCTION

Several researchers are investigating the use of Artificial Intelligence techniques in project planning. For the main part, there is a concentration of the development of tools to aid in the implementation of existing planning and scheduling models. For example, Hendrickson et al (1) in their paper presented at the Fourth International Symposium on Robotics and Artificial Intelligence in Building Construction described the **Contruction Planex** system which produce project networks and Levitt and Kunz (2) described the **Platform** system for supporting Project Management using the traditional techniques of networks, barcharts and resource profiles in conjunction with Expert Systems.

Both these papers described methods which are very important because of their underlying use of familiar techniques which are widely accepted.

However, whilst these approaches offer immediate usefulness and the prospect of solving some of the more common problems encountered when using the techniques, by their very nature they are not designed to cope with planning problems for which networks are not the ideal tool. Several authors (for example, Arditi (3), Peer (4), Jaafare (5) have described problems with the applying the methods and other authors (for example Birrell (6)) have postulated more resource based scheduling methods in which the flow of resources through the work on site is the dominant factor in producing a plan of work.

These latter methods appear in many cases to model reality better than do the traditional techniques because they are more able to offer continuity of use to the resources. They do not however take into account the site layout, structure shape and geography in any way and therefore would require considerable alteration for use in a more mechanised environment in which shape and layout are important.

**Construction Planex** tackles this problem to some extent by defining the location and geometry of structural elements and producing the project network with reference to these. This solution appears well suited to projects such as buildings where there is a close relationship between structural element and activity. In other projects where perhaps networks are not the ideal planning tool, the technique appears harder to apply.

Kim et al (7) in their paper describe **SITEPLAN** a system designed to help locate temporary construction facilities. This appears to take into account not only the spatial arrangement of the site but also the temporal nature of the layout.

This paper describes another automated construction planning method which takes into account site layout as well as the nature of the work being done and the order in which it must be completed. After a brief description of the technique, results of experiments with the system are presented and areas where more work is required are discussed.

## THE METHOD

The method developed is based on that first described by Morgan (8) and Mawdesley et al (9). It can be summarised in steps:

1. The construction site is divided into grid squares in the same way as described by Au and Parti (10) in their scheduling game. Each grid square contains a pencil of finished work.

2. Expert systems are used to generate the detailed work necessary to construct the finished work in the pencil. At this stage, it is recognised for example, that formwork is required for concrete work.

3. The work in each pencil is formed into the order in which it must be done.This is equivalent to forming a network for the individual pencils of work. In earlier work was described as an algorithmic procedure but more recently areas have been recognised in which this construction logic can only be generated using Expert System techniques.

4. Resources are assigned to groups of grid squares to carry out the work. This is the scheduling routine. It requires some method of grouping together grid squares or elements to form activities.

The ability of the method to produce good schedules depends on its ability to select groups of elements for a resource to work on. In order to do this in a practical manner, the system requires knowledge of

- the structural element shapes
- the shape and size of the area required by the resource in order to work
- the productivity of a resource on any area

- the ability of the resource to move around site

THE EXPERIMENTS

The method has been tested extensively to determine its ability to mode reality. The performance is illustrated by means of a simple site and various resource types.

THE RESOURCES

The required resource shapes are

- A line
- A block

The line shape is that which might be adopted by a resource moving on a face work operation such as excavation for roadworks or for a structure such as steel frame building where the structural elements are linear.

The block shape models structural elements such as foundations and insitu concrete floors and resources such as cranes which are able to service large areas.

Any other required shape can be obtained however, these have been found sufficient to model many situations.

THE SITE

The site used for illustration of movement has a single work type over its whole area. The resources used can all do this work, have an optimum size of 9 elements and require a one element space around the actual working area to provide working space. All these parameters can be varied for different sites and resources.

THE RESULTS

Typical results of experiments run are shown in figs 1 to 6 and table 1.

In the figures, the symbols have the following meaning:

| | |
|---|---|
| s | Some work to be done |
| 1,2 | The numbers of the resources actually working |
| W | Space required by the resource but not actually being worked on. |
| . | A grid square where no work is to be done |

It can be seen from figs 1, 2, 3 and 4 that in large unrestricted sites both block and resource shapes can be modelled very effectively. Table 1 shows a comparison between the actual and intended shapes, using second moment of area as a measure. The correspondence between the two is excellent.

On more restricted sites however, the actual shapes obtained are rather different from intended as is shown in fig. 6.1 to 6.3 and table 1. This difference occurs because the model overrides the resource shape in order to give an optimum resource work area in terms of size.

Figures 5.1 to 5.3 show another situation in which the resources do not always adopt the desired shape. In this situation, the resource given access at the left can attain the correct shape immediately whilst the one with access at the right only achieves the correct shape after completing enough work to develop a workface. Because of the rectangular nature of this site, there will also be some work done with the resource in the wrong shape. The model does however maintain the correct work area wherever possible.

This tendency to adopt size rather than shape in all circumstances requires alteration. However, at present it is proving difficult to formulate a rule base which will give shape priority in some situations and size priority in others. It is thought that the recognition of this requires considerable study of actual resource working.

Movement of the resources around site is illustrated in all the figures. The accesses were given as the corners of the site. It can be seen that, given a starting place the resources can move around unrestricted sites in an efficient manner. When the sites are restricted either in size or shape or have resources working in close proximity to one another then movements can be difficult. This corresponds well with reality when restricted working can cause inefficient resource movement.

Figure 5 shows a particular problem where giving a resource access at one corner enabled it to adopt its optimum shape and orientation immediately shilst access at another corner required considerable work to be done before its desired orientation and shape were achieved.

Interference between resources is illustrated in figs 2.1 to 2.3 and 4.1 to 4.3. Here, two resources were given the same access to the site. The model produced a situation where the resources interfered with each others progress and 'leap-frogged' over each other.

## CONCLUSION AND THE FUTURE

It has been demonstrated that it is possible to model the movement of resources around site and incorporate it into a schedule. Work is continuing to improve the method and the rule base. It is envisaged that the actual movement of the resource will eventually be governed by a complex rule base similar to that used at present and incorporating:

- Physical attributes of the resource such as its ability to move and the size of work area required.

- The nature and positions of the accesses provided around the site.

- The nature of the site for travelling.

- The size and shape of the structural elements

As indicated above, problems exist in balancing these and recognising situations in which each becomes dominant. Work is in progress to overcome this.

The other major problem area is in computer power required. The accuracy of the model depends on the fineness of the grid. As the grid is made finer, the accuracy of modelling increases but the computer power required for processing also increases. Work is being done to determine the 'best' grid size

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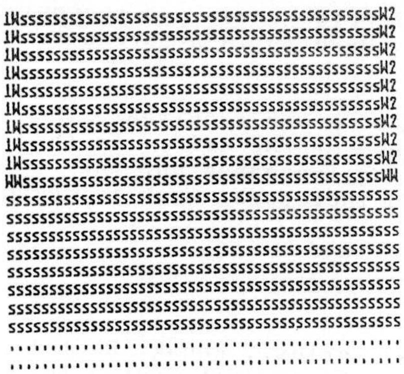

fig 1.1

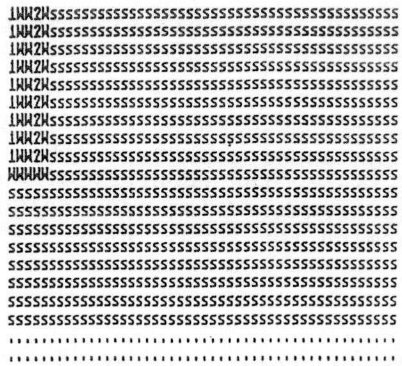

fig 2.1

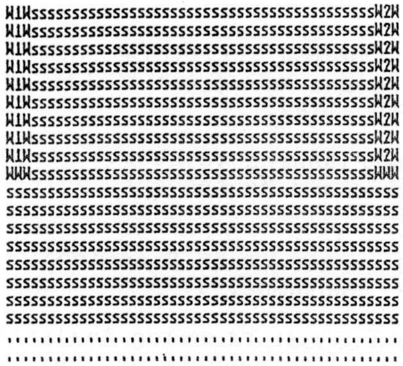

fig 1.2

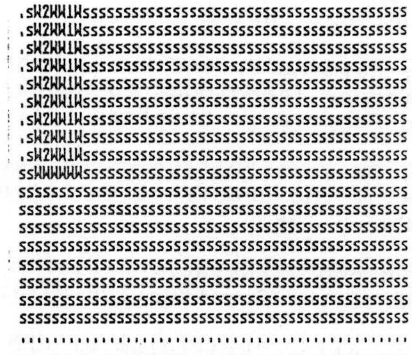

fig 2.2

fig 1.3

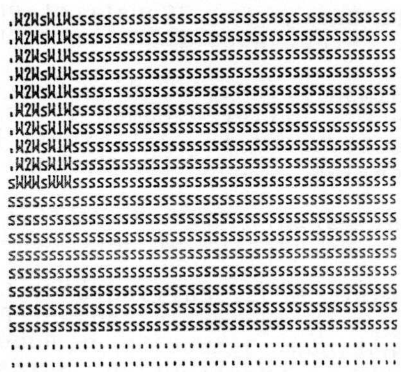

fig 2.3

figures showing movement of resources

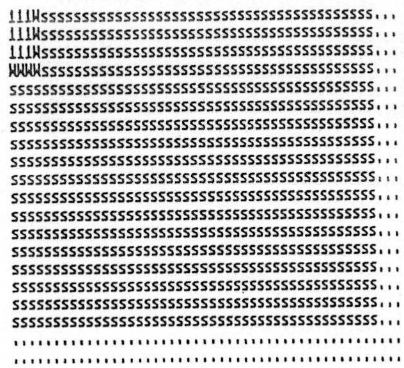

fig 3.1

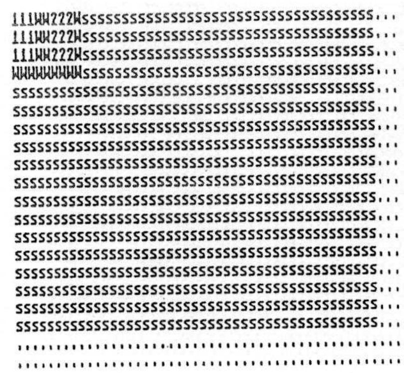

fig 4.1

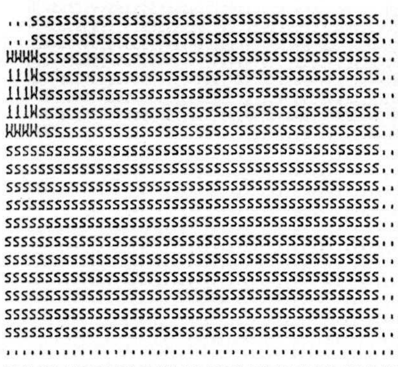

fig 3.2

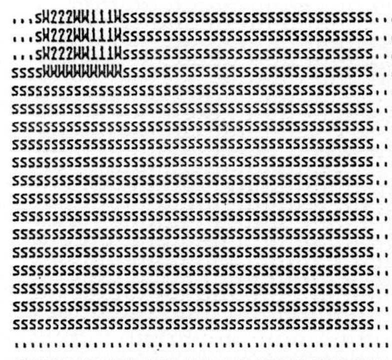

fig 4.2

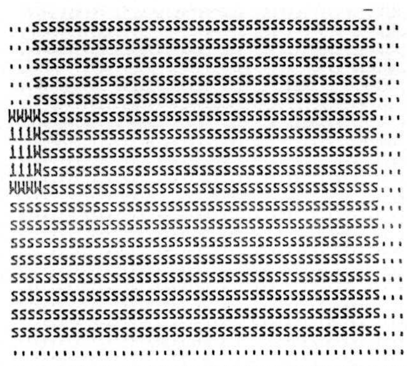

fig 3.3

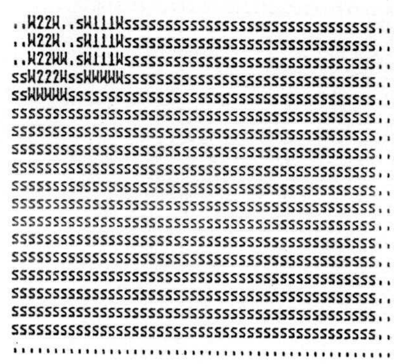

fig 4.3

figures showing movement of resources

fig 5.1

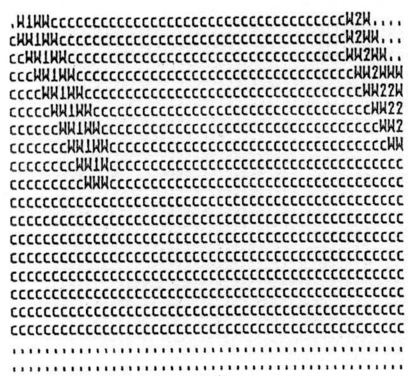

fig 5.2

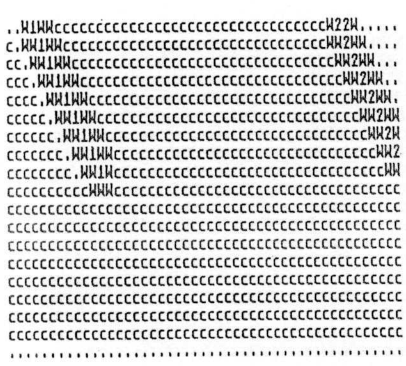

fig 5.3

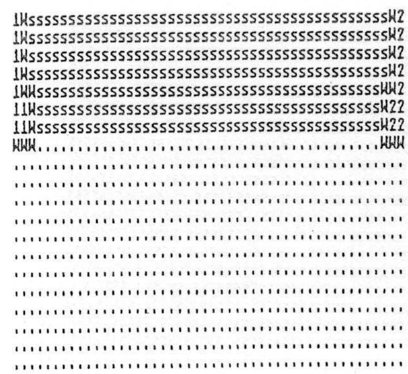

fig 6.1

fig 6.2

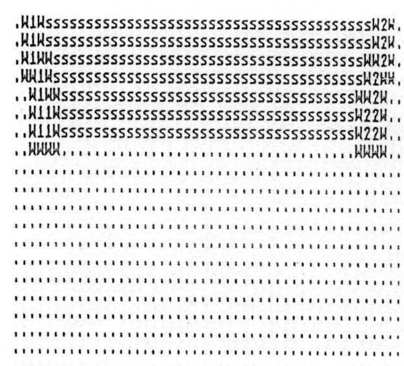

fig 6.3

figures showing movement of resources

| Experiment Number | Resource Number | Size: Desired | Size: Mean Actual | Size: s.d. Actual | Size: Desired/Actual | Second Moment of Area XX: Desired | Second Moment of Area XX: Mean Actual | Second Moment of Area XX: s.d Actual | Second Moment of Area XX: Desired/Actual | Second Moment of Area YY: Desired | Second Moment of Area YY: Mean Actual | Second Moment of Area YY: s.d. Actual | Second Moment of Area YY: Desired/Actual | Travel: Mean | Travel: s.d. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 9 | 9.082 | 0.566 | 0.991 | 0 | 0.148 | 1.022 | - | 60 | 61.730 | 11.986 | 0.972 | 1.667 | 3.328 |
| | 2 | 9 | 9.109 | 0.729 | 0.988 | 0 | 0.076 | 0.510 | - | 60 | 59.913 | 0.583 | 1.001 | 1.667 | 3.328 |
| 2 | 1 | 9 | 9.000 | 0.000 | 1.000 | 0 | 0.000 | 0.000 | 0.000 | 60 | 60.000 | 0.000 | 1.000 | 2.688 | 2.575 |
| | 2 | 9 | 9.000 | 0.000 | 1.000 | 0 | 0.000 | 0.000 | 0.000 | 60 | 60.000 | 0.000 | 1.000 | 2.688 | 2.575 |
| 3 | 1 | 9 | 9.101 | 0.451 | 0.989 | 6 | 8.030 | 3.115 | 0.747 | 6 | 6.505 | 1.821 | 0.922 | 3.019 | 0.265 |
| 4 | 1 | 9 | 9.109 | 0.598 | 0.988 | 6 | 7.852 | 3.974 | 0.764 | 6 | 8.062 | 4.976 | 0.744 | 4.307 | 3.060 |
| | 2 | 9 | 9.310 | 1.185 | 0.967 | 6 | 8.052 | 6.865 | 0.745 | 6 | 8.463 | 5.286 | 0.709 | 4.307 | 3.060 |
| 5 | 1 | 9 | 9.167 | 0.687 | 0.982 | 60 | 43.100 | 11.173 | 1.392 | 60 | 33.360 | 6.615 | 1.799 | 2.296 | 4.204 |
| | | 9 | 9.500 | 2.062 | 0.947 | 60 | 33.127 | 14.615 | 1.811 | 60 | 34.037 | 9.367 | 1.763 | 2.296 | 4.204 |
| 6 | 1 | 9 | 9.150 | 0.477 | 0.984 | 0 | 30.393 | 19.706 | - | 60 | 31.721 | 10.927 | 1.891 | 1.211 | 0.521 |
| | | 9 | 9.000 | 0.000 | 1.000 | 0 | 30.902 | 21.171 | - | 60 | 32.523 | 7.586 | 1.845 | 1.211 | 0.521 |

Key to experiment Numbers

1. Two resources, desired shape vertical line, different accesses, unrestricted site
2. Two resources, desired shape vertical line, same access, unrestricted site
3. One resource, desired shape block, unrestricted site
4. Two resources, desired shape block, same accesses, unrestricted site
5. Two resources, desired shape inclined line, different accesses, unrestricted site
6. Two resources, desired shape vertical line, different accesses, restricted site

Table 1 Results of Experiments