IMPLICATIONS FOR THE EFFECT OF STANDARDISATION AND PRE-ASSEMBLY ON HEALTH, SAFETY AND ACCIDENT CAUSALITY: PRELIMINARY RESULTS

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The Department of Trade and Industry (DTI) has highlighted health and safety as being under-represented in Government-funded research. The Health and Safety Executive (HSE) acknowledges that Standardisation & Pre-Assembly (S&P) need to be properly evaluated for their effect on health and safety. The adoption of S&P is widely supported for many reasons - including claims that it will improve safety performance. Most experts agree that this should be the case. However, there is no conclusive evidence that this is the case - much is anecdotal. There has been no real investigation of the actual causal relationship between accidents and the change in construction methods initiated by S&P strategies. Furthermore, although the actual health & safety risks reduce on site with S&P, the hazards change and need careful consideration throughout the project process. This paper reports on the preliminary findings of a research project which aims to provide a comprehensive study covering, non-volumetric, volumetric and modular building approaches across engineering construction, civil engineering and building sectors. It will establish the extent of the effect of S&P on health, safety and accident causality in construction. A particular aim is to inform industry of the benefits and risks of using S&P. The process will involve 1) Ergonomic work place audits to elicit key areas of concern regarding health and safety in off-site fabrication. 2) The development of a decision making process framework to identify areas of risk and benefit for both conventional on-site construction and off-site fabrication. This paper presents and delivers an overview of the salient issues relating to the research. Preliminary results and a selection of conclusions are presented.

Keywords: construction planning, decision analysis, health and safety, prefabrication, standardisation.

INTRODUCTION

This paper is the first of a series of papers reporting on health and safety driven research on standardisation and pre-assembly. Standardisation is the extensive use of processes and components with regularity and repetition. Off-site pre-assembly where element manufacture and assembly occur before installation represents the optimisation of manufacturing techniques in the construction industry. The research project will identify and establish the extent of the effect of Standardisation and Pre-assembly (S&P) on health, safety and accident causality in construction. A guidance tool will be developed to Provide construction professionals with accurate techniques for assessing health and safety implications in off-site fabrication. This will enable educated and reliable provision for health and safety performance across engineering construction, civil engineering and building sectors.

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Research efforts in the area of S&P were focused on the benefits of effective use of the principles of off-site fabrication (Neale *et al.* 1993), and in the opportunity for improved project performance (Tatum *et al.* 1986). However, no coordinated study into the health and safety implications of the use of S&P has been commissioned to date. Using a semi-structured approach, site visits were undertaken, incorporating interviews with managers, operatives and workplace observation. Factors considered ranged from ergonomic workplace audits, senior management involvement in health and safety, responsive health and injury record keeping systems, age of employees, length of employment, workplace environment and the installation of safety devices on machinery.

The Problem

Accidents that occur during construction activities often result in injury, for employees on the construction site these accidents are sometimes serious. Accidents can also occur after the works have been completed caused through faulty design or construction, causing death or injury to those engaged in maintenance work and to members of the public. The Health and Safety Executive (HSE 1992), reports that in a typical decade about 1500 people are killed on construction sites in the United Kingdom and 25,000-30,000 are seriously injured. In addition, 300,000-400,000 suffer injuries sufficient to keep them off their normal work duties for at least three days. Moreover, the HSE (1992) also indicate that the risk of a major injury is two-and-a-half times greater and the risk of a fatal injury nearly five times greater in the construction industry than in the manufacturing industry.

After analysing fatal accidents in the construction industry the HSE (1988) indicated that falls account for approximately half of all accidents in construction. Prior to this the HSE (1983) claimed:

"the general pattern of accidents remains very little different from earlier years...it is possible to write in advance the epitaphs of men who will be killed each year, in falls through roofs, when painting under roofs, by contact with overhead lines and in trenches. Declining accident figures so often only reflect declining construction activity".

It is evident that the issues relating to safety and health in the construction industry require ongoing research to investigate the effect of change and help understand and investigate associated risks. This research project will identify and establish the extent of the effect of S&P on health, safety and accident causality in the construction industry. The results will provide detailed guidance for exploiting the techniques in a manner that improves safety and well being of all those involved in the construction process.

Gibb (1999) states that there are a number of health and safety benefits from the use of off-site fabrication. However, there remains the problem of validating the extent to which off site manufacturing can be directly linked to improvements in health and safety. The research currently undertaken here is intended to provide a real investigation of the actual causal relationship between accidents and construction methods and strategies such as S&P. Furthermore, although the actual health & safety risks are expected to reduce with S&P, the research will identify the changing hazards throughout the construction process.

There are four main objectives for the research:

To identify the nature and extent of the affect of off-site pre-assembly on occupational safety and health in the construction industry - this is expected to have both a positive and negative affect.

To apply the review strategies developed in the current Loughborough work with the HSE to S&P applications.

To develop a health and safety risk model for S&P.

To provide strategic and detailed guidance to enable project teams to exploit the techniques in a manner that ensures the safety and well being of all those involved in the process.

BACKGROUND

The research project will involve the collaboration of major industry players. In particular, the research will accompany current work based on accident causality (Gyi *et al.* 1999) and occupational health management issues as discussed by Gibb *et al.* (1999). The use of interviews in this type of research as presented by Gyi *et al.* (1997) is important in this type of research and will be used extensively. The linking of accident and incident causality with the implementation of S&P is an essential component of the research project. The work carried out in the area of accident causation and intervention as detailed by Gibb *et al.* (1996) was of significant benefit in establishing a foundation for the research process.

Two major problems will be addressed by this project:

The health and safety benefits or disadvantages for S&P to date are largely anecdotal and require substantiating through a thorough research study.

Health and safety guidance on the use of S&P at both a strategic and detailed level is generally sketchy and incomplete.

METHODOLOGY

The overall paradigm adopted for the research was that of an interpretative approach (Habermas, 1970). A preliminary set of semi-structured interviews was carried out with managers and operatives at all levels in both conventional and off-site manufacturing construction organisations. An overview of the sequence of the research phases are outlined below:

Problem statement. Namely that no evidence exists to prove that standardisation & pre-assembly is indeed responsible for the amelioration in health and safety. Anecdotal statements from industry experts for example, state that by moving the on-site work to a manufacturing environment the risks will be reduced (Gibb, 1999).

To research the problem. To liase with industry and conduct detailed investigation through formal audits. To identify from these interviews areas that need to be further researched for example, the transfer of site operatives and practices immediately to a manufacturing environment direct from site with little or no instruction or training in off site manufacturing.

To formulate a hypothesis or solution set to the problem. In particular the use of a risk model to identify those areas where risks exist and to then offer guidance and support tools to assist in the management of off-site fabrication. To test the hypothesis. Using a set of recommendations developed from the research and the risk model in industry.

Finally draw conclusions from the research. Using an iterative approach drawn from both the main research and the risk model results obtained from industry

The research is collecting in-depth information from the respondents, which will in turn be used to advise industry. The information is provided by a number of industrial collaborators from a wide spectrum of both conventional construction organisations and off site manufacturing to reflect the diverse nature of the construction industry and improve the quality of the data collected.

The profile of the industrial collaborators is shown in Table 1.

Table 1: Profile of Industrial Collaborators

Industrial Collaborator	**Main Business Activity**
Case study A	Design and installation of fast-build wall systems
Case study B	Leading supplier of structural and architectural precast concrete elements,
Case study C	One of the largest construction companies in the UK with work in most construction sectors.
Case study D	Market leader in pre-assembled building services,
Case study E	An international architectural firm that works for one third of the FTSE 100 companies with over 80 percent of its work is derived from repeat commissions
Case study F	Construction of off-site manufactured modular units
Case study G	Leading supplier of modular buildings

Preliminary interviews identified the need to formalise the method of data capture. This in turn suggested the need to create a framework which would allow comparison to be made between off-site pre-assembly and conventional construction techniques for similar building components. The diagram below indicates an abbreviated version for the operational task of creating the brickwork element of a commercial building. This will be extended to form the basis of a decision making process framework for conventional and off-site pre-assembly construction techniques.

The approach for the initial stage of the research was to develop a number of research questionnaires which would form the basis of data collection and explore the issues identified through the project aims and those which emerged from preliminary interviews. A number of questionnaires were investigated. For example, Blake and Mouton's (1985) management style questionnaire was considered but was not used in this instance. An essential requirement of the fieldwork was to conduct comparable ergonomic health and safety work-place audits for both conventional construction processes and off-site pre-assembly. These are more satisfactorily carried out in the form of loose structured prompt sheets or simple checklists. In addition advice on the ergonomic content of the questionnaires was obtained from an ergonomic consultant. This was considered appropriate, enabling key ergonomic issues to remain in the foreground during data collection.

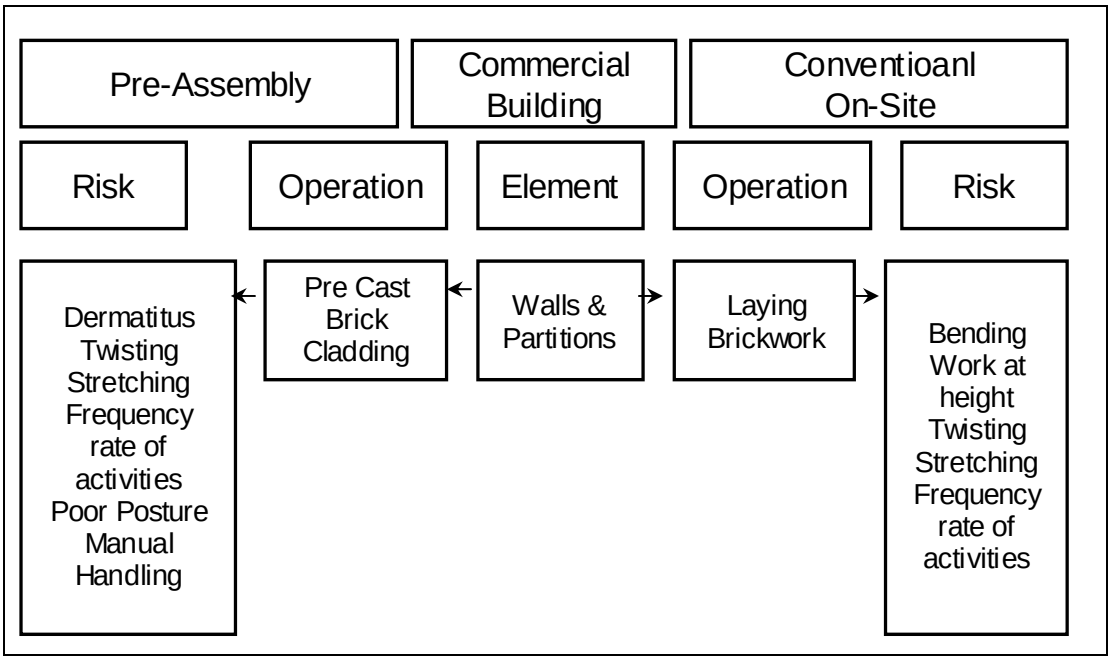

Figure 1 Comparison of risks for the creation of brickwork in Conventional versus Off-Site Pre-assembly construction.

The ergonomic audits were carried out by studying a number of case projects for each sector under consideration. Aspects considered included manual handling, potential for muscular skeletal disorders, and exposure to hazardous substances, noise, hand-arm vibration as well as material and plant risks such as crane usage. Social issues, skills, training and de-skilling were also considered. Historical data from conventional site construction was used as a benchmark for data validation.

PRELIMINARY RESULTS

The fieldwork at each case study firm involved an initial interview, which lasted 60 minutes, normally with the Director, Operations Manager and Safety Advisor. Examples of questions concerning health and safety are given in Table 2. The researcher asked questions concerning health and safety practices. Wherever possible, specific examples of recent health and safety issues were requested. This assisted validation of claims regarding activities, and provided additional information about safety practices in use. A period of observation followed, in which an overview of the layout at each workstation was recorded normally by photograph. A description of the operation carried out by the operative was obtained before direct observation of the task commenced. After several iterations of the task under investigation the interviewer used an ergonomic schedule, with questions containing ergonomic prompts in the same order and with the same wording. This was to maintain objectivity. A more detailed ergonomic checklist was then used to code specific data which would be used for comparison with the complementary conventional on site operation. The second interview lasted approximately 20 minutes and was used to ask follow-up questions where more information on health was required. This also enabled clarification concerning previous responses. The researcher was also able to re-present some questions as a check for consistency of responses.

Table 2: Examples of interview questions

How many hours per week do you normally work?

Have you had any pain, aches or discomfort in the last four weeks?
Did you have similar pain before this job?
Have you taken any time off because of your pain?

If you have taken time off, how long were you away?

In the following body areas, have you experienced any pain, ache or discomfort?

Upper limbs	**In the last 4 weeks**	**In the last 7 days**
Neck		
Shoulders		
Elbows		
Wrists		
Fingers		
Lower limbs		
Upper back		
Lower back		
Hips		
Knees		
Shins		
Ankles		

A number of issues came to the fore during the first set of studies. Some method statements were not written with the construction workforce in mind. The choice of vocabulary and the length of the outline of the system of work to be adopted raised ambiguity and concern for a number of team leaders charged with the task of interpreting the instructions. This area will be considered throughout the remainder of the research project.

All of the collaborating organisations had discharged their statutory duty by providing and issuing their employees with a company safety policy. The provision of personal protective equipment (PPE) was observed to be available to all employees although unless directed by regulation the mandatory use of such equipment was not rigidly enforced in some circumstances. For example knee protection was provided for certain tasks but its use was left to the discretion of the operative. There appeared to be several situations where the training in use of PPE was inadequate and there was evidence of inappropriate design for use.

A number of accident and minor injuries were inadequately reported. The lack of a detailed description of the type of injury, its location and the perceived cause were often recorded with insufficient information. In some instances the reported incident was incorrectly recorded. The importation of poor site practices transferred to the off-site manufacturing environment was observed. Many of the practices seen on site, such as incorrect use of personal protective clothing and the failure by a number of key operatives to acknowledge their role in the maintenance of health and safety, recurred in the off-site manufacturing environment. The use of inappropriate or ill-adjusted hand or power tools revealed a number of problems for example, the lack of

the correct range and selection for the task. The high dependence on brute force especially where a technique was adapted to get around a poor set out or confined area. The limited knowledge of task alternatives without instruction for best practice techniques.

The distinction between the engineering sector and the building sector in organisations involved in off-site pre-assembly suggested that more emphasis was placed on layout and design for safety of workstation and environment in the engineering off-site manufacturing sector than the building sector. The engineering sector placed greater emphasis on visitor control, the use of designated storage areas, colour coded delineated walkways and material storage areas.

From conversation with the safety supervisor appointed by one subcontractor employed by one of the collaborating organisations it was revealed that there was no attempt made by the safety department or site management to check whether the subcontractor had any knowledge or special training in health and safety. In addition the site management were sometimes unaware of the nature of the work and identity of some of the subcontractors on their sites. This was also found to be the case in work carried out by Dawson *et al.* (1988), who also indicated that in their case studies many site managers did not know the identity of individuals on their sites and in some cases the identity of particular subcontractor organisations.

CONCLUSIONS

After a relatively small sample of studies the extent to which firm conclusions can be drawn may be in doubt. However, the purpose of the research was to collect detailed in depth case study information not to undertake a statistical analytical survey. In order that the research conclusions remain viable the technique of methodological triangulation was adopted. Triangulation involves securing consistency of research findings from complementary research methods. In this case the methodological triangulation would utilise case study research, questionnaire surveys and action research.

The methodology presented has been developed from a pilot study using the technique of action research. The audit tools developed were used for data gathering and to assist in the identification of those areas where safety and particularly health issues exist. The tools have proved useful in maintaining the focus and direction of the research. In addition the use of a pilot audit tool trailled on a number of preliminary site visits enabled superfluous and redundant elements in the development of the tool to be omitted.

In connection with the case studies it was concluded that the first major conflict between maintaining health and safety objectives occurred when safety considerations threatened construction productivity.

The health and safety policies of the case studies on the whole were very commendable, often more specific and specialised than the law requires. However, several of the safety representatives in the case studies complained about the way management dealt with the competing priorities of safety and productivity. At times production was given priority over safety where safety management intervention would result in loss of production.

A critical in depth analysis of the full extent of the effect of standardisation & pre-assembly on health, safety and accident causality in construction will follow this

preliminary evaluation. It will include a health and safety risk model for standardisation & pre-assembly which will be tested in industry. When complete, the analysis will be used to develop a best practice guide for health and safety management of off-site standardisation & pre-assembly in each sector.

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