# DEVELOPMENT OF AN INTEGRATED GROUND MODELLING SYSTEM

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Ground conditions play a major role in any civil engineering or building project, they influence the design of all aspects of the site. Large costs can be attributed to this type of work, often referred to as earthworks. Effective IT support for the design decision-making process has the potential to generate significant cost savings. This paper aims to overview some of the findings of the specification, software survey, software solution and the development work required to develop such a system.).

The background work, data collection processes and analysis techniques used in the development of the specification and software survey are described briefly. The chosen software (base software) and the specification are summarized. The specification is split into two parts: the core system and the extended systems. The core system is the focus of the research as it will satisfy the requirements of the construction team as a whole. The extended systems will integrate with the core system and will serve the needs of the specialists.

The areas in which the commercial software solution fails to meet the specification requirements are standardization, design links and detailed costing. The solution to these developments is currently being addressed in the form of a theoretical prototype.

Keywords: cost, earthwork, integration, link, standardization.

## INTRODUCTION

The development of a specification for an Integrated Ground Modelling System (IGMS) is the prime objective of this research. When completed this will meet the requirements of the construction industry in terms of ground data storage, processing and output. It's major objective is to optimize groundwork and earthwork activities, hence save costs.

The main advantage of developing such a system is the increased availability of accurate project data. This will lead to:

- the ability to make better project decisions and reduce risks associated with the lack of data,
- the eradication of duplicate information,
- the ability to find the cheapest workable option in the minimum time,
- easy data (survey and design in 2D and 3D) viewing, manipulation and updating,
- cost reduction through optimizing resources and time savings, and
- increased communication between all construction team members.

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The development of the IGMS is part of an on-going research project at the University of Teesside. Several papers have been published: Dawood *et al.* (1997a, 1997b), McMahon *et al.* (1998).

## RESEARCH BACKGROUND

The data collection process involved conducting a literature review and software survey. Preliminary semi-structured interviews were used to develop the initial draft specification of the system which was verified through further industrial involvement. The specification requirements were collated via a scoring system which highly rated those which the industry considered the most important. Please refer to previous publications by the authors for more background information.

The industrial sample used covered a wide range of job functions and nineteen interviewees were used during the initial semi-structured draft specification development. The verification of this draft involved all of the preliminary interviewees and other relevant personnel, this helped further refine it. This process allowed a comprehensive list of specification requirements to be obtained. Many of the items on the list were specialist requirements requested by an individual with specialized job functions.

The specification was split into two parts the first covers the core requirements to be used by the construction team. The second part of the specification is intended to cover the requirements of the specialist. These requirements represent a list of functions the IGMS will perform. The IGMS has therefore been separated into the core system and the extended systems.

A comprehensive software survey was undertaken to establish the state-of-the-art and determine if all the needs of the construction industry were being met. The functionality of the commercial systems were analysed against the specification requirements. A matrix analysis was undertaken which allowed each commercial product to be given an overall score.

The software chosen to best meet the InSite specification was: AutoCAD R14, AutoCAD Map, MOSSpro, MXSite, Strata3, Scan2Cad and a surveying translator. These were chosen because their joint score was 98.56% against the specification.

The integration of these products is kept to a minimum due to the available transfer formats. See Figure 1 for a graphical representation of this integration.

## INSITE SPECIFICATION

The core system represents the major part of the developed specification and the heart of proposed IGMS. All construction team members will have access to this, the extended systems will communicate with the core. This will allow each member of the construction team access to a fully integrated system as well as having their own specialized software at their fingertips.

The core system will be centralized with all team members having access. The extended systems will be modular with limited access. The interaction between each extended system and the core will be two way, i.e. data can be sent from and to the core system. Some of the extended systems may have interaction with each other.

There are three main functions that the core system must achieve. (i) The model must allow manipulation of the ground surfaces and the locations and sizes of all site

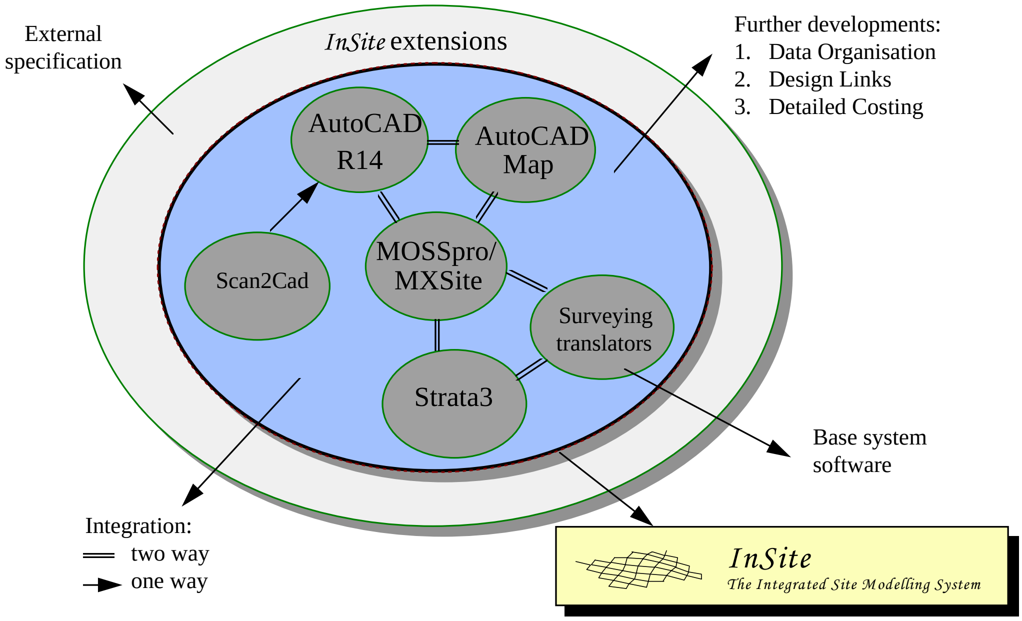


**Figure 1**: Base software selection

elements (ii) Quantities and costs must be produced for every "what-if" to allow comparisons to be made between options. (iii) The construction site must be viewed in 3D, this will allow all technical and non-technical staff to better understand the site and what is contained within it.

The core system is now the main focus of the research, this has been named InSite - The Integrated Site Modelling System. The extended systems are not considered in great detail in this research, however further developments to this research could undertake integrating these with InSite.

The list of requirements were compared against the list of functions available within the commercial ground modelling market. Three main areas which required work were identified, these were:

- Standardization - to allow all procedures and names to be standardized, reducing user errors. This includes a standard naming convention (SNC) and standard procedures with an aim to automate in the future.
- Detailed Costing Model (DCM) - to allow all quantity and costing data to be collected and organized. To allow the generation of project costs and Bills of Quantities (BoQs).
- Design links and rules - between site elements to reduce errors and eventually allow automation to occur. Internal Element Rules and links are needed to allow checks to be made upon each individual element.

A Theoretical Prototype is currently being developed which addresses these three research areas. It is the intention of the research team to store all information in a database which will integrate with the chosen base software. An overview of this document is given in the next section.

## THEORETICAL PROTOTYPE

The Theoretical Prototype addresses the development issues which have been raised through this research. There are three main topics which were highlighted in the previous section. In depth interviews were undertaken to allow the prototype to be designed and verified at various stages.

The InSite data structure will be held within a database with structuring and transfer standards[3] (Bjork 1992b). The Theoretical Prototype details this in a generic format which will allow integration with any base software and could be implemented within any database. An overview of these structures are given in the following sections.

A case study is being used throughout the Theoretical Prototype development for verification purposes. This represents a typical retail store development within a confined site can be seen in Figure 2. The layout has been chosen as it contains site elements which are commonly found within a typical project. The layout is intended to allow site features such as site constraints, design parameters and general problems to be identified, formalized and solved. Once the system is fully designed a variety of case studies will be used in the verification process.

### Standardization

Data organization and standardization must be considered a priority throughout the IGMS design and development. Standardization will be the key to many manual and semi-automatic procedures reducing user errors. It also will eventually lead the way to a fully automated system.

The organization of data will not only be relevant to one part of the ground modelling system but all data must be updated and organized globally. Initially the standard data structure will be implemented within InSite only. As the extended systems are added the data structure will be extended to accommodate them.

Standardization can be achieved through a standard naming convention (SNC) which will be utilized throughout InSite. Not only will the naming convention be standard but so will many of the procedures. In the future many standard procedures can then be automated. Since all procedures will be standardized the risk of user error will be minimized.

All 3D models are created from individual objects such as elements, points and strings. Surfaces are used to allow volumetric quantities to be calculated and output as text files. Each of these separate parts of the model have been considered in the data structure.

Each element will be given a unique ID code and descriptive name. The ID code will be used by InSite to identify the element, whereas the descriptive name will be the user’s reference. All objects within the model will link to a particular element, this will allow the user better understanding and will be utilized within the design links (Bjork 1992a).

The data structure for the standardization is shown in Figure 3 and Figure 4. The subsequent design link and DCM structures (not given) will tie into this. They will call upon existing data to prevent double inputting and will allow checks to be made.

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[3] See, for example: http://www.aisintl.com/case/method.html#ORM, http://wwwis.cs.utwente.nl:8080/dmrg/MEE/misop020/, http://www.fec.newcastle.edu.au/~mgbgr/info302/niam/index.htm

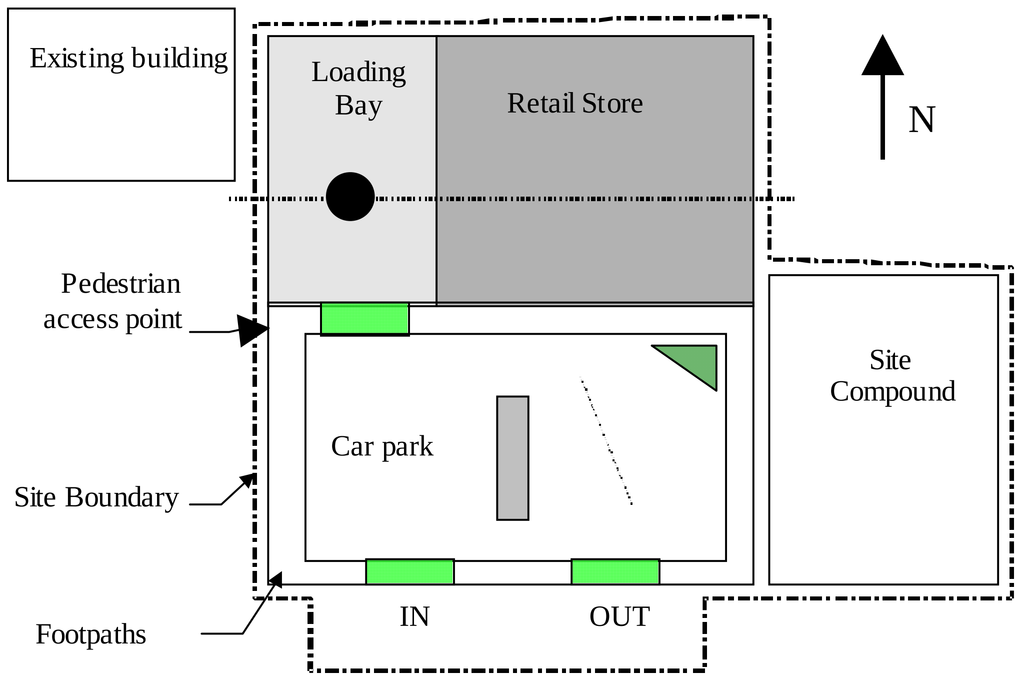


**Figure 2**: Case study site

**Design Links and Rules**

The design links and rules are intended to aid the re-design process allowing more efficient earthwork optimization to be undertaken. The design links are split into two parts: links between elements (Site Links) and links within each element (Element Links).

The Site Links will be assigned using Rule Parameters which will specify element to element connectivity. Whereas element parameters will be used to defined the Element Links and Element Rules within each individual element. The Element Links will be used to allow all parts of each element to remain connected. This will comply with the SNC, therefore all building Element Links must only contain building string codes.

Without Element Rules the Site Links would dictate the element design. To allow an appropriate design will be produced Element Rules are required. Each element will have a list of parameters, such as maximum gradient.

There are four generic Site Links which will allow all the site elements to be connected and individually checked. These are:

- Boundary Site Link - this is a checking rule which will allow the areas around the site to be checked against height difference (H), plan distance (P) and the boundary element envelope factor (H/P).
- Tie-In Site Link - this is to specify elements which tie-in with each other in terms of plan location and level. Such instances include the relationship between the existing road external to the site and the proposed entrance road. This will be a re-design rule, the connection between the elements will remain even when one of the elements is moved.

*Project* (ProjID, Proj_name)
*Element* (ProjID, ElemID, Elem-name, Elem_desc)
*String* (ProjID, ElemID, StringID)
*String_Link* (ProjID, ElemID, StringID, StringLink, Start, End)
*Point* (ProjID, ElemID, StringID, PointID, x_east, y_north, z_level)
*Surface* (ProjID, SurfaceID, Sur_name)
*Surface_Boundary* (SurfaceID, ProjID, ElemID, StringID)
*Surface_String* (SurfaceID, ProjID, ElemID, StringID, StringLink)
*Volume_Output* (ProjID, VolName, Orig_surface, Sec_surface, Vol_bound, Vol_date, Vol_time, Vol_cut, Vol_fill)
*Generic_Element* (GenElem, Gen_elem_type, Gen_elem_desc)
*Generic_String* (GenString, Gen_str_type, Gen_string_cat, Rel_gen_elem)
*Generic_Surface* (GenSur, Gen_sur_type, Gen_sur_desc, Allow_string_cat, Allow_elem_cat)
*Generic_Volume_Output* (GenVolName, Gen_vol_desc, Gen_vol_orig_sur, Gen_vol_sec_sur, Gen_vol_bound)

**Figure 3**: SNC Tables and Entities

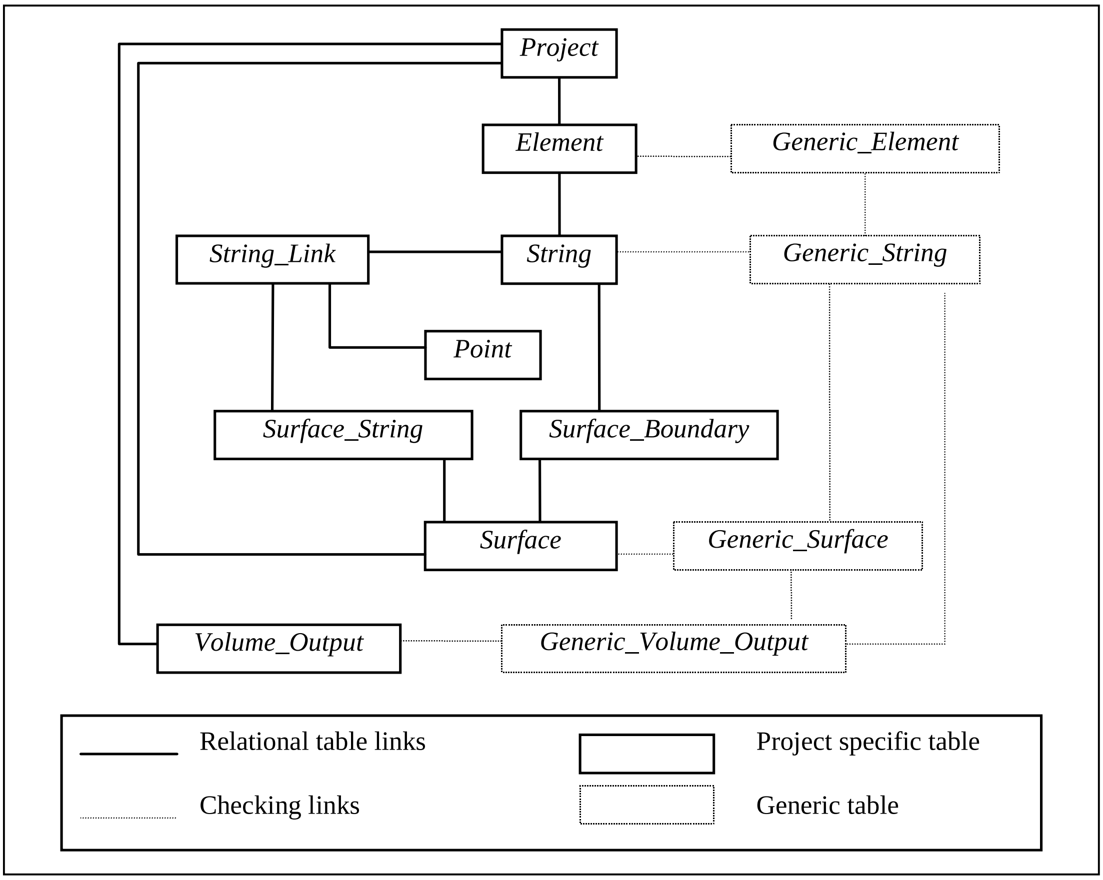


**Figure 4**: SNC Data Structure

- Height Site Link - this rule is similar to the tie-in rule except that there will be a height difference along the connecting line. An example of this will be where a kerb is used to defined the boundary between a road and footpath, the height difference will be the kerb face. This will also be a re-design rule, connected elements will automatically move to follow the rule.

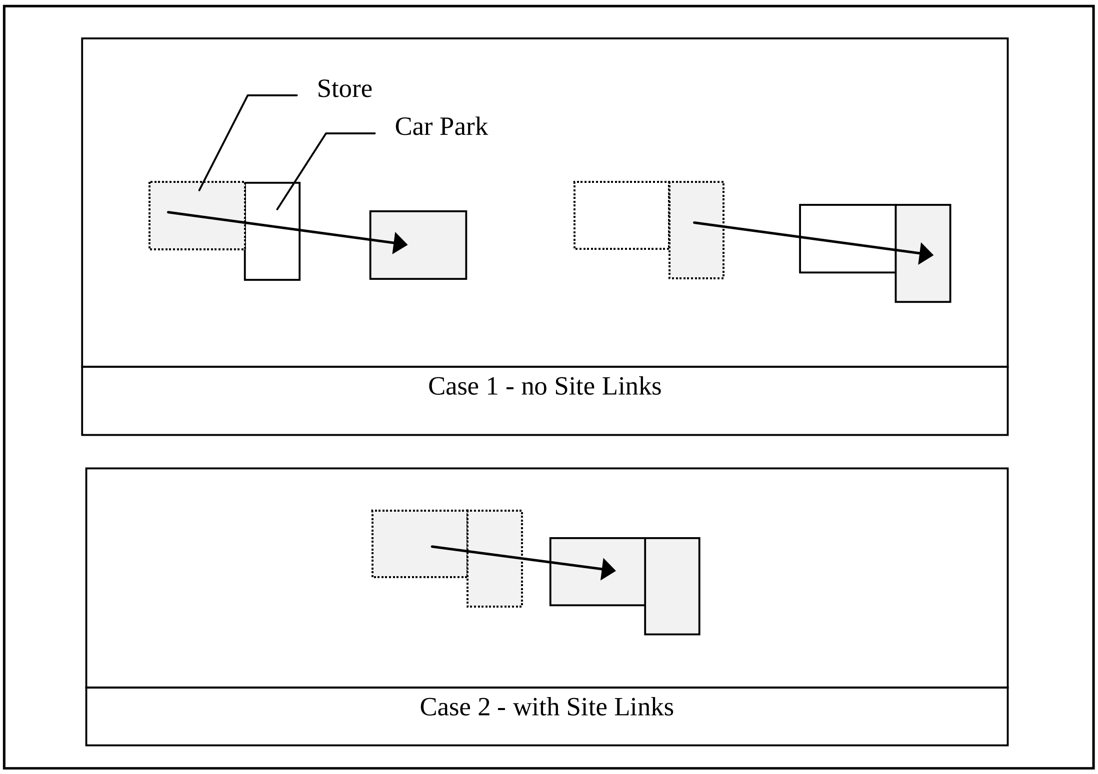


**Figure 5**: Example demonstrating the advantage of site links

- Difference Site Link - this allows points which have a defined level or plan distance to be specified. This will be a checking rule, any non-compliance will generate an error message.

There are two generic types of Element Rules which will allow assignment of Rule Parameters to elements:

- Fixed Element Rule - this allows part or all of an element to be fixed in location. This could be in plan location or elevation. This will be a checking only rule where any parameter attributes which are breached will cause an error message to be created.
- General Element Rules - each element type will have it's own set of element parameters which will usually be defined from local, national or user-defined standards.

There will be a generic Element Link assigned to each generic element type:

- Element Links - Each generic element type will have it's own type of Element Links which will defined the relationships between parts of the element.

All of these rules will be stored within a database structure which builds upon that shown in Figure 3 and Figure 4. Links will be made to the element, string and point tables which will allow all of these links and rules to be enforced and checked.

The advantages of undertaking this process are time savings and error reduction benefits. The time savings will allow more re-design options to be investigated in the same time, this will result in a more efficient design solution being found. Errors will be reduced since all site elements will be checked against the assigned rule and element parameters.

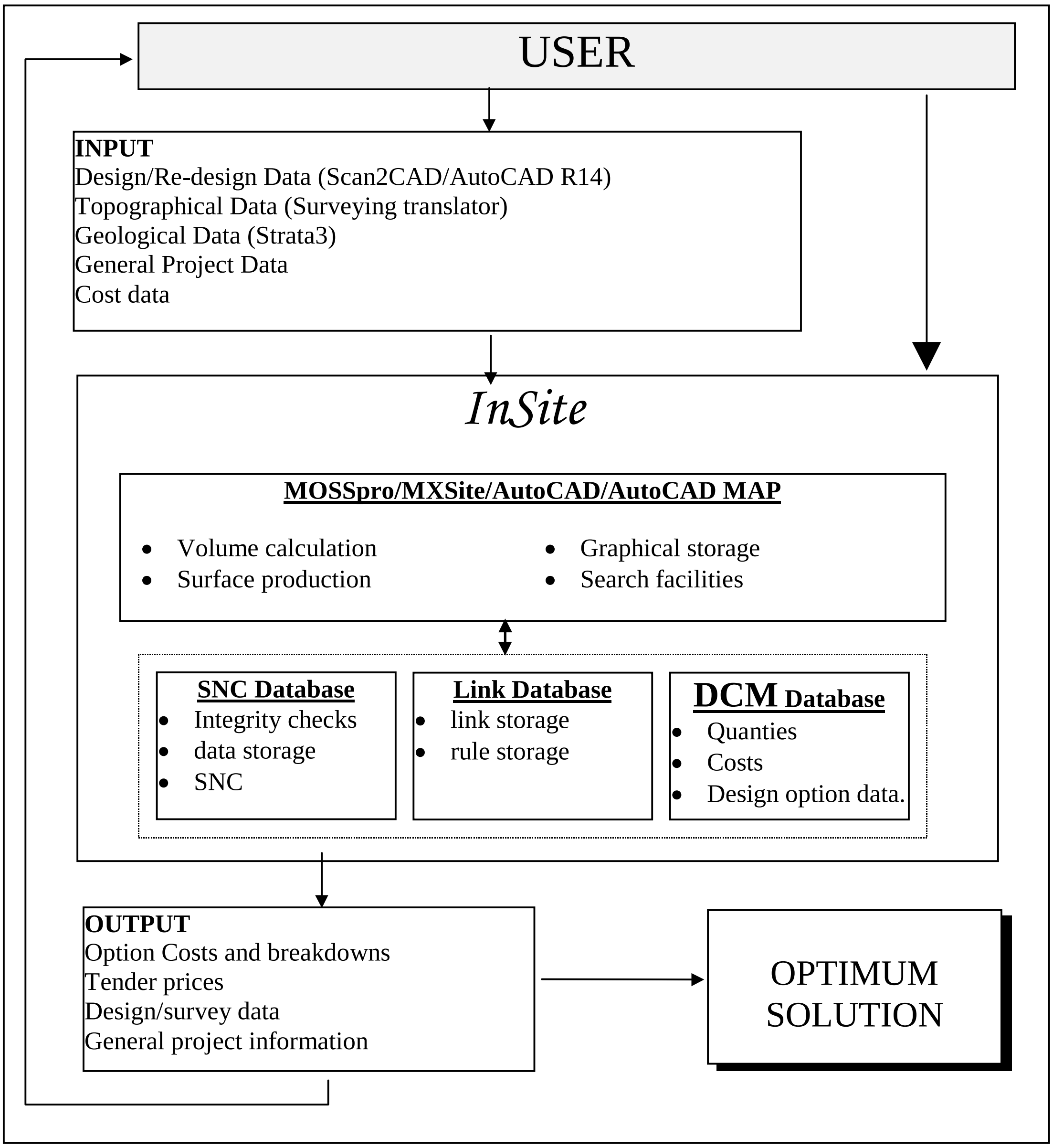


**Figure 6**: InSite DCM Model

The benefits of assigning Site Links (connectivity of element to element) can be seen in the simple example shown in Figure 5. In this example only two elements are shown. A full working project will have many more elements to consider and so the time savings and risk reduction will be more substantial.

### Detailed Costing Model (DCM)

The main aim of the DCM is to generate detailed costs to allow easy and quick assessments of different design options. It will be designed to organize the measured volumes from the base software and assign costs.

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 MOSSpro/ MXSite. If the user needs to see the cost rates or any other aspect of the cost evaluation system they should be able to open it up easily.

There will be two types of quantities and costs to consider within the DCM structure. The first is the CESMM values which will correspond to the rules within the CESMM documentation. The quantity and cost rate values can be applied straight to the Bill of Quantities (BoQ) document. These values are very important if the contractual relationship specifies a BoQ has to be used, such as a traditional contract.

The data within the DCM needs to be organized to allow the correct quantities to be assigned to the correct costs. Each item needs a unique code which identifies it from all others. Procedures for updating the DCM must be standardized along with those throughout InSite.

The DCM data structure will rely upon the unique identifying codes outlined in the previous sub-sections. The costing information will directly relate to an individual volumetric output file, for example total_topsoil.txt represents the topsoil strip volume this will be assigned the topsoil-rate to achieve the cost for this operation.

The DCM database can be seen in Figure 6, this highlights how the costing model will interact with other parts of InSite.

## CONCLUSIONS

Preliminary semi-structured interviews were used to develop a draft specification and verify it. A comprehensive software survey scored commercial products against the specification requirements to allow a combination to be used as a base software.

There were three areas identified which required development, these were: standardization, design links and detailed costing. These developments have been formalized into a theoretical prototype.

A case study is being used through the theoretical prototype development to verify naming conventions, data structures, design links and costing issues. The prototype is being designed as a generic system which will integrate with any base software.

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