Int. J. Engng Ed. Vol. 21, No. 6, pp. 1195–1202, 2005
Printed in Great Britain.

0949-149X/91 $3.00+0.00

The Use of a Simulation Model as a Game for Teaching Management of Projects in Construction*

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Project control is an essential task of management of construction projects and good planning and control have long been recognised as having beneficial effects on the success of a project. However the efficacy of control techniques that are widely taught in management courses is almost impossible to prove. It is also very difficult on a theoretical basis to help students to understand the effects of their decisions and thereby enable them to learn the mixture of science and art which is project control. The use of management games for teaching in construction has the advantage of enabling participants to be put into complex, realistic project situations without incurring the financial and time penalties which would accrue if real projects were used. This paper describes a simulation model of an earthmoving project, which is used as a management game, to provide players with experience in the management and control of construction projects. The model contains many of the aspects of a real project including planning, decision-making, uncertainty, environmental effects, finance and a realistic physical model of the project and resource operation. The paper draws conclusions both on its effectiveness for control and on its use for teaching and learning.

INTRODUCTION

PROJECT PLANNING and control are two of the essential tasks of project management. Good planning and control have long been recognised as having beneficial effects on the success of a project. Poor planning and control, on the other hand, have also been recognised as major contributors to the poor performance of projects. Not surprisingly therefore, most, if not all, undergraduate courses in project management, contain elements of planning and control. Most medium and large sized organisations invest large amounts of money, time and effort, training their professionals in planning and control. Whilst this training is more practical than the theoretical approach adopted in most undergraduate programmes, the techniques used are usually traditional.

The effectiveness of the techniques taught in these courses is, at best, difficult to prove. Some work has been done to determine and illustrate the differences between different control mechanisms (see for example [1]) and several authors have developed new planning methods and criticised others (see for example [2]). However, such work is based on theories rather than practice and none of it takes into account all of the aspects of a project and the inherent complexity brought about by their interaction.

In addition to the difficulty of assessing the effectiveness of planning and control, assessing the effectiveness and efficiency of a method of teaching them is problematical. People learn through a variety of mechanisms and what is viewed as good by one person for one topic may be viewed as being less good by another person or by the same person on a different topic. Some will like to learn by studying theories while others will like to learn by example and practice.

Games are not new to civil engineering education and training. In the UK, Loughborough University has, for many years, run a national game, see [3], for graduate members of the Institution of Civil Engineers which allows them to take the role of company managers bidding for work in a competitive environment and carrying out the work that they win in order to make the company successful. A competitive element is included in

* Accepted 17 February 2005.

this because the teams play against each other to make the greatest profit for their company. The winning team is awarded a prize and considerable publicity in the professional press.

Another game which illustrates the use of the technology in an industrial rather than an academic environment is the Arousal game developed at Reading [4]. In this the players are assigned to various roles within a construction company such as a managing director, a contract manager or a marketing manager. The players are asked to take managerial decision following a group discussion period that represents three months. Each decision is fed into the computer which processes their effect on the company data supplies.

This paper describes an attempt to provide a mechanism for people to learn about planning and control of a project by experiencing them. It uses a simulation of a construction project which participants can plan and control with some degree of reality but without the inordinate cost implied by learning on a real project. The simulation model is described and experience with it is discussed. Student feedback on certain aspects is provided.

THE SIMULATION/GAME

The idea of using a computer simulation or management game to help students learn about complex issues is not new. Gilgeous and D'Cruz [5] describe games stretching back over many years. The use of management games for teaching and learning about project planning and control is also not new and was described by Scott and Cullingford [6]. Further, Au and Parti [7] described the use of a game using a project with a significant amount of earthmoving as a basis. Not all games have to be complex and computer based and Tommelein *et al.* [8] describe one which can be run either manually or on a computer to illustrate the interaction of parties on a project. More recently, the Internet has featured with games as part of the learning environment [9].

Despite all these developments, games are still little used in the real world, perhaps because of their inability to capture the attention of people brought up with computer games as a major form of entertainment.

Whilst not competing with the leisure games, this game combines the experience of players and traditional teachers and engineers to provide a user interface and style of play that is both interesting and informative.

The detailed objectives of the game are:

- To provide a 'realistic' model of a construction project which will react in physical and financial terms to the decisions made and actions taken by the player.
- To provide reports as might be expected on a real project.
- To include uncertainty but to control it in such a manner as not to hide the effects of control actions.
- To be suitable for use by both undergraduates and practicing engineers.

The user interface

The game is written in Pascal and was developed in the Borland Delphi IDE. The interface was designed to make use of the computer power and to develop and maintain the players' motivation and to present the players with reports which might be expected on a real project.

The project

The game is based on a project to construct a rock-fill dam with a clay core. The finished dam is 30 m high and 300 m wide at the top. Figure 1 shows a general arrangement of the site. It indicates some of the features to be considered by the player including the design and maintenance of temporary haul roads; the environmental impact of the work (including working close to a Site of Special Scientific Interest); and the effect of the work on neighbours. This is in addition to the normal planning and control considerations present on an isolated site.

The player's tasks

The player takes the part of the contractor's project manager and is responsible for the planning, resource selection and use, the control and the reporting to the company management.

Planning is required for both the physical and financial aspects of the project. It must be carried out and the project plan input to the computer before work can start on the actual construction. The plan can be amended at any time but the system remembers all plans and reports against the agreed one.

Resources are required to excavate, transport and place the rock and clay and to maintain the haul roads. A typical screen for the choice of plant is shown in figure 2. Basic information on the equipment is provided on this screen but it is usually insufficient to make effective decisions. To aid the player and to increase the verisimilitude of the game various resources are provided. These include:

- Links to web sites of equipment companies such as Komatsu and Caterpillar.
- Links to web sites of contracting organisations.
- Links to notes and PowerPoint presentations on equipment selection and use.
- Links to notes on the operation and use of teams of equipment.

Management resources are also required and have to be selected by the player. For example, the number of engineers to supervise the rock excavation, transport and placing must be considered together with the amount of money to be spent on training them in the quality, safety and environmental matters.

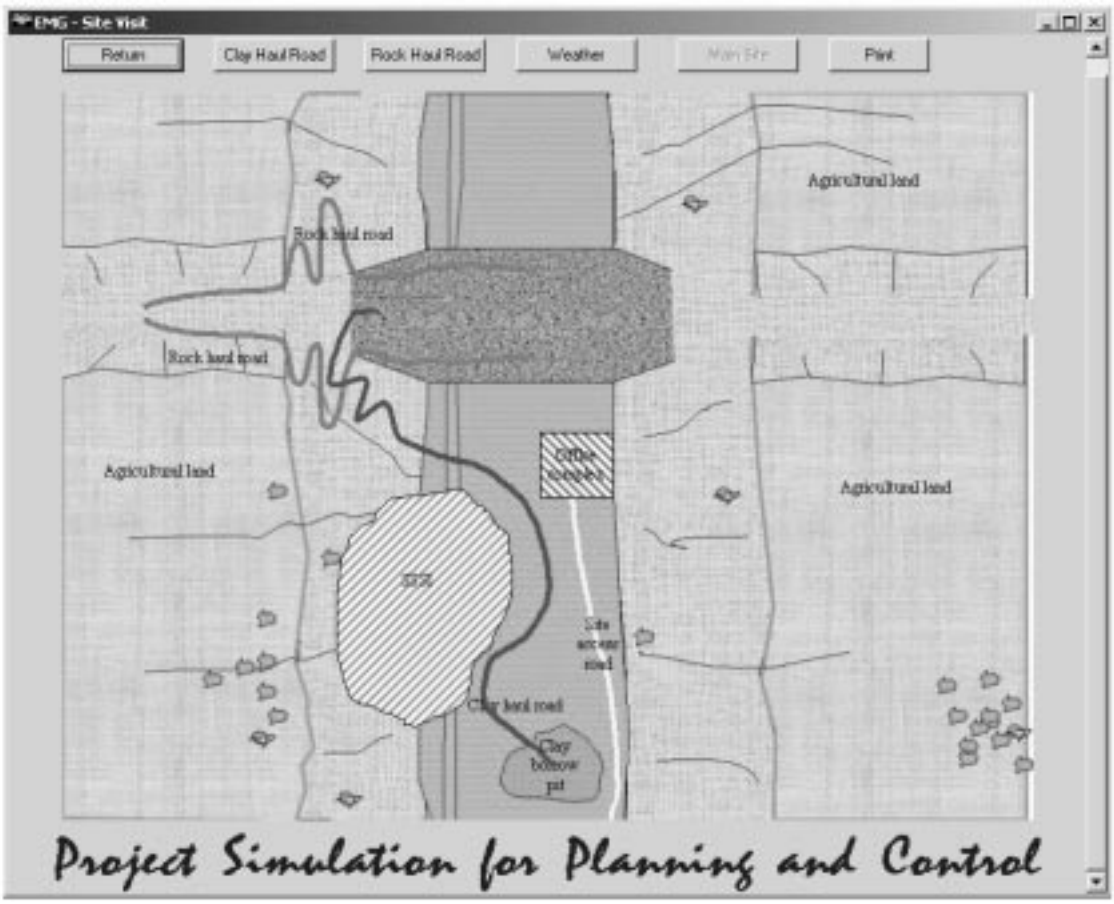

Fig. 1. General arrangement of the site.

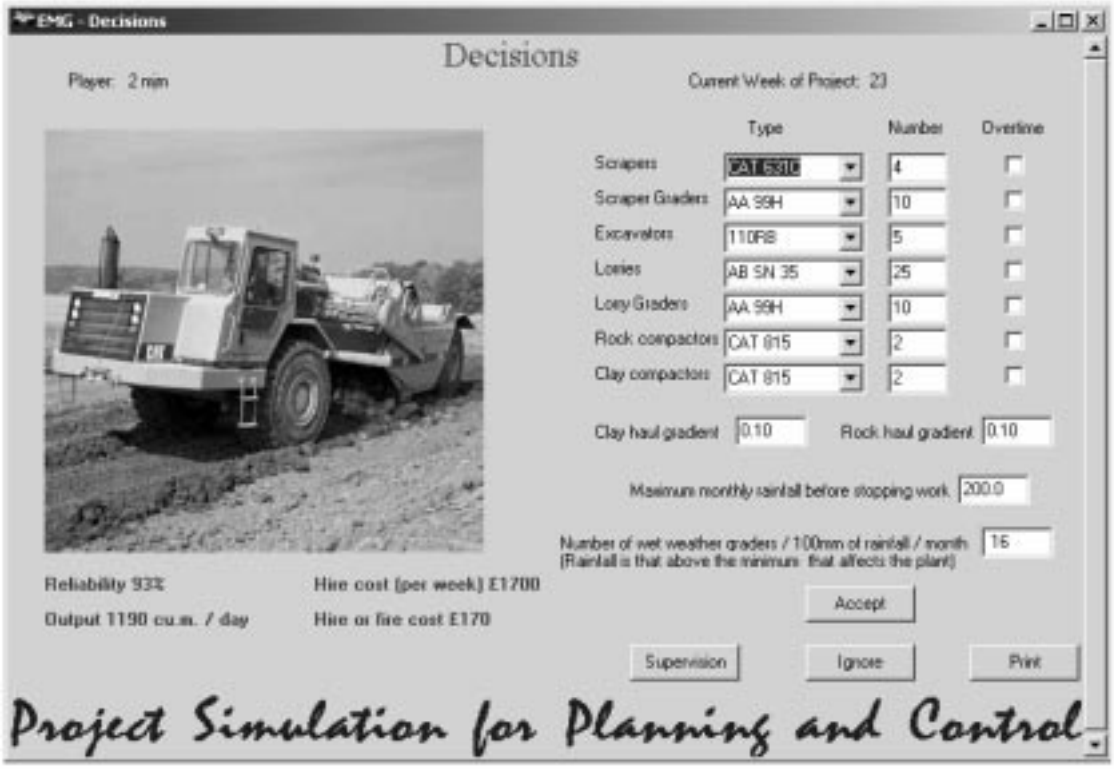

Fig. 2. A typical decision screen.

Fig. 3. A typical text report screen.

Reports

The player receives reports from the game in many formats as would happen on a real project. There are some aspects which would be picked up from meetings and mail. These are reported as text and are illustrated in Fig. 3. It can be seen that these refer to a large range of aspects including work quality, environmental impact, training issues and problems with progress. This type of information would be obtained from many sources in reality and would depend on the staff and reporting mechanisms on the project. In the game, the amount of this material also depends to some extent on the staff and its training.

The more formal control information can also be provided by the system although its availability depends directly on the staff employed. If few staff are employed, few reports will be produced or can be viewed. The information is available in numerical form or it can be produced as several forms of graph. Figure 4 shows a graph of performance variance during construction.

All the most common control charts are available from the system and players can chose which they want to use to help them make decisions.

EXPERIENCE WITH THE GAME

The game has been run as part of undergraduate courses. It has also been used by a contracting company as part of its graduate recruitment and selection procedure.

Undergraduate course

This was part of a normally lecture-based course. Participants worked in small groups (2, 3 or 4). Groups were both necessary, because of the large number in the class, and beneficial because they encouraged discussion and peer learning.

Before starting work on the project, each group was required to produce a programme of work, a financial plan and a proposed control method. These had to be presented to the main company board.

In every case, it was observed that the students were optimistic in their view of the project. The plans showed that the plant would work at optimum output, there would be no effect of team working, the plant fleets would always be balanced, no uncertain events would happen and control would hardly be necessary. Students were prepared to defend their view of the project even when questioned. They had analysed the data provided and were convinced that they had the 'correct' solution.

The agreed plan was input to the system before work on the dam commenced. Each group was then able to 'run the game' (or work on their own project) independently but had to report to the group board as agreed at the briefing.

The game monitored progress against this plan and attempted to make suggestions as to the need to re-plan. If re-planning were done, the system monitored against both the original plan and the most up-to-date plan available.

Participants very quickly realised the optimism

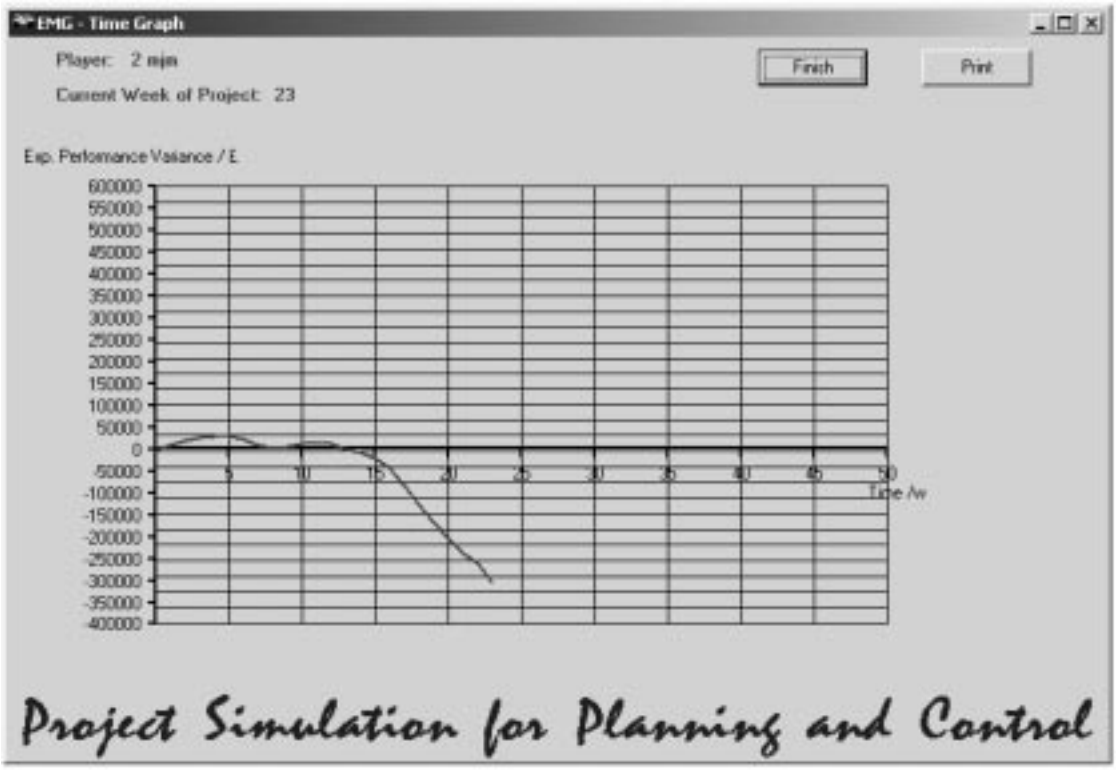

Fig. 4. A typical variance graph.

of their original plan and took some form of control action. In almost all cases, this involved trying to build the plan at the planned rate and ignoring all other aspects (finance, quality, safety and the environment).

At the end of the project, each group was asked to report to the management board of the company to explain its performance. This ensured that the students thought carefully about their decisions.

Student feedback was also sought through a questionnaire. The responses to one specific question are provided in Table 1.

The main points reported by the students include:

- The difference between theory and practice
- The importance of obtaining realistic rather than optimistic data
- The importance of control
- The need for planning and control even when faced with an uncertain world

One student/group commented on the possibility of learning from mistakes. This arose because they realised that the information that was generated by the game showed, for example, how the productivity was affected when the wrong amount of money was spent on training. Such an analysis enabled the group to determine the relative importance of the various factors affecting the project.

It can also be seen that some students are beginning to realise the importance of risk management.

Company recruitment

Recruitment of high quality civil engineering graduates has been difficult for a number of years in the UK. Many companies have realised that they are competing for the best people with organisations from other industries as well as with those with a construction base.

One major 'construction to services' company used the game as part of its recruitment process. It invited students interested in joining them to attend a course run one evening per week over four weeks. The course consisted partly of lectures and partly of the game. The lectures were on topics which the company thought were important to their operation and included decision making, risk management, team building, communication and project planning and control. All the lectures were given by senior people from the company and were illustrated using their own real projects and features from the game.

The participant were observed at all stages of the game from their team building through the decision making and planning to the completion of the project. When the project was finished, all groups were asked to present their project to senior company personnel.

The company were very pleased with the game especially in the way that it demonstrated the complexity of real projects and the need to consider so many apparently unrelated topics in order to manage it. They commented on how well it enabled them to observe the behaviour of the participants in a near-realistic environment.

Table 1. Students' comments

What if anything did you learn from the game, which could not have been learned more easily from traditional lectures? Please give reasons for your statement.
• Theory and practice are very different. Need good memory.
• You see the results of your decisions very quickly after you make them. Instead of talking, it is doing.
• The plant suppliers use very optimistic output rates for their machinery.
• My capability to plan and react to the real time actions. The fact that theory isn't always the same as practice.
• It is always better to learn from practical situations rather than just to hear someone talking about it.
• Practical learning situations are more effective. This game shows that nothing can be planned and controlled exactly.
• The control part. Especially unexpected events.
• Making an initial plan and finding out it has to be changed.
• You can plan in detail but in reality it is always different.
• You shouldn't trust the manufacturer information on machine production. Decision making in actual life is more than good planning.
• The original planning is never the best planning, because it is not known what the factors like the plant performance are in real life.
• You can't always trust the numbers given by a manufacturer of trucks (example) and other information.
• I don't trust manufacturers (actual performance very low).
• The interaction between many variables; and how to react to changes etc.
• Risks involved in projects especially information by manufactures, which you are learning by your own mistakes during the project. Mistakes are 'useful'.
• The numbers given by the manufacturers are not reliable.
• Seeing things go wrong much more than you'd expect. Being able to respond to situations.
• I learned about the difference between theory and practice.

The participants enjoyed the experience and found it rewarding not only because many were offered employment but also because the company offered a first prize of £400 and a second prize of £100! (The choice of prize winners was made by the company and not based solely on the amount of profit made.)

EFFECTIVENESS OF CONTROL AND LEARNING

The use of a game to teach management can be justified on many levels but it is important to attempt to assess its effectiveness. To this end, the game produces a summary measure of the performance of the player throughout the game and the results of this are presented below.

The summary measure

In addition to the normal project control parameters, the system produces a summary measure which is a linear arithmetic combination of the following factors:

- Current expenditure—planned expenditure.
- Current income—planned income.
- Current balance—planned balance.
- Current clay height—planned clay height.
- Current rock height—planned rock height.

The lower the value of the summary measure the better the player is performing relative to the plan. A score of 50 would be considered excellent and a score of 500 would be poor.

Participant performance

Eleven groups of 3 players were monitored during their playing of the game and the values of the summary measure which they achieved was recorded. The average result of the groups over time is shown in Fig. 5.

Several points can be made from these results. Firstly, the game is made particularly easy at the start as the weather is set to have little uncertainty and consequently has a minimal effect on the progress of the work. This is reflected in the general reduction in the summary score over the first few weeks of the project. Players can use this initial period to understand the effects of control actions.

As the game progresses, the uncertainties inherent in the game increase. This is caused by many factors such as the equipment affecting the haul roads, the effects of the initial safety, quality and environmental training, and the weather changing as a different period of year is reached. At this stage, all players experienced a considerable amount of difficulty controlling their project to plan as can be seen by the marked increase in summary measure.

However, players generally learned how to control the situation and the summary measure decreased in most cases. By the end of the project, the work could be considered to be in control although all were some considerable distance from their planned position. (The increase in measure towards the end of the project is caused by some groups going over their allowed duration and incurring liquidated damages costs)

Although this graph indicates a general improvement, the performance of the individual groups is not so clear. This is shown in Fig. 6.

In this figure, the performance of individual groups relative to their own maximum summary figure is shown. Once again, the smaller the value, the better the performance. From this it can be seen that some groups performed much better than others. The worst groups were still achieving

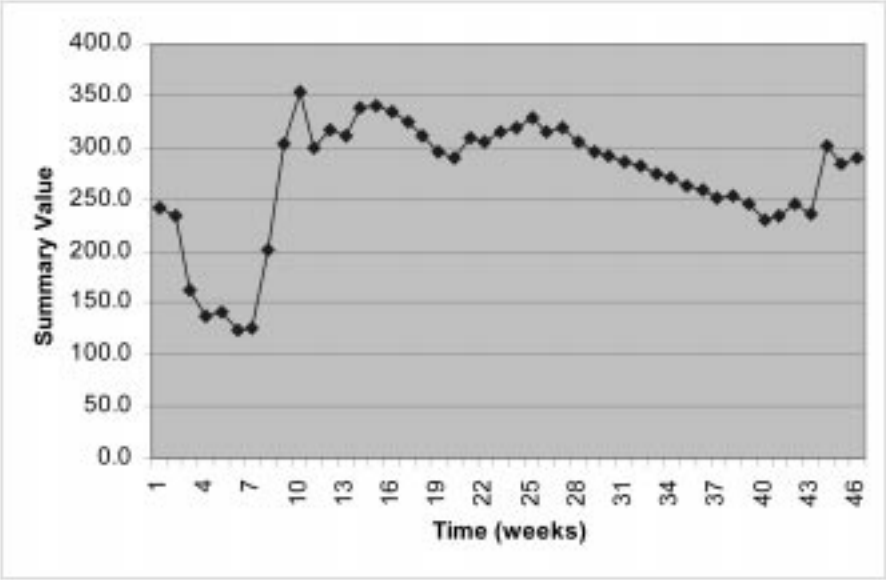

Fig. 5. Average performance of groups.

summary measure values near their maximum 75% of the way through the project indicating that they were having great difficulty controlling their performance. This is also apparent in the shallow gradient of the line. The best groups, by contrast, were able to improve their performance consistently throughout the last half of the project.

CONCLUSIONS

The paper has described a game which has been produced to help with the teaching and learning of project planning and control. It has also described some of the experience gained from its operation.

Students commented on how the game gave them an insight into the reality of projects which theories did not allow.

Industry commented on the realism and how it enabled players to develop and show skills which could not be lectured.

The attempts at measuring the performance of the players provide some evidence of the learning effects of the game although more experiments are necessary to determine whether or not these are really achieved.

The game is based on a single dam-construction civil engineering project. Another game is under development based on the building industry and allowing players to experience the benefits and drawbacks of employing subcontractors rather than permanent employees.

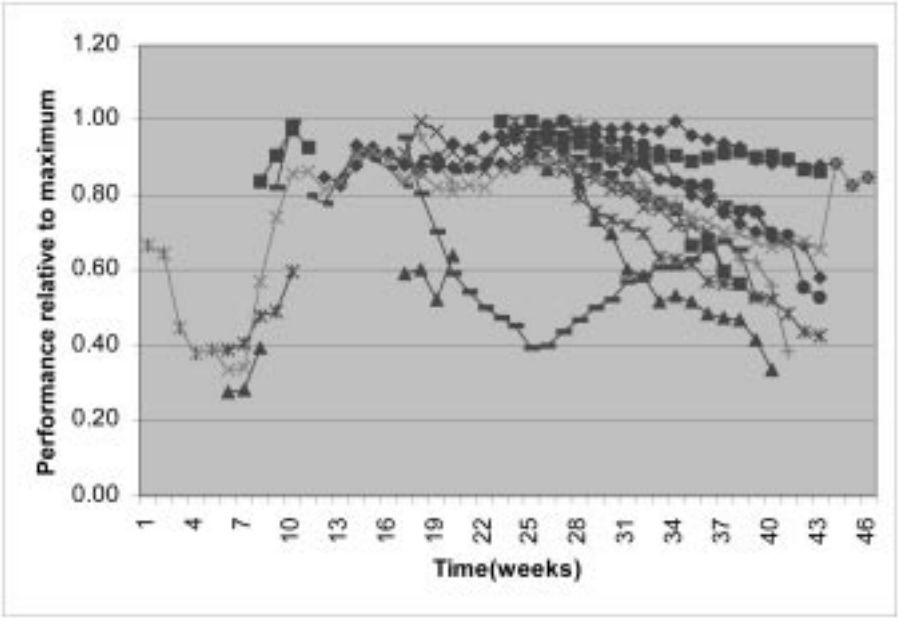

Fig. 6. Performance of groups relative to their own worst measure value.

REFERENCES

1. S. H. Al-Jibouri and M. J. Mawdesley, Two cost control models and their effectiveness for controlling construction projects, *Proc. XVth Int. Cost Engineering Conf.*, Rotterdam, April 1998.
2. Karim and Adeli, Object-oriented information model for construction project management, *J. Construction Engineering and Management*, ASCE, **125**(5) 1999, pp. 361–367.
3. R. McCaffer, T. Thorpe, Merit—The manual for a computer management game, Research Report, Balfour Beatty, 1988.
4. P. Lansley, Arousal: A model to match reality, *J. European Industrial Training*, **6**(6), 1982.
5. V. Gileous and M. D. Çruz, A study of business and management games, *Management Development Review*, **9**(1), 1996, pp. 32–40.
6. D. Scott and G. Cullingford, Scheduling games for construction industry training, *J. Construction Division*, **99**, CO6, 1973, pp. 81–92.
7. T. Au, E. Parti Building construction game—general description, *J. Construction Division*, ASCE, **95**, CO1, 1969, pp. 1–9.
8. Tommelein, Riley and Howell, Parade game: impact of work flow variability on trade performance, *J. Construction Engineering and Management*, ASCE, 1999, pp 304–310.
9. Sawney, Mund and Koczenasz , Internet-based interactive construction management learning system, *J. Construction Education*, **6**(3), (2001), pp 124–138.

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