THE DEVELOPMENT OF A PROJECT AND SITE INVESTIGATION RISK EVALUATION MODEL

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This paper describes the development of a model that could be used in practice to improve Site Investigation (SI) procedures and reduce risk associated with uncertain site conditions. The developed model Project and Site Investigation Risk Evaluation Model (PSIREM) ultimately provides a reliable means of presenting both the SI data and the complexity of the project relative to SI information, thereby providing the opportunity to assess the risk associated with a specific project and the inadequacy of available SI information. Despite the wealth of knowledge and information available, the UK construction industry seems to be failing in the use of these existing models and systems to improve decision making for site investigation work. A questionnaire survey of over 1,000 construction practitioners revealed that less than 1% used any form of risk assessment method specific to site and ground conditions. Whilst 23% admitted that their only attempt to carry out any kind of risk assessment was to satisfy the requirements of the Construction (Design and Management) Regulations (CDM 1994).The work described in this paper is based upon data and information collected from a literature search, questionnaire survey, and semi/structured interviews. This research has been used to develop a model (PSIREM) for the appraisal of risk associated with site investigation. Case studies of 36 selected construction projects within the UK have been carried out. The developed PSIREM has been used, together with the findings of the case studies, to objectively measure the level of risk and to develop a mapping risk index associated with an inadequate site investigation. This provides a concise appraisal of risk associated with uncertain site investigation information, which clients/practitioners can map against to establish a prediction of the risk they are exposed to for any given project.

Keywords: project complexity, risk management, site investigation procedures.

INTRODUCTION

The methodology used throughout this research programme has been presented in earlier papers (Ashton and Gidado 2001,2001a, 2002, 2002a). The literature review, questionnaire survey and the case studies seem to suggest that clients and consultants are not best served by the current site investigation procedures. Research has revealed many existing guidelines, models and code of practice set out to assist in the delivery of a professional service in site investigation (Weltman and Head 1983; Alhalaby and Whyte 1994; Berkeley *et al.*. 1991; Jaafari 2001). However, the problem appears to stem from a general lack of awareness regarding scale of risk associated with inadequate site investigation and the unavailability of a reliable system to communicate such data. The failure to evaluate this risk has been documented through the past few decades (NEDO 1983, 1988; NAO 1994; Ashton 1998) and the need to develop a Site Investigation Risk Evaluation System (SIRES), in order to reduce risk associated with uncertain site conditions is long overdue.

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THE PROPOSED NEW SYSTEM TO IMPROVE SITE INVESTIGATION

The proposed system has been designed in three parts, identified in Figure 1 as three sub-systems. Although not specifically modelled around risk management principles, the proposed system incorporated the identification, analysis and response phases within the site investigation process.

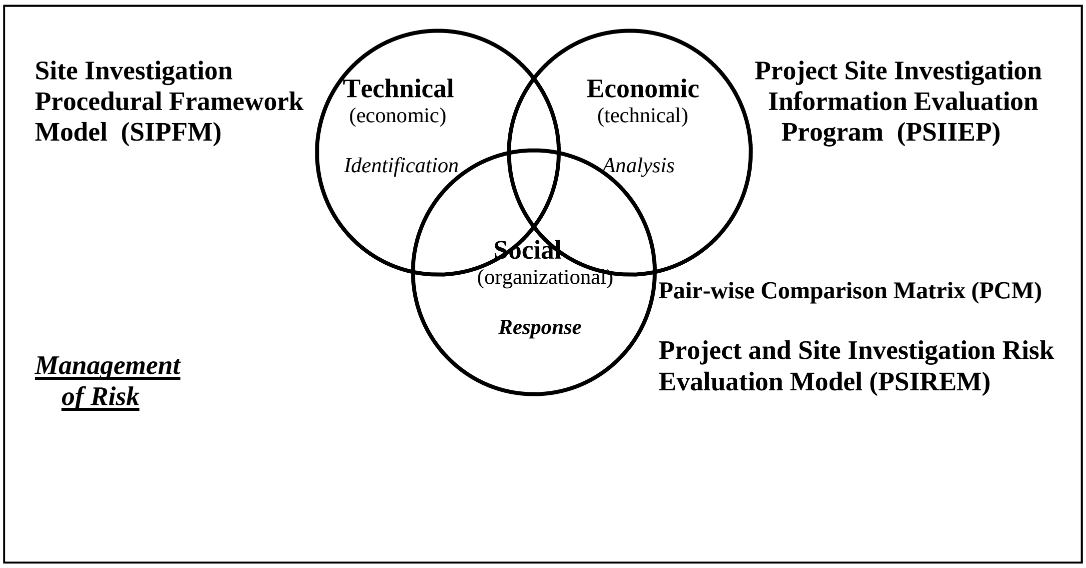

Figure 1: Investigative Elements of the Site Investigation Risk Evaluation System

Pair-wise Comparison Matrix (PCM), a technique synonymous with Value Management, enables the SIRES to incorporate a social and organizational dimension to the investigative and evaluation process. Thus far the Social-technical relationships have not been incorporated in risk models such as Willmer (1988) Computer Aided Simulation for Project Appraisal and Review (CASPAR), Operation and maintenance risk analysis (OMRA^{TM}), or the European Risk Management Methodology (RISKMAM^{TM}). However, SIRES has achieved this element by using the Pair-wise Comparison Matrix (PCM), establishing key questions, resulting from semi-structured interviews conducted with a smaller sample of construction professionals, selected from the questionnaire survey results.

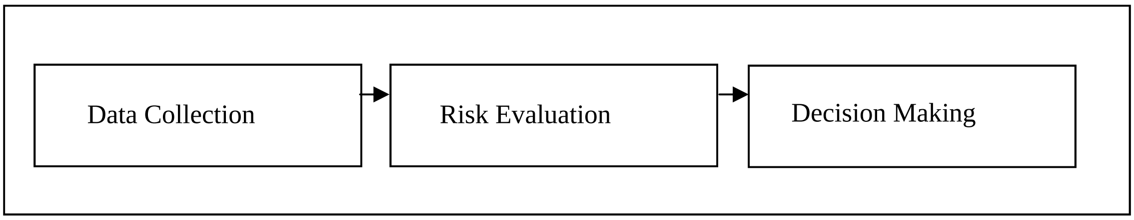

Figure 2: Site Investigation Process

Figure 2 outlines the three generic processes of conducting site investigative work. Risk evaluation of the SI data collected at the earliest stage of a project enables decisions to be made regarding the proposed design solution or action required to provide the most appropriate management response to achieve the project aim.

Each subsystem in Figure 1 is disaggregated and a three-part system has been developed with each part specifically addressing respective subsystem. The developed system, called Site Investigation Risk Evaluation System (SIRES), is depicted in Figure 3. The system is primarily developed to aid those specifying and ultimately authorizing detailed site and ground investigation for construction. SIRES (Ashton 2003) provides guidance to construction professional regarding the:

- establishment of the project organization and the procurement route;
- establishment of the client brief;
- determination of the scope of site and ground investigation;
- review the outline design proposal and carry out site investigation; and
- review of the final site investigation report.

Just as in the generic model, SIRES is also made of 3 key processes. The first part of the system is a model called Site Investigation Procedural Framework Model (SIPFM), which has been developed in order to collect the site investigation data through a logical and progressive sequence of events. The SIPFM is described in Ashton and Gidado (2001). The second process involves the use of a computer program (PSIIEP) that enables the data to be analysed and an evaluation of the quantity and quality of information is delivered via two indices called Site Investigation Information Index (SII) and Project Complexity Index (PCI). SII represents the SI information, whilst the PCI provides an evaluation of the projects level of complexity relative to SI matters. This process is described in Ashton & Gidado (2002). Finally, a decision making model that provides the medium through which the two indices can be used to provide a concise appraisal of risk has been developed. The development of this part of SIRES is the main aim of this paper.

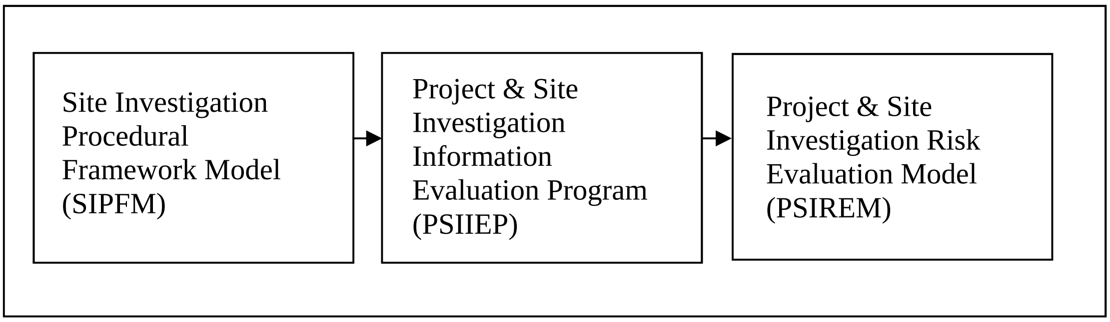

Figure 3: Site Investigation Risk Evaluation System (SIRES)

Within the various phases of the SIPFM, the research identified where measures could have been taken and risk analysis techniques applied to assist in the identification of risk associated with the development of a site and ground investigation. A Checklist Model was used as a benchmark of SI practice, whilst checking the process of the site investigation against individual case studies. The checklist model formed the base for the development Site Investigation Procedural Framework Model (SIPFM).

THE DEVELOPMENT OF THE PROJECT AND SITE INVESTIGATION RISK EVALUATION MODEL (PSIREM)

The overall aim of the research has been to develop a system that can be used by construction practitioners to objectively establish the level of risk associated with an inadequate site investigation. In order to achieve that aim, earlier research identified that the PSIREM must address issues of complexity, availability and cost, be user friendly and minimise the time required to complete the exercise.

This research presents its findings behind a growing tide of scepticism regarding the usefulness of complex risk analysis techniques among construction practitioners (Wood and Ellis, 2001) whilst further research has indicated that current risk analysis techniques are not being used effectively, if being used at all. White and Fortune (2002) identified that 65% of project management organizations did not use any risk assessment tools. Therefore, if the PSIREM is to be adopted it must provide meaningful results to the investigative practitioner and to clients; an issue cited by Peacock and White (1992) as a key factor of client dissatisfaction with current site investigation procedures.

The data collected using case studies and questionnaire has provided a representative sample of issues experienced by the aforementioned sample group. The holistic advantage afforded by case studies, compatible with the ideas of Glaser and Strauss (1967) regarding the continual restatement of the theory upon which the data was gathered. Case studies were identified following offers made by the respondents of the questionnaire survey. Some of the case studies were very good examples of well-managed projects, yet, had suffered difficulties due to unforeseen site conditions. Other examples of poorly managed sites with poor SI information had disastrous consequences for all concerned. The importance of the case study data was that it provided irrefutable evidence to support the need to improve site investigation procedures, as suggested by Williams (1999). For further research findings on 36 case study tests refer to Ashton (2003).

The Project and Site Investigation Risk Evaluation Model (PSIREM), shown in Figure 4, has been divided into three sections. The top part of the graph is used with case studies with a Project Complexity Index (PCI) figure between 0.1 ~ 10.0, obtained having carried out the exercise using the Project Site Investigation Information Program (PSIIEP). These projects characterize the easiest cases based upon the criteria used to assess the adequacy of available site investigation information in association with project complexity. The mid section of the model is used with projects having recorded a PCI figure between 10.1 ~ 20.0. The lower portion of the PSIREM Model is used for those projects that have scored a high Project Complexity Index, between 20.1 ~ 30.0. These case studies correspond to projects that historically suffered difficulties unless a high degree of adequate SI data was made available.

The Project and Site Investigation Risk Evaluation Model has a demarcation line on the left hand side on each of the three sections. The demarcation line represents a point from which the Site Investigation Information Index (SIII) figure must exceed. For example: if a project is graded at a medium level having scored a Project Complexity Index (PCI) value 15.0, then the index for the level of site investigation information must be greater than 70 SIII. The lowest graded project has a minimum demarcation point at 50 SIII, whilst the highest level of complex projects has a cut-off point at 75 SIII.

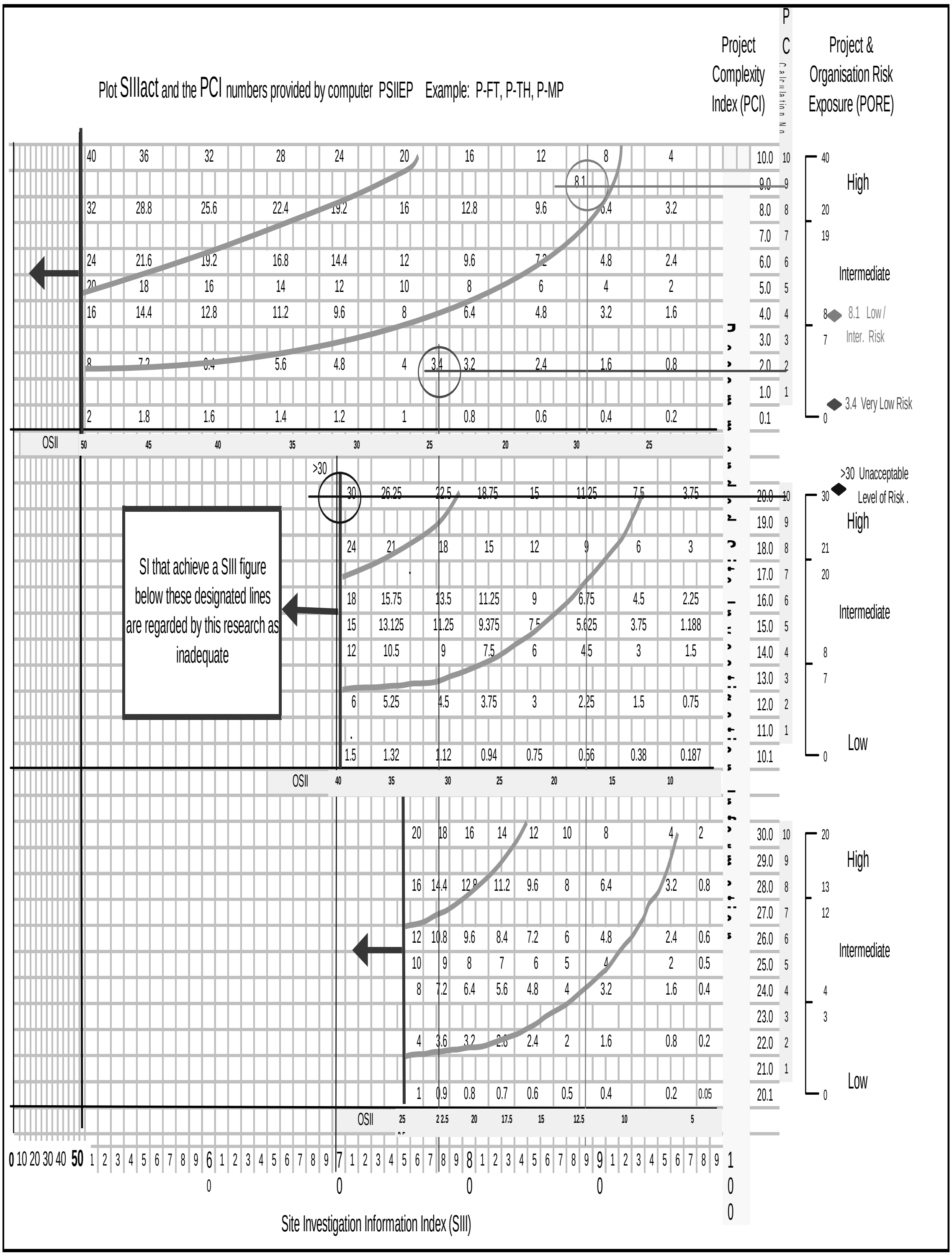

Figure 4: The Project and Site Investigation Risk Evaluation Model

Using case study analysis material, a graphical illustration of the projects' exposure to risk is established and called PORE. Within each of the three sections of the model, two curved lines mark an upper and lower boundary of Project Organization's Risk Exposure (PORE). These boundaries were established by calculating both maximum and minimum limits for acceptability regarding the level of risk - high, medium and low – as a result of the amount of site investigation information and the degree of project complexity.

The maximum level for a Project Organization's Risk Exposure has been represented as $PORE_{max}$. The $PORE_{max}$ limit has been established by calculating the maximum values for project complexity by the worse case scenario regarding the amount of Outstanding Site Investigation Information (OSIII), multiplied by a factor called the Site Investigation Assessment Factor (SIAF).

The SI Assessment Factor was a calculative factor which enabled a range from between 0~40 for relatively easy projects. Whilst moderately complex projects, which have well-managed sites and adequate SI information ranged from 0~30. Complex developments having innovative design and/or requiring unique techniques to overcome potentially hazardous conditions were allocated a range from between 0~20.

TESTING THE PROPOSED NEW SYSTEM

In order to thoroughly test and evaluate the PSIIEP and the PSIREM, the respective PCI and SIII values of the thirty-six case studies have been plotted on the PSIREM model and critically reviewed. For further research findings and 36 case study tests refer to Ashton (2003). To illustrate the use of the PSIREM, data from three new randomly selected live case study projects have been collected and plotted on the model shown in Figure 4, using 3 cycles on the model to highlight points where their respective PCI and SII meet. Absolute access to all case study data provided a unique opportunity to crosscheck the projected PORE value with the known outcome of the project. The three cases outlined experienced extreme difficulties during and after the design and construction phases, with presumed negative financial consequence. Each of the case studies is discussed as follows:

Case Study P-FT

The case study referred to as P-FT was a housing development. With a project complexity index of 8.9, the development was relatively straightforward. A piled foundation system was required on a green field site because of ground water and poor ground bearing capacity. The site team were very experienced with the type and methods of construction. The anomaly was that the site showed signs of contamination. The SIII was 89, yet several investigative aspects were overlooked. Although some issues surrounding the serviceability needs of the site and the development had been considered, the critical area of surveying the width of the access roads and whether overhead cables could cause a problem remained unchecked. Historically, the cost of this oversight ran into several thousands of pounds, a cost met by the contractor.

Case Study P-TH

P-TH was a project with ideal site and environmental conditions. With a PCI of just 1.7 and a SIII of 77.99 the PORE index was very low at 3.4 within a scale range of 0~40. Even this project suffered a minor problem that had further investigative work been undertaken, could have been identified, thus enabling the opportunity to reduce the impact of its eventual occurrence. Having analysed the case studies, it appears that Local knowledge has often been overlooked during routine site investigative work. This case highlighted the circumstance where a local resident knew of a disused service line that had not been identified during the review of utility data, yet, caused a considerable delay during construction operations. Although the delay did not result in a financial or a time related contractual problem, the re-scheduling of work, materials and labour was a difficulty the site team could have eliminated with prior knowledge and forethought.

Case Study P-MP

The third and final case study used to test the accuracy and validity of the PSIIEP and the PSIREM, had a PORE value at the highest possible acceptable limit within the middle range of project complexity. Having a PORE 30 score clearly this project identified that further site investigation work was required, however, the project went ahead with inadequate site investigation and the entire project plan was based misleading information. Time was of the essence within the design-and-build contract. A catalogue of site-based difficulties resulted in project cost and time overruns with changing sequence working. The PSIIEP highlighted deficiencies within the SI, the shortfall regarding the inadequacy of the finances invested in order to conduct a thorough investigation was the first in a string of discrepancies between good practice and poorly conducted SI work. Recording barely satisfactory results when reviewing the Ordinance Survey data files and Local Authority record offices, combined with similar results when checking the Geological information sheet memoirs and an even less convincing analysis of the mining and mineral deposit records resulted with inevitable difficulties being experienced by the project team based on site.

CONCLUSION

Despite the wealth of knowledge and geo-technical advances that have been made over the past decade, Ashton (2003) identified significant problems with the adequacy of site and ground investigative procedures. Perhaps the most compelling of which was that 80% of contractors within the past three years had sought redress in one form or another for difficulties faced during substructure work caused as a direct consequence of inadequate SI information. The introduction of quality assurance, ‘Best Practice’, EEC code of practice, and the recent revision of BS5930: 1999 appear not to have significantly improved SI procedures within the construction environment. The global research programme identified key SI components via the SIPFM that would provide adequate SI information to the design process. Further, the PSIIEP provides the means to establish a projects complexity relative to SI information. These tools direct efforts regarding the collection and identification of SI data and may be used to benchmark and analyse the investigative process. Having learned lessons from earlier works, this research programme endeavoured to establish a simple, but, not simplistic, technique designed to identify an organizations exposure to risk as a result of unforeseen site conditions. The significance of the Project and Site Investigation Risk Evaluation Model (PSIREM) presented within this paper is that it is capable of delivering a Project Organization’s Risk Exposure (PORE) associated with uncertain site conditions. The use of graphical illustration of the data provides ease of use and simple to understand and/or comprehend. The research has not attempted to assess the impact of risk upon an organization rather it has focused on developing a model to assist with the identification of those factors that contribute to uncertainty associated with unforeseen site conditions. This provides the opportunity for organizations to implement management procedures in order to reduce the risk. Although previous attempts have been made by other research to improve site investigation procedures; this paper has provided a new system developed, in collaboration with construction professionals, to provide a thorough framework within which to conduct the site investigation process for construction work.

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