THE UTILISATION OF IT FOR MANAGING GROUND INFORMATION AND OPTIMISING EARTHWORKS

Paula McMahon[1], Nashwan N Dawood and Brian Hobbs

School of Science and Technology, University of Teesside, Borough Road, Middlesbrough, TS1 3BA, UK

Ground information describes any data that details existing or proposed site conditions regarding the ground surface or that beneath it. It can be obtained from the site survey, site investigation or the site design. Managing the design of the ground profile can be very complicated as there are many options available, many of these options will be designed with an aim to optimise the earthwork quantities. The volume of earthworks can lead to very substantial cost implications.

The research undertaken to date has involved development of a system specification, conducting a general software survey and detailed analysis on several software systems. A scoring system was used to evaluate the commercial systems. Industrial interviews were used as a basis to develop the system specification.

This research proposes to develop a prototype for an integrated ground modelling system called *InSite*. This system will aid the construction team when managing ground data by allowing all information to be better organised and automate certain earthworks optimisation processes. Costs will automatically be applied to the relevant quantities using a detailed costing model (*DCM*). All proposed developments have been based upon the requirements within the specification.

Keywords: CESMM, digital terrain modelling (DTM), earthworks, estimating, integration.

GENERAL INTRODUCTION

Ground conditions play a major role in any civil engineering or building project, they influence the design of all aspects of the site. Most construction sites have some degree of ground re-shaping in order to accommodate the design, this will involve excavating some areas and filling others. The process of moving site materials is often termed earthworks.

The costs of moving earth can be substantial on many projects within a confined site, it can easily be the cause of a project making huge losses, or equally make large profits. A contractor can often win or loose a tender based on the earthwork price alone. Therefore minimising the earthwork quantities is a very worthwhile exercise.

Accurate calculation of detailed volumetric quantities is essential. Hand calculations are time consuming and often “guess-work” and so are not ideal. Commercial ground modelling systems can produce quantities very quickly based upon the inputted digital terrain models (DTMs). However generally there is little organisation to this information and so the scope for error can be large. (Dawood *et al.* 1997b).

[1] *p.mcmahon@tees.ac.uk*

McMahon, P, Dawood, N N and Hobbs, B (1998) The utilization of it for managing ground information and optimizing earthworks. *In:* Hughes, W (Ed.), *14th Annual ARCOM Conference*, 9-11 September 1998, University of Reading. Association of Researchers in Construction Management, Vol. 1, 288-97.

RESEARCH AIMS

The aim of this research is to develop a prototype for an integrated ground modelling system, *InSite*. The development of this includes integrating commercial software packages to form a base on which to work, add intelligent links to aid re-design, create a naming convention standard to increase automation and create a Detailed Costing Model (*DCM*). All of the development issues are based upon requirements within the specification developed as part of this research (Dawood *et al.* 1997a).

Digital Terrain Models (DTMs) are the triangulated models created to represent ground surfaces. By standardising the way DTMs are created, stored and manipulated, relevant information can be transferred to a developed costing model (*DCM*) automatically. This information can then be organised in such a way to enable the user access to all quantitative data. The *DCM* will be updated automatically as design changes occur, links to standard costing schemes, such as CESMM3 Civil Engineering (formerly Wessex), will also be integrated within the *DCM* output.

It is envisaged that the deliverables of the proposed integrated system, *InSite* will yield to the following:

- reduction in errors due to automation,
- time savings will be made,
- more design options can be investigated (in the same time) allowing an optimum solution to be found, and
- 'actual' and 'bill' quantities (CESMM) output.

The following section detailed the work undertaken to date, this has included interviews, software survey and specification development.

ESTABLISHING STATE-OF-THE-ART

The literature review revealed that many other research projects are being undertaken to achieve the same goals of time saving and integration. The closest is the ToCEE project funded by ESPIRIT has an aim to standardise information exchange to support a concurrent environment. Large scale and geotechnical structures have been chosen to demonstrate the software tools (ToCEE 1998). There are many other large projects being undertaken with the same goals:

- STEP - Standard for the Exchange of Product data, ISO exchange standards (STEP 1998)
- ICON - Integration in COnstruction, developing an information framework for the construction industry (Sarshar et al 1994)
- COMMIT - COnstruction Modelling Methodologies for Intelligent InTegration using the guidelines set out in STEP and ICON (Rezgui et al 1998)
- CONCUR proposes to formulate a forum for integrated design, improved communications and neutral exchange formats throughout the life-cycle of a project (CONCUR 1998, Cook 1997)

Optimisation of earthworks quantities has also been investigated by many others. Many of these projects have been aimed at highway design, these include:

- Terra-Firma, Software development by Nottingham University to automatically calculate earthwork quantities from a road design (Askew et al 1995)
- Earthworks optimisation - theoretical study of optimisation techniques for roadworks (Jayawardane and Price 1994).

SPECIFICATION DEVELOPMENT AND SOFTWARE SURVEY

Nineteen preliminary industrial interviews were used to develop the specification of an integrated ground modelling system. These interviews were semi-structured where the interview questions were drafted but were not rigidly set due to the varied nature of job functions of each of the interviewees. The main objective of the interviews was to establish a list of requirements to allow a specification to be developed. Other objectives of the interviews were to establish background information about each interviewee, previous project work and the use of computers within the industry (current and future).

The list of system requirements established from interviews was compiled, a split between specialised functions and the general functions required by the majority of construction team members was evident. The main requirements of the whole construction are considered as the core system requirements. These were listed in derail within the specification, the specification also briefly outlines the specialist functions required. Core specification requirements were split into two categories (i) essential, and (ii) desirable. These reflected the number of interviewees requesting the functions and the importance they placed upon them. This research proposes to develop a prototype of the core system requirements, this will be known as *InSite*.

A software survey was undertaken to establish the state-of-the-art in available commercial packages. This mainly concentrated upon civil engineering design and DTM creation software.

A software survey found many good commercial packages available within the UK market place. The initial evaluation of packages was a matrix style logging system where all the functions were noted. As the *InSite* specification developed the software survey was refined. The initial function matrix was analysed to find those software packages which best met the *InSite* specification requirements.

The 'best fit' was evaluated against a scoring system. This system related to the specification requirements: essential = 2 points, desirable = 1 point. Most of the packages that were fully evaluated were aimed at the civil engineering market, except for Surpac2000, which is marketed towards mining. Due to the variety of specification requirements a stand-alone civil engineering package did not achieve a satisfactory score. An integration of several commercial systems was investigated.

SYSTEM SPECIFICATION

The *InSite* system specification has been developed as part of the research, the specification consists of a list of functional requirements established from industrial interviews for an integrated ground modelling system. The aim of this is to prove the usefulness of a ground modelling system that will eventually be able to automatically redesign the ground profile of a site, visualise information and output associated costs.

The software combination chosen to be used within *InSite* was the highest scoring using the scoring system described earlier. The chosen civil engineering package was

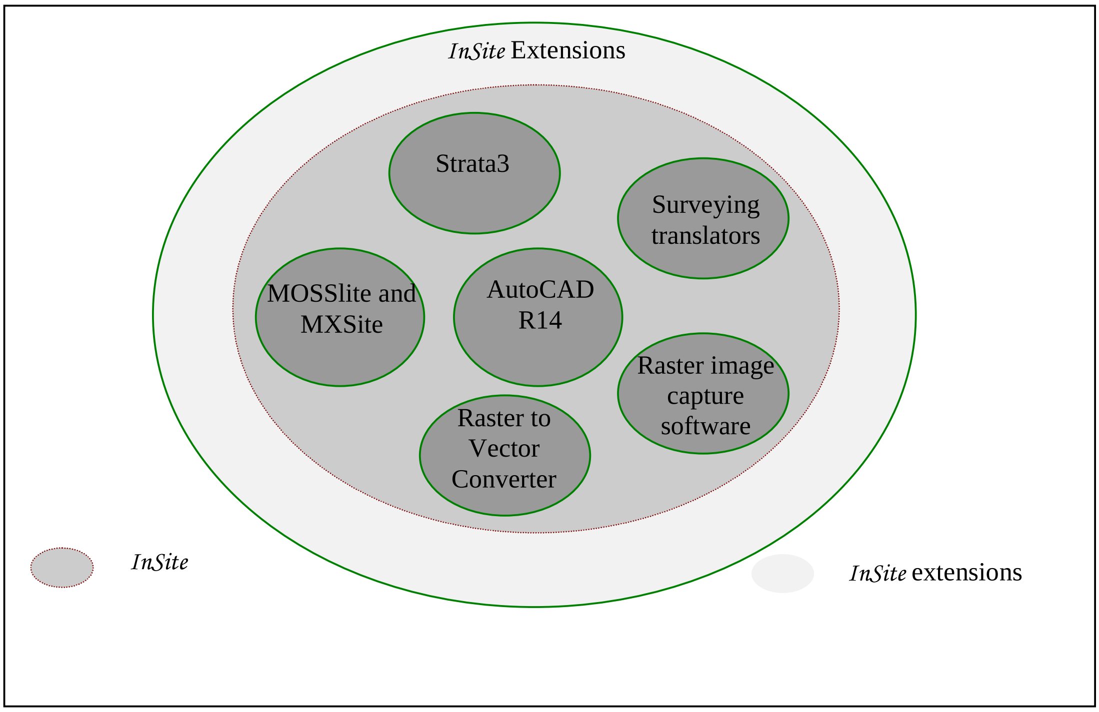

Figure 1: *InSite* system components: the base system

MOSS, this is the UK's preferred civil engineering software marketed in modules by Infrasoft (formerly MOSS Systems Limited). This will be used along with the world's most popular CAD package (AutoCAD by AutoDesk) to allow site designs and DTMs to be created. Several translator software products and a specialised strata creation tool (Strata3) will also be used. Figure 1 shows the integration of commercial software packages, together the software combination will be used as a base to *InSite*.

There were three main areas identified within the *InSite specification* that have not been satisfied by the software combination above. These are data organisation, intelligent design links and detailed costing.

Better data organisation will enable the design to be automated and costs to be produced. Many of the elements, such as car parks and roads, within the site will be given standard names or codes. This will help to identify each element with respect to the design and volume calculations.

The automatic design process will be made possible with a series of intelligent design links which specify which site elements will be affected when another element is moved. These links will define which elements need to be moved as part of the re-design process.

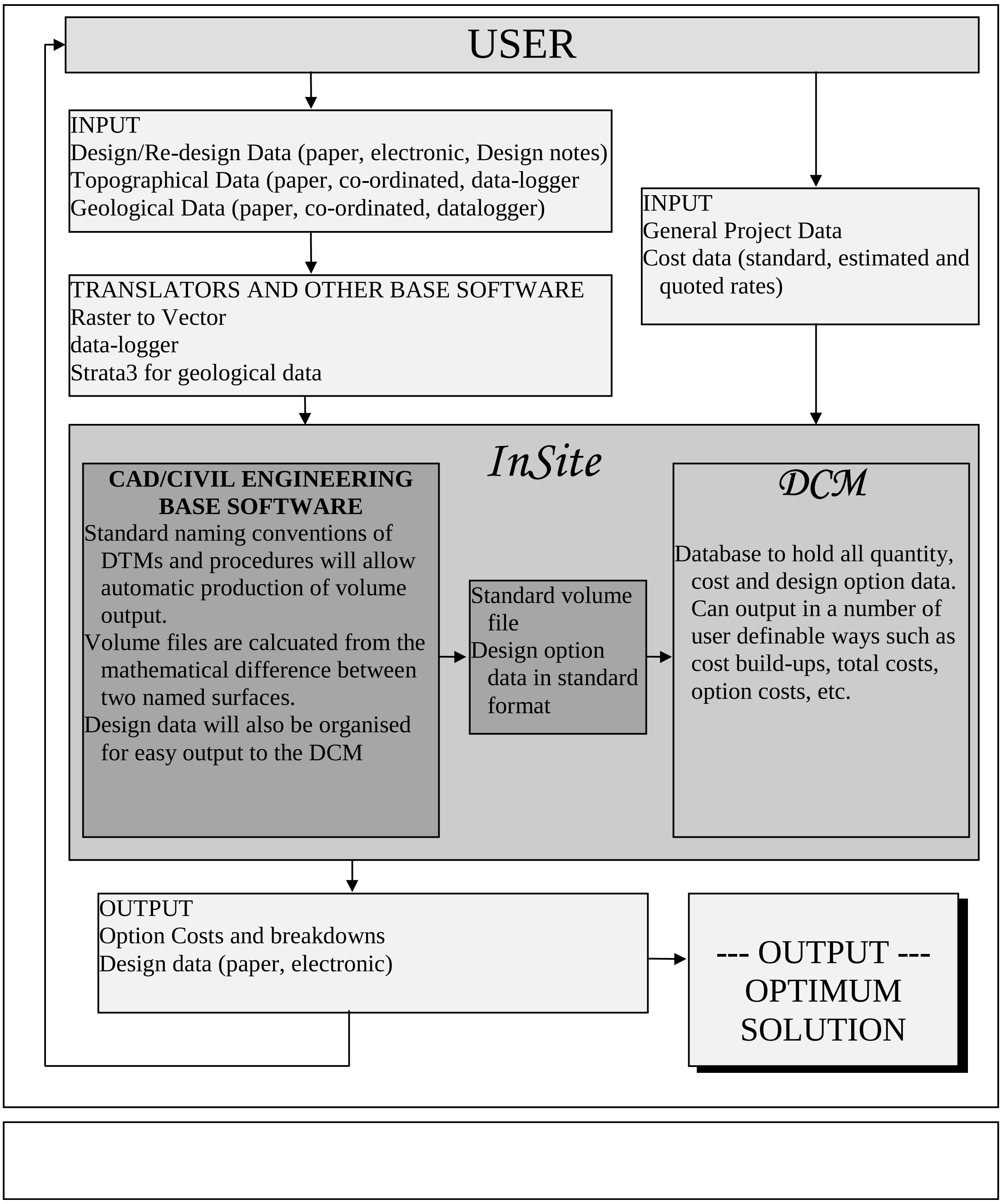

Figure 2: *InSite* Data Model

The costing rates will be applied using a detailed costing model (*DCM*), this will refer to the standard naming/coding conventions used within the integrated commercial packages. The *DCM* will consider two different types of cost rate, (i) those which will actually be undertaken on the site, and (ii) those which correspond with CESMM, for bill of quantity production. There is a software package (IcePac by CSSP) on the market that separates these two types of costs, it will also output the bill of quantities and other reports (IcePac 1998). However this is not specific to ground modelling and no links back into CAD are available. It is intended that the volumetric calculations will also be more accurate using *InSite* as up to date design DTMs will also be used.

It is proposed that the developed system, *InSite*, will lead to increased time and cost savings with respect to error reduction, re-design, earthwork optimisation, cost

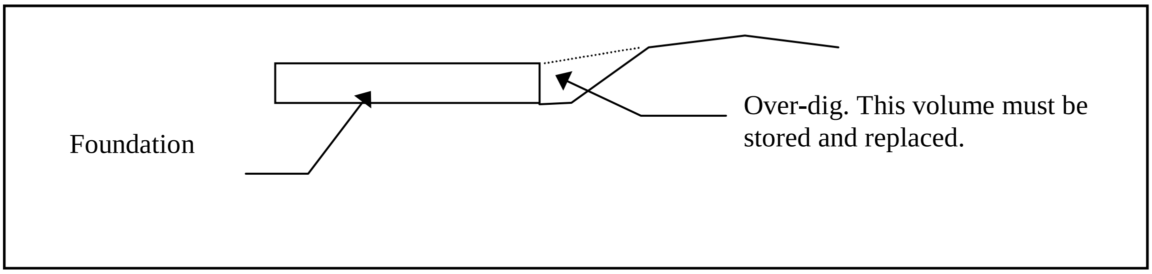

Figure 3: Diagram showing over-dig at the side of an excavation

estimates and the bill of quantities production. A broad overview of the system can be seen in Figure 2.

The following details the main research work currently undertaken in the development of the prototype.

Standardisation
A standard format will be adopted for naming CAD layers, elements and digital terrain models (DTMs sometimes referred to as surfaces). Naming conventions will comply to existing formats within AutoCAD and MOSS. There are many advantages that can be achieved by undertaking this work, these include:

- Standard naming conventions will aid in the data organisation issues, names should be standardised for layers, elements, DTMs, drawings, files, point data, etc.
- all users should immediately know what each volumetric output file represents, this will also make it easier for organising data onto the detailed costing model,
- all drawings will be easily understood and instantly recognisably, and
- procedures for producing quantities will allow the correct quantities to be easily produced and no quantities will be forgotten about.

Detailed Costing Model
The main aim of the Detailed Cost Model (*DCM*) is to generate costs to allow easy and quick assessments of different design options. It will be designed to organise the measured volumes from the commercial engineering package and assign costs. There will also be a link from the model back to the commercial ground modelling package within *InSite*.

The completed *DCM* will be based on a database, this is currently being developed using MicroSoft Access as it is easily integrated and there are many programming functions within it. However much of the data may remain within the MOSS/AutoCAD database and only be called upon by Access for costing and reporting purposes. The *DCM* need not be seen by the user at all times. It could be working in the background sending the most important information (overall cost) back to the commercial package within *InSite*. If the user needs to see the cost rates or any other aspect of the *DCM* should be opened separately.

The data within the database needs to be organised to allow the correct quantities to be assigned the correct costs. There are also many other issues that need investigating such as which volume calculations, drawings and design option are being worked with. Many data organisation issues will be dealt with by using standard names/codes for elements held within the MOSS/AutoCAD database.

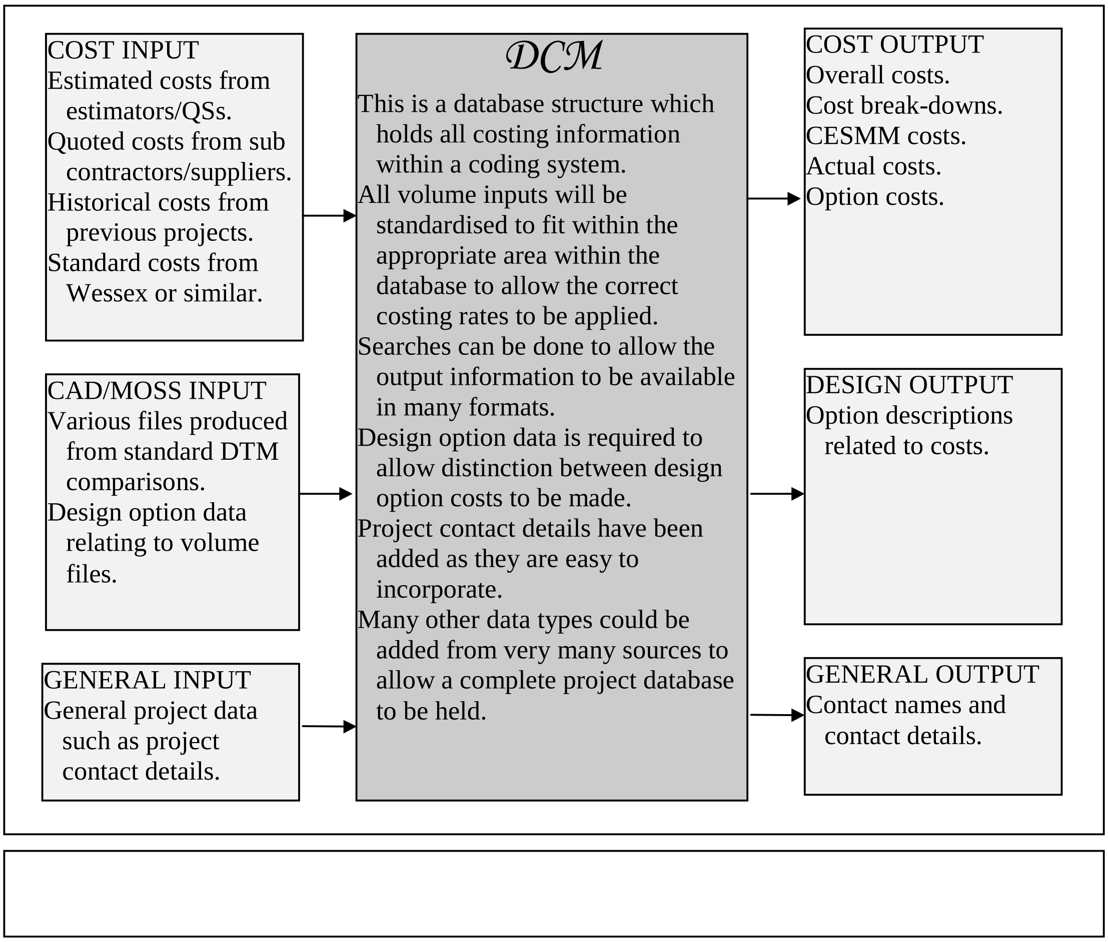

Figure 4: *DCM* data model

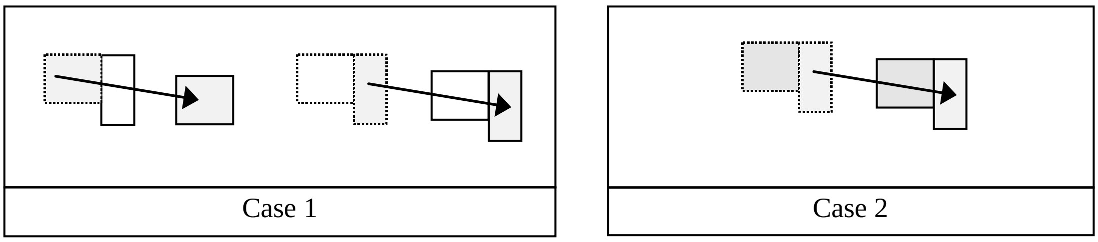

Figure 5: Example demonstrating the advantage of linking elements

There is a major issue with respect to organisation for bill of quantity production. Two types of rates must be considered, (i) CESMM rates which can be directly inserted into the bill of quantities, and (ii) Actual or non-CESMM rates these represent the actual quantities of work that are needed. Figure 3 illustrates a simple example, the over-dig required for safety is not included for in the bill of quantities rate.

A simple model of the DCM has been created, this needs to be further refined through a semi-structured interview process and NIAM model verification before the database structure can be finalised (NIAM 1998).

Links

Elements on the site will be linked to help in the re-design process. This will save time and reduce errors when trying different options and making design changes. Various links will be required to allow both plan location and level data to be properly associated.

Figure 5 shows a simple site made up of a car park and store. This is a very simplified site to demonstrate the advantages of linking elements. In reality there will be very many elements that will require linking together.

The car park and the store have two simple relationships, wherever the store moves in plan the car park must also move alongside. Also the two finished floor levels (FFL) must remain the same. The first case shows the procedure that must be undertaken to achieve a global move (without links). This shows the store must be moved to its new location, then the carpark also has to be moved. The second case shows that if the two components are linked the move can be done in one operation. This not only saves time but also will reduce errors when placing the second component relative to the first.

The definition of the connectivity could vary depending on the layout, distance apart and offset of each of the elements. It is suggested that a primary element is chosen from which all links must be related. This primary element will control all the elements connected to it. This for example could be a retail store, where the footpaths, loading bays and car parks are all placed relative to the store.

At any time throughout the life of a project any of the links must be allowed to be changed or broken. Extra links should also be able to be inserted. This is part of the design specification and can be encapsulated in a form of knowledge base where amendments can be made.

INSITE DEVELOPMENT - RESEARCH STATUS

The research team is currently integrating the Base System, all existing formats used by the commercial are being investigated. The basic outline of the *DCM* has been compiled and semi-structured interviews are being undertaken to establish a detailed *DCM* specification.

The five main stages of the *InSite* development have been shown below, this is an outline of the work to be done.

1. The integration of a Base System. This will be used as a platform for *InSite*. Possible commercial package combinations for this use have been established through a comprehensive software survey.
2. The development of a detailed costing model (*DCM*). This will be a database model used to allow design costs to be produced.
3. *InSite* Standardisation. All elements of the prototype will be assigned standard naming conventions, these will be used to allow volume creation procedures to be automated.
4. Intelligent link specification. Intelligent links between all elements of a site model, such as buildings and car parks, will help reduce errors and increase design productivity.
5. System verification. The whole of *InSite* will be verified using case study information.

The remaining tasks to develop *InSite* will be undertaken within the resrach timetable. *InSite* standardisation and intelligent link issues will be addressed at the same time as the *DCM* development. System verification will also be an on-going process.

CONCLUSIONS

The prime objective of the research work is to develop a prototype for an integrated ground modelling system, *InSite*. This will be achieved through integrating commercially available software packages and developing extra functions to allow the core system specification to be met. These developments include standardising naming conventions and procedures, developing a Detailed Costing Model (*DCM*) and defining intelligent links that will aid in the re-design process. The *InSite* prototype will allow better organisation of ground data with improved manipulation facilities allowing vital feedback to the construction team to produce the most optimum site design.

The functions within *InSite* will help to produce time and cost savings for the whole construction team.

ACKNOWLEDGEMENTS

This project is jointly funded by Taylor Woodrow Construction Northern Limited and the University of Teesside. The authors would like to acknowledge the financial contribution of these two institutions.

REFERENCES

Askew W.H, Mawdesley M.J and Patterson D.E. (1995) Computer aided generation of earthworks activities in project planning, *Development in Computational Techniques for Civil Engineering,* 17-23.

CONCUR (1998) **CONCUR project on the internet** http://ivope.ivo.fi/concur/descript1.htm

Cook, C. (1997) *The Virtual Highway Research Project, Phase 1 - pilot research stage, Project report for the Highways Agency*, Taylor Woodrow Management Group, November 1997.

Dawood, N.N., P. McMahon and B. Hobbs (1997a) Development of an integrated ground modelling system for the construction team, *Procs 1st International Conference on Concurrent Engineering, CEC '97,* July, London.

Dawood, N.N., P. McMahon and B. Hobbs (1997b) Development of a computer-based ground modelling system for the construction industry, *The Mouchel Centenary Conference on Innovation in Civil and Structural Engineering*, 1997.

IcePac (1998) **IcePac by CSSP** http://www.cssp.demon.co.uk/icepac.htm

Jayawardane K.W and A.D.F. Price A.D.F. (1994) A new approach for optimising earth moving operations. Part II, *Procs Civil Engineers and Transportation,* **105** November 1994, 249-258

McMahon, P (1998a) *Development of an integrated ground modelling system for construction projects,* MPhil transfer report (draft), University of Teesside internal document, 1998.

McMahon, P. (1998b) *Specification for a "ground modelling system"*, University of Teesside internal document, 1998.

McMahon, P. (1998c) *"Ground modelling system" improvements*, University of Teesside internal document, 1998.

Rezgui Y, A. Brown, G. Cooper, G. Aouad, J. Kirkham and P. Brandon (1998) **An integrated framework for evolving construction models** http://www.salford.ac.uk/iti/projects/commit/papers/ifecm/ifecm.html

Sarshar M, J. Powell, G. Auoad, P. Brandon, F. Brown, G. Cooper, S. Ford, J. Kirkham and B. Young (1994) Object orientated and information engineering methods: a hybrid approach to information modelling in construction, *International Journal of Construction Information Technology*, **2**(3), 83-96.

STEP 1998 STEP: **The ISO STEP Standards**
http://www.steptool.com/library/standard/

ToCEE 1998 **ToCEE project on the internet**
http://wwwcib.bau.tu-dresden.de/tocee/

NIAM 1998 **Various NIAM sources on the WWW**
http://www.aisintl.com/case/method.html#ORM
http://wwwis.cs.utwente.nl:8080/dmrg/MEE/misop020/
http://essential.stragtegies.com/publications/modeling/compare.htm
http:// essential.stragtegies.com/publications/niam.htm