

CIB072

## **Health and safety management of offsite construction - how close are we to production manufacturing?**

**Lawrence McKay, Alistair Gibb, Roger Haslam and Martyn Pendlebury**  
Loughborough University, Loughborough, Leicestershire, LE11 3TU, UK

### **ABSTRACT**

Producing buildings in a factory, offsite production, dramatically improves overall health and safety performance, but there is no room for complacency. This paper presents the results of a questionnaire and interview survey using multiple sources of data linked with peer debriefing from eight major offsite production facilities. In particular, health and safety benefits along with the trend toward a production manufacturing environment are identified. The research found that attitudes toward production oriented health and safety in offsite are still in the embryonic stage, but are developing rapidly with increased awareness from management. To realise the positive outcomes from the health and safety benefits that offsite entails, offsite manufacturers must adopt a mindset akin to that already existing in the mainstream manufacturing sector. Many offsite manufacturers adopt site based techniques “under cover” of a factory. The health and safety benefits of offsite may be well understood and promoted in several arenas, academia, government initiatives and the health regulatory bodies, but unless the manufacturers themselves embrace the full health and safety potential of offsite, misunderstanding and ignorance will remain a barrier to improved health and safety performance. This work formed part of a UK government funded project, HASPREST.

*Keywords:* Safety, health, Offsite production, manufacturing.

### **1. INTRODUCTION**

The goal of this paper is to identify how close the current offsite production facilities in the UK are to the manufacturing sector in terms of health and safety practice. The results of an interview survey and observations from a significant number of major offsite production facilities are presented. In particular, health and safety benefits, along with the trend toward a production manufacturing

environment, are identified. This work formed part of a UK government funded project entitled HASPREST

The OSP industry is an important emerging sector in modern economies. OSP industries, coupled with related industries such as the manufacture of building products and systems, designers, and property developers, account for approximately 15 per cent of the national product of most countries (Seaden, Manseau 2001). The main factors influencing the development of OSP are the performance of the economy, levels of investment, and developments in materials technology, production, and installation equipment, government regulations also impact on the market. In terms of OSP growth trends, during the early 1990s there was little growth due to the recession and reduced construction and industrial investment, however, 1999 and 2000 showed a moderate improvement in growth with an overall growth forecast for 2006 of 8 per cent (AMA research 2002). The expected increase in modern methods of construction and the desire for more innovation in construction, fuel the belief that there will be an increased contribution to economic growth and hence an increase in OSP. It is argued however, that problems of poor rates of investment especially in research and development, coupled with poor communication between academia and industry (Dulaimi et al. 2002) contribute to the view that the industry has much more potential to innovate. This is supported by (Tatum 1991) who adds that the construction industry professionals must review their need to innovate and work in close partnership with Government.

The UK construction industry has a lower fatal accident rate than most other EU member states and the US (Eurostat 1996). A similar situation exists for non-fatal accidents. However, one third of all work fatalities in the UK happen in construction and it's employees are six times more likely to be killed at work than employees in manufacturing (HSC 2001a). A number of high profile initiatives have been carried out that address the industry's poor health and safety record. These include Rethinking Construction (DETR 1998) and Accelerating Change (Strategic Forum for Construction 2002). Despite these efforts, from the "league table" of industries, construction still has one of the highest rates of fatal and major injuries (HSC 2001a). The advent of innovation and modern methods of construction using OSP have offered a possible route to improvement. Many contractors are embracing the drive toward OSP, which is the manufacture of construction elements, components, modules and complete buildings in a factory environment. OSP is changing the causal relationship between accidents and construction methods and while the health & safety risks reduce with OSP, the actual hazards change and these need to be considered carefully throughout the project process.

In the last twenty five years there has been a marked effort to attempt to improve the management of health and safety in the construction industry to address this lack of performance. Surveys commissioned by the Health and Safety Executive (HSE) have identified that poor management leads to 75 per cent of the causes of

fatal accidents (HSE 1988) and that health and safety risks during a project need to be managed correctly (HSC 1995b).

## **2. RESEARCH METHOD**

### *2.1 Site interviews and ergonomic audits*

The main background to this research is described in (McKay et al 2002). Detailed questionnaires, ergonomic assessment forms, manual handling assessment forms and both semi structured and focused interviews were used to identify the OSP company's health and safety practices. The purpose was to identify how OSP can improve health performance and reduce accident risks, and how this data can be used to develop health and safety improvement strategies. Best practice examples were noted from the manufacturing industry in particular car production and the manufacture of aluminium products for the building industry.

### *2.2 The sample*

The 33 personnel interviewed were experienced managers with responsibility for health and safety or operatives who actually performed the tasks within the OSP facility. The OSP companies were representative of the type of product mix currently available in the UK OSP market. They included eight companies from the construction and OSP building sector (i.e. the manufacture of structural and architectural precast concrete elements and modular buildings, mainly for the residential and education sector), two of the companies were from the manufacturing industry. The information obtained to some degree reflects their own experiences and opinion. The eight OSP companies were manufacturers who generally were responsible for installing the OSP units. Access to the companies was through steering group participation as well as through the European Construction Institute, an organization made up of clients, contractors, architects, construction professionals and the various trade associations.

### *2.3 Interview schedule*

The observations and interviews at each company were split in two parts. The first part took the form of a two-hour interview based on the channel framework as proposed by (Reason 1991). The importance of maintaining a regular and consistent record and analysis of these proactive safety state indicators, in order to ensure that managers are in touch with the companies health and safety "state of health". The interviews were recorded by the researcher. To ensure validity multiple sources of data were used (triangulation) and critical discussion with peers (peer debriefing) along with allowing the sample to respond to the interview interpretations (member checking) were used. This method ensures research rigour after (Erlandson et al., 1993). A summary of the type of questions asked is given in Table 1.

The second part of the observation and interview process involved direct observation and interviews at workstations or on site to gain an understanding of the operative's views on the effects of the work on their health and their willingness to adopt to changes in work. Task analysis was carried out on all of

*Health and safety management of offsite construction - how close are we to production manufacturing?*

the production processes and installation methods observed (manual handling, use of tools, access to the work and interaction method with automation and plant) to identify the health risks involved. Ergonomic assessments were made of the various installation methods to provide a measurement of the loading on the operatives' bodies and an indication of the necessity for change. The RULA (rapid upper limb assessment) postural analysis tool as described by (McAtamney, Corlett 1993) was used for this work in parallel with ergonomic checklist observation sheets. Table 2 overleaf shows a summary of the issues addressed.

**Table 1:** Sample of the type of questions and discussion points during interviews (Excerpt).

<b>Questions and issues</b>	
Channel 1 Reporting systems	Details of project data, where is the data kept, is the data analysed for causal factors, what are the causation factors
Channel 2 Unsafe act	Definition of unsafe act, what is /is not deemed unsafe
Channel 3 Precursor of unsafe acts	Workplace design with regard to ergonomic considerations, ergonomic assessment techniques, observation techniques, task unsafe act simulation exercises
Channel 4 Failure indicators	Safety audits, frequency, techniques, number and type of safety checks, use of audit data
Channel 5 Safety culture	Health surveillance, pre-employment medicals, screening, alcohol and substance abuse policies, Visitor control PPE

**Table 2:** Sample of the type of observations and ergonomic issues at workplace inspection (Excerpt).

<b>Observation and ergonomic issues</b>	
Workplace data	Visitor control, PPE (Correct type, available, worn), Noise, Air quality, Lighting, Trip hazards: inadequate space for legs and feet, headroom, avoiding twisting, steps, stairs, ramps Required height: Activity suitable for workers between 1.5m and 2m:
Ergonomic data	Extension of arms: Movements required for reach up to 30cm Grip: Power grip only Trunk movement: Large movements bending under 90 degrees
Manual handling	Load: Difficult to handle due to: Weight, height, width, depth, unevenly distributed when carried, difficult to grasp, sharp at corners edges, constructed of unsound material, problem of a two handed power grip.
Task analysis	Risk apparent with: standing posture, sitting posture, prolonged actions, pushing, pulling, twisting, stooping, reaching forward, overhead, peaks in workload, working without break, job organization, unsuitable tools, mechanical aids, imposed work rate

During this observation and interview process, copies of any method statements, risk assessment, accident reports, health and safety policies were obtained as evidence to support and prompt discussion during the interviews.

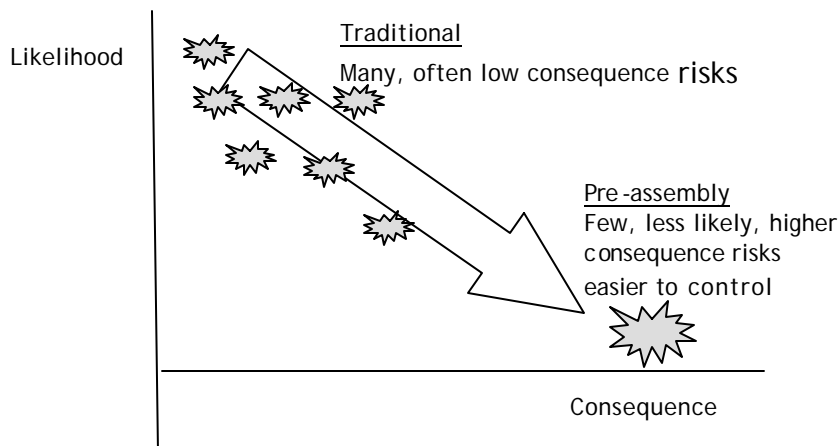
### 3. RESULTS AND DISCUSSIONS

A full analysis of the results is out with the scope of this paper, however a discussion of the main health and safety benefits observed in OSP are described, this data formed the main deliverable of the HASPREST research project.

The results of the audits showed that by taking the work away from the construction site, into a factory, the control of risks is increased. Simplistically, the manufacturing sector is between 4 and 6 times safer than construction (UK statistics on fatal and major accidents). Furthermore, although these statistics are heavily influenced by the large 'non-construction-related' manufacturing sector, there is still evidence that manufacturing for construction is safer for a number of reasons, including:

- Risks are less as they are easier to control
- Training is easier to achieve
- There is less trade overlap
- There is a much lower workforce turnover
- People 'look out' for one another

The main thing that happens to on-site risks by using OSP is that the many, common-place, high-likelihood, low consequence risks are largely replaced by fewer, higher potential consequence risks, which are much less likely to occur as they tend to be easier to identify and control.

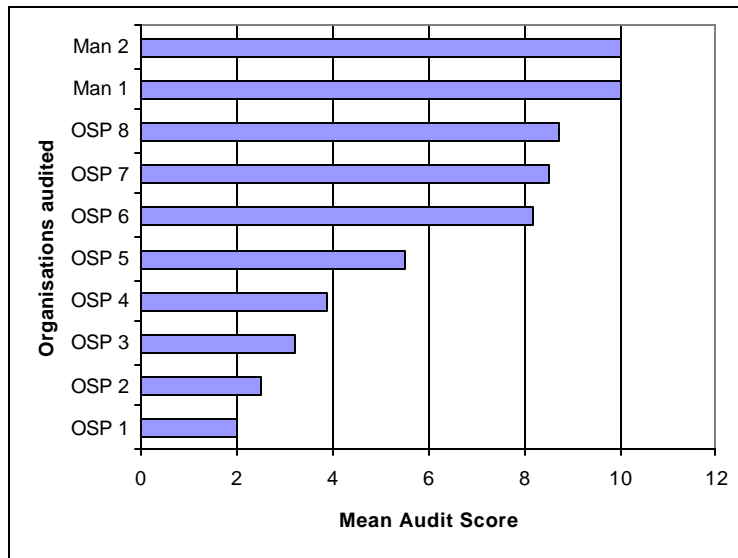


**Figure 1** What happens to risk through increased use of pre-assembly (Gibb, 2003)

In total some 40 audits were carried out, over the ten companies. The organisations were ranked in the following way; three OSP companies in the

*Health and safety management of offsite construction - how close are we to production manufacturing?*

author's opinion were approaching production manufacturing attitudes towards health and safety; two made some efforts and three were no different to that of an average construction site. The two non-construction companies were used as a comparison with the manufacturing sector (Man 1, Man 2 in figure 2). The audit used a points system. Points were awarded for workstation layout, ergonomic consideration of the task, use of tools and the support and training systems in place, coupled with health monitoring systems. The companies were ranked as shown in figure 2.



**Figure 2:** OSP organisations ranking with regard to providing an indication of how close they resemble production manufacturing attitudes towards health and safety. (1 =low, 10 =high)

The key issues were that those that were approaching production manufacturing attitudes toward health and safety, had considered and invested in ergonomic consultation in terms of workplace and workstation layout design. Consideration of the task and how the operative interacts with tools, noise, lighting, climate, vibration etc had been considered for the relevant task. Continuous health monitoring systems were in place to monitor the operatives' health on a weekly basis through blood analysis and regular reports from the company physician. The shift patterns were rotated on a 3 shift pattern, representation from the workforce had been actively encouraged and included in shift design.

Key issues relating to those that were poor at approaching production manufacturing attitudes toward health and safety, included workplace layout that was similar to site based conditions, little regard of operative task, to no

*Health and safety management of offsite construction - how close are we to production manufacturing?*

---

consideration of delineated zones for material storage, component or module production, poor feedback from employees regarding production, high staff turnover and violation of safety rules.

**4. HOW CAN OSP MANUFACTURERS TAKE APPROPRIATE ACTION TO REDUCE THE HEALTH AND SAFETY RISKS AND LEARN FROM MANUFACTURING?**

*Factory manufacture of multi-service distribution modules*



*ã Loughborough*



*ã Loughborough*

**Figure 3:** Factory manufacture of multi-service distribution modules

This case study illustrates the following main benefits which were identified following interviews and audits conducted over several visits. The distribution modules were manufactured by Crown House Engineering. In normal practice the ductwork and cabling would be installed on site after the suspension brackets and trays were welded in place. However, in this project the units were fully finished with all internal cabling and ductwork installed at a convenient bench height at Crown House's manufacturing works before the units were transported to site (Figure 3). The audits at the organisations sites found that the main benefits were:

- Reduced construction programme
- Better control of welding operations
- Elimination of the need for working at height
- Elimination of the need for site scaffolding
- less risk of contamination
- less risk of trips, slips, falls
- Materials are mechanically handled right to the workface
- Work in open spaces as against the confined spaces on-site
- Significantly lower trade overlap and interface
- Work at workbench level, with reduction in MSDs, as no crouching required, safer workbench level inspection possible
- Elimination of working at heights
- General welfare facilities better in the factory environment

*Health and safety management of offsite construction - how close are we to production manufacturing?*

These audits, and other research data were used as the basis for the HASPREST CD part of which involved the development of checklists to help managers understand what to look for in terms of health and safety. Table 3 is adapted from the HASPREST CD and illustrates a checklist that has been developed from this work to show what aspects should be considered by OSP companies to improve health and safety performance:

**Table 3: How Manufacturing can reduce health and safety risks (Excerpt)**

Main operations affected	H&S issues	How manufacturing can reduce H & S risks
Deliver materials etc to factory	Various	PPE typically employed on construction sites is not necessarily enforced in many manufacturing facilities (e.g. head protection is rarely used). However, the manufacturer should be able to demonstrate that the risks have been assessed and the appropriate hierarchy of risk elimination, reduction and control has been employed
Assemble frame structure	Manual / mechanical handling	Weight and centre of gravity and safe lifting points should be clearly identified on each element to facilitate mechanical and manual handling where appropriate
Weld channels / box sections, paint frame	MSDs, cuts etc burns, fumes Overhead work, COSHH	Should be easier to control in factory
Install plinths/box sections/brackets for plant pressure vessels etc	MH, mechanical handling	More control, clean environment less risk of contamination, electrical shorts.
Install pipe-work and valves, control panels. Install control panels	Manual handling, crouching, restricted work area, manual handling	Volumetric pods enable "traditional" operations normally done in congested areas to be re-engineered to increase productivity as well as reduce health and safety risks. For example, units with small, restricted floor areas may benefit from mechanical plant being installed prior to the walls being assembled. Best practice manufacturers will select such methods, whereas others tend just to transfer site traditions into a factory environment. Inspectors should seek to encourage such process innovations
Transport	MSDs, cuts etc. craneage, road traffic etc	More organised as fewer, larger deliveries, More likely to be mechanically handled, Check that transport and delivery method minimise manual handling, Weight and centre of gravity and safe lifting points should be clearly identified on each element to facilitate mechanical and manual handling where appropriate, Review packaging and orientation to facilitate safe unloading without double handling

## 5. CONCLUSIONS

This paper has argued that the OSP industry in the UK can benefit, in terms of health and safety, by taking best practice and innovative techniques from the manufacturing industry. One of the main things that can be done is to increase the amount of ergonomic design consideration in the workplace and utilise new safeguards such as health monitoring and surveillance. These health systems are not new and have been in operation in the manufacturing industry for many years, but action by OSP managers early in the design and planning stages will help to

eliminate certain hazards and transform the working environment so that the safety and occupational health of operatives are improved and can be controlled.

The survey found that many OSP manufacturers still adopt site-based techniques “under cover” of a factory. Although there was a desire among those interviewed to see an increase in production-oriented techniques, a lack of management focus towards production orientated practice was observed. The health and safety benefits of OSP may be well understood and promoted in several arenas, academia, government initiatives and the health regulatory bodies. However, unless the OSP industry embraces a manufacturing culture, the opportunity for increased health and safety performance will be delayed, reducing protection to operatives’ health.

## **6. ACKNOWLEDGEMENTS**

The authors acknowledge the significant contribution from a large number of industrial collaborators and government representatives on the projects covered by this paper.

## **7. REFERENCES**

- AMA research 2002, *The UK Prefabricated Buildings Market Report*, AMA Research, Cheltenham, UK.
- DETR (1998) *Rethinking construction: The report of the Construction Task Force*, DETR: London.
- Dulaimi, M.F., Ling, F.Y.Y., Ofori, G. & De Silva, N. 2002, "Enhancing integration and innovation in construction", *Building Research and Information*, vol. 30, no. 4, pp. 237-247.
- Erlandson, D.A., Harris, E.L., Skipper, B.L. and Allen, S.D. (1993) *Doing Naturalistic Enquiry. A Guide to Methods*, Sage Publications, London.
- Eurostat (1996) *Accidents at Work in the EU in 1996 - Statistics in FOCUS, Theme 3 - 4/2000*,
- Gibb, A.G.F., (2003), Dry sites – impacts of off-site production and automation on accidents and occupational health risks, Association of Planning Supervisors CPD events, October-December, APS, Edinburgh, Scotland.
- Hignett, S., McAtamney, L. 2000, "Rapid Entire Body Assessment (REBA)", *Applied Ergonomics*, vol. 31, no. 2, pp. 201-205.
- HSC, (2001a) *Health and safety Statistics 2000/01*. HSE Books: Sudbury, Suffolk.
- HSC 1995b, *Designing for Health and Safety in Construction: A guide for Designers on the Construction. Design and Management Regulations 1994*, Health and Safety Commission, Sudbury, Suffolk, HSE Books.
- HSE 1988, *Blackspot construction: A study of Five Years fatal Accidents in the Building and Civil Engineering Industries*, Health and Safety Executive HMSO, London.
- McAtamney, L., Corlett, E.N. 1993, "RULA: a survey method for the investigation of work-related upper limb disorders", *Applied Ergonomics*, vol. 24, no. 2, pp. 91-99.

*Health and safety management of offsite construction - how close are we to  
production manufacturing?*

---

- McKay, L.J., Gibb, A.G.F., Haslam, R., Pendlebury, M. 2002, "Implications for the effect of Standardisation and Pre-Assembly on Health, Safety and Accident causality-Preliminary Results ", pp. 257-64.
- Reason, J. (1991) Too little and too late: a commentary on accident and incident reporting systems, in near Miss Reporting as a Safety Tool, van der schaaf, T.W., Lucas, D.A., and Hale, A.R. (eds), Butterworth-Heinemann, Oxford, pp.9-26.
- Seaden, G., Manseau, A. 2001, "Public policy and construction innovation", *Building Research and Information*, vol. 29, no. 3, pp. 182-196.
- Strategic Forum for Construction (2002) Accelerating Change (Rethinking Construction: London).
- Tatum, C.B. 1991, "Incentives for technological innovation in construction", *Construction Congress '91, Apr 13-16 1991* Publ by ASCE, New York, NY, USA, Cambridge, MA, USA, pp. 447.