BSRIA

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Site Productivity - 2002

A guide to the uptake of improvements

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CONTENTS

EXECUTIVE SUMMARY

The BSRIA report *TN 14/97 Improving M&E Site Productivity*, published in April 1997, concluded that improved processes during the pre-construction and construction phases of a project, combined with the use of innovative products and better trained personnel, would enable key building services elements to be installed in less than 10% of conventionally accepted timeframes.

The key conclusion from this subsequent research exercise is that those UK construction project teams that implemented improvement strategies and actions in accordance with BSRIA best practice recommendations have realised significant improvements in site productivity.

1 The construction projects that demonstrated the greatest uptake of the 63 BSRIA best practice recommendations produced the highest levels of construction site productivity

Table 1: Summary showing how many of the 63 recommendations were implemented on the four study projects. One point for full implementation of each recommendation, and half a point for a partial implementation.

	Christ Church Court	Stansted Airport	Vodafone HQ	LivingWell
Observed full uptake of recommendation	15	27	31	5
Observed partial uptake of recommendation	40	30	26	26
No observed uptake of recommendation	8	6	6	32
Total points accumulated by project	35	42	44	17

2 The teams that designed for high site productivity, used innovative components and exploited off-site manufacture realised a step-change improvement in construction-site productivity rates

This research exercise independently identified the following key examples of best practice, where project teams reduced system installation times to less than 10% of conventional site timeframes:

- Prefabricated mechanical and electrical module installation on the Stansted Airport terminal extension project

- Prefabricated plantrooms on the Vodafone HQ project
- Prefabricated electrical risers on the Vodafone HQ project
- Multi-service chilled beams on the Vodafone HQ project.

When compared with international site productivity data collected by BSRIA over the last eight years, these projects have established new, best practice levels of performance.

The Christ Church Court study project was another notable success. Although installation methodologies were largely based upon traditional site practices, the average production (or output) increased by 25% compared to 1997 benchmarks because the project team significantly reduced site delays.

3 Multi-disciplinary working, reduced site delays, off-site manufacture and the use of innovative components and tools are crucial to improving site productivity

Although many factors influence project performance, this research identified four critical success factors that have enabled the monitored construction project teams to improve their site productivity:

- Convergence between disciplines through more multi-disciplinary and collaborative design, manufacture and installation
- Stabilisation of the site working environment by minimising delays and reducing rework
- Minimisation of site activity through the exploitation of off-site manufacture
- Quicker system composition on site through the use of innovative components and tools.

4 More enlightened and strategic project management at the start of a project will deliver the greatest potential for improvements in site productivity

While every BSRIA best practice recommendation will play a role in helping to deliver better project performance, the research showed that those recommendations which fall in the category of construction philosophy had the greatest potential to drive change and improve installation performance. The recommendations in this category, which were proposed by BSRIA in 1997, are:

- A comprehensive constructability review that involves specialist m&e contractors should promote construction efficiency and good access

- Designs and specifications presented to site operatives should promote the minimisation of site activities
- Prefabrication and pre-assembly should be considered
- Standard time saving components and connections should be used
- The quantity of types and sizes should be rationalised.

These recommendations are concerned with fundamental changes on construction projects, rather than trying to manage or improve flawed, inappropriate or overly complex existing processes. They therefore have their origins in process management and production management, rather than project or contract management.

This change of emphasis from tactical and transactional thinking to strategic thinking, and from construction phase fire-fighting to pre-construction phase re-definition and preparation, is something that needs to become more widespread in UK construction.

This research initiative showed that, within this topic of construction philosophy, significant progress has been made in concurrent engineering and product innovation in UK construction projects during the last five years. The study proved that the use of these approaches meets clients' needs while delivering great reductions in both site labour consumption and construction programme times.

5 Although the use of innovative products and off-site manufacturing techniques can deliver a huge improvement in construction project performance, their true value is still not being fully exploited

Prefabricated elements - and many other innovative site-based systems - demand a different construction process and an evolved skill-set among management and installing operatives. The installation of large building services modules, for example, is completely different to conventional practice because it relies more on logistical and material handling skills than traditional building services skills.

This research project showed that although these modern products can deliver a step-change in construction project performance, their true value is not being fully exploited. This is because of the absence of appropriately trained site personnel, well-defined modern processes and genuine production-focused collaborative environments. These shortcomings continue to produce constraints that create significant variability in the site installation performance of these items.

These same key restraining forces, or barriers to process stability and improvement, were also observed in this research project as the root causes behind the delays and installation variability that affected the conventional site activities monitored.

6 For the benefits of innovative working to be realised, major improvements in planning, co-ordination and control are required

The research on this project has confirmed that concentrating on these factors, such as rapid assembly products and off-site manufacture, can generate enormous construction programme time benefits. However, the site observations have also proved that a paradigm shift in site installation methodology and performance can only be delivered if the pre-requisites such as work sequence, explanatory drawings, appropriate equipment and work stages are well defined, planned and executed.

The very nature of the pre-fabricated module installation process amplifies the cause and effect relationship of constraints when compared to conventional site installation. This is because a constraint can cause installation activity to cease completely in a pre-fabricated module approach, while in conventional practice composed of work elements often between one minute and five minutes in duration, alternative work can often be found in the event of a constraint to installation activity. Both are inefficient and can be considered as waste, but the traditional approach, while having lower levels of output, is inherently more flexible.

This situation makes the planning, co-ordination and control of a construction process using prefabricated elements even more important than that required by conventional practice.

7 The use of innovative ways of working, innovative products and new communication technologies needs to become more widespread

For the productivity improvements outlined in this report to be more widespread the construction industry needs to become more aware of innovative products and processes. It also needs to invest more in training and education, and to teach its people how new products can result in a more cost-effective and productive construction process. Enabling technologies that underpin investment in education, training and innovation include, for example, barcoding of construction elements, wearable tablet and notebook computers, and radio frequency identification tools.

Overall, the need for research, development and application of more production-focused processes and products, combined with the development of people capable of delivering innovative ways of working, remains as strong as ever.

BACKGROUND TO THE RESEARCH

2.1 INTRODUCTION

The organisations that construct and maintain the built environment are the largest industrial cluster in the European Union. They represent 11% of total gross domestic product (GDP), an annual turnover in 1999 of £520 billion and a quarter of all industrial output. According to *RTD Strategies for European Construction*, published by Villa Real in 1999, this cluster involves 2·7 million enterprises and employs 30 million people. Furthermore, the DTI *Construction Statistics Annual 2001* shows that the annual value of work undertaken in 2000, by the 163 426 contractors working in UK construction, was £56 billion. These organisations employed 945 000 people of which 466 000 were site operatives.

Businesses and their construction supply chains are becoming increasingly aware that the work of this construction community affects the overheads of all industrial and commercial activities. It therefore follows that the international competitiveness of all industries can be improved with better construction productivity and quality. Indeed, construction industry clients and the people that produce the built environment have begun to realise that buildings, and the spaces and systems within them, are productive assets not simply crude containers.

We now have a more positive climate for change within the UK construction industry than at any time in the industry's recent history. Two key published reports, *Constructing the Team* (1994), and *Rethinking Construction* (1998), have been uniquely followed-up by an action programme.

These reports reconfirmed the benefits of working in collaboration and cooperation, in place of the traditional attitudes, which were at best remote, and at worst adversarial. They also clearly stated that performance measurement was a critical success factor in any continuous improvement initiative.

2.2 PROGRESS SINCE 1997

This research project was supported by the DTI and the construction industry to produce independent, real-world data that construction supply chains could employ to improve the performance of their projects.

Previous BSRIA research undertaken between 1995 and 1997 monitored seven projects and isolated the critical success factors behind the best performing teams and activities. It then translated these into a series of 63 pre-construction phase and construction phase best practice recommendations.

The recommendations were divided into 10 categories: contract strategy, project planning, project organisation, services design, construction philosophy, temporary works, procurement strategy, work arrangement, work area control and installation. The common thread of

these 63 recommendations was to make available time and productive time equal by eliminating delays, and then to optimise what was produced during productive time.

This optimisation means that project teams should aim for high production rates. Specialist trade contractors also need to install in a manner that meets the needs of all other parties working on the same construction project, as well as their own needs. Success also requires improvements in collaborative working and management.

During this research period, construction has begun to shift from a labour-intensive industry to a knowledge and capital-intensive industry. Some construction sites are now characterised by more fixed assets and fewer, but better trained and better managed staff.

This progress is de-skilling or eliminating many aspects of traditional site practice. As a consequence, however, a new set of skills are required, relating to enabling technologies, collaborative working and information literacy. To quote the 1998 Construction Task Force report *Rethinking Construction:*

Site construction needs to be carried out by a relatively small dedicated team of multi-skilled site operatives who develop their expertise over a series of projects. Modern building techniques require fewer specialist craftsmen but more workers able to undertake a range of functions based around processes rather than trade skills.

Elsewhere in the construction supply chain, raw materials are being supplanted by components and sub-systems to be assembled on site. There is also increasing convergence between different disciplines and a trend towards greatly increased design and engineering inputs to products. Within the design process, sustainability, total cost of ownership, and building occupant performance are increasingly important design parameters.

2.3 THE UPTAKE OF IMPROVEMENTS

This follow-on BSRIA project: Site Productivity Improvements – Adoption of Best Practice Recommendations, was initiated to monitor four construction projects that had implemented some of the 63 BSRIA best practice recommendations. The objective of the work was to use the original BSRIA database on delays and installation rates as a point of reference, and then to analyse the impact that the adoption of these recommendations would have on the performance of construction sites.

The four projects studied are an office development in the City of London called Christ Church Court, the terminal extension project at Stansted Airport, the construction of a new worldwide headquarters for Vodafone in Newbury, and a pair of LivingWell health club facilities in Ashford and Perth.

The projects monitored during this research exercise have reacted to the demands of the modern business world and implemented numerous industry best practice recommendations. A key aspect was the understanding by the project teams of the need to improve, coupled with the willingness to try. They also permitted BSRIA to independently analyse their performance.

The impact of the recommendations has been varied: some have contributed to emerging paradigm shifts in the construction process, some have generated a quantifiable step-change in construction site performance, some have had less significant impact and others still face technological, intellectual or organisational barriers to implementation.

However, the one common benefit that all the project teams have shared is that their thought processes have been changed through their willingness to challenge and improve conventional practice. These teams are now in a position to build upon the successes that they have created. They also have a greater and more focused understanding of the critical success factors which require further improvement.

BSRIA hopes that the data and evidence gathered through the Uptake of Productivity Improvements project will act as a catalyst for change and improvement within all construction organisations. The results speak for themselves. All construction firms have to do in order to profit from productivity is to apply the measures that work.

2.4 THE TYPICAL BUILDING SITE

An effective starting point for a continuous improvement initiative is to establish a simple representation of a typical working day, as shown below. A diagram of his nature can often be used as a focal point for explanations, discussions and feedback amongst all levels of project personnel.

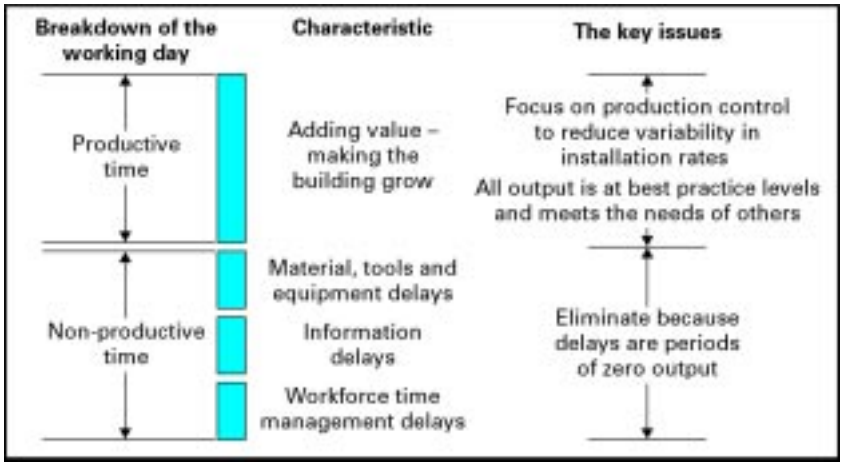

Figure 1: Breakdown of a typical working day on a construction project.

BSRIA's primary and secondary research over the last eight years indicates that competition is not the main driving force behind change

and success. It is the exception and generally provides an unsustainable foundation for any company or enterprise. Recent work on the evolution of species on Earth, for example, identified that collaboration is a much more widespread and important driver for change.

Life depends not on the survival of the fittest but the survival of the very fittest, which means that the species that flourish are the ones able to cope best with their environments.

It appears that in contemporary business, the nature of what clients expect from their construction supply chains, and what construction supply chain organisations expect from each other, is evolving. The traditional physical construction outputs are now considered to be the minimum that is required. The leading companies are combining these physical deliverables with levels of service provision that is reducing variability, cost and time, while increasing predictability, customer satisfaction, safety and profit. A contrast between traditional and new construction industry deliverables is shown below.

Table 2: Traditional and contemporary construction industry deliverables.

Traditional construction industry deliverables	Contemporary construction industry deliverables
Drawings, specifications, contracts, change orders, requests for information, boilers, pipework system	Timeliness, accuracy, cost-effectiveness, appropriateness, safety, full co-ordination, reliability, flexibility, transparency, minimum waste

Tomorrow's winners will have changed their culture through a clear understanding of what their real deliverables are. Collaboration, both internally and externally will be a key driver in the delivery of these new construction outputs.

In making this transition, successful enterprises will have evolved from being project-centred to a business-delivery culture. Consequently, process management will take precedence over project management as the technique best suited to meeting and exceeding clients' expectations. In process management, teams search for improvement through questions such as "Why is it like this?", "What are the key factors inhibiting performance?" and "How can it be improved?". This is in contrast to project management, which focuses on managing what currently exists.

2.5 SYSTEMS THINKING

In the quest for understanding, control or improvement, organisations have traditionally tried to break things into their smallest elements. Indeed, research shows that most management practices, contractual arrangements and work-scoping methodologies in construction also

adopt this approach through the composition of independent, single-disciplinary work packages and the formation of organisational or sub-contract hierarchies. This approach inhibits communication and collaboration and often creates a culture based on own needs rather than project objectives.

In contrast, systems-thinking examines the interfaces and interdependencies that exist in and between products or processes. It is a much more powerful mechanism for convergence, delivery and improvement. The most successful projects monitored during this research exercise have adopted this philosophy and consequently generated significant performance improvement in site production rates.

2.6 MANUFACTURING AND ASSEMBLY

The production stage of a construction project involves the three core inter-related sub-processes of design, manufacture and assembly. In order to reduce waste during the production phase, it is essential that the manufacturing and assembly processes inform the design.

Early integration of knowledge from manufacturers and specialist trade contractors plays an important role in the delivery of these objectives. This approach enables greater levels of standardisation, rationalisation and off-site manufacture, through the selection and integration of standard components around a co-ordinated manufacturing and assembly plan.

2.7 FIRST-RUN STUDIES

First-run studies are a means of prototyping an operation or process, recording the plans and testing it prior to full implementation on a project. They are an effective means of delivering improvement, through feedback from physical activities to planning and design. The objective is to determine the best means, methods and sequencing that enable quality work assignments to be made.

First-run studies are carried out prior to the scheduled execution of the process, while there is time to acquire different or additional prerequisites and resources.

More information on the first-run studies is included in the feedback from the Stansted Terminal Extension and Vodafone Headquarters projects in this report. The Lean Construction Institute (www.leanconstruction.org) is also an excellent resource for data on construction-related production management and first-run studies.

2.8 PRODUCTS NOT FUNCTIONS

Traditional construction methodologies have focused on the functions of the construction team rather than building products. For example, we tend to think in terms of work undertaken by a pipe fitter, an electrician or a duct erector, rather what is required to install a fan coil

unit in the most efficient and effective manner.

Consequently, as BSRIA research has shown, typical installation processes involve multiple visits to the same work area by numerous trades. Each trade normally has its own material supply chain, different personnel, independent programmes and separate working drawings. Production control is complex due to the vast number of interfaces and interdependencies that exist, and because the objectives of the individual specialist trade contractors, and the people that work for them, often conflict. The end result is an unstable production environment, which causes time, cost, quality and safety problems. A better approach, as called for by the report *Rethinking Construction*, is to integrate the process and the team around the product.

2.9 PRODUCTION MANAGEMENT

BSRIA research has shown that traditional construction management is often focused more on managing contracts than delivering high levels of installation performance. Normal sub-contract and work package cultures, which are prevalent in UK construction, break projects down into independent elements, and create hierarchies within each element. The recipients of sub-contracts are often less able to manage the work scope and its inherent risks than the originators of the sub-contract. Consequently, this methodology generally introduces inefficiency and ineffectiveness wherever it is applied.

This contractual approach, where the emphasis is on "Who does what" or "Get someone else to do it", rather than a production approach with an emphasis on "What is the best mechanism for delivering optimum production rates, quality or safety?" often loses a holistic, collaborative, mutually beneficial viewpoint and neglects to properly manage interfaces and interdependencies. UK productivity, as factually shown in BSRIA research, is therefore often way below international best practice levels.

The construction industry needs to focus more on the mechanisms for delivering high production rates, with inherent safety and quality, at the outset of projects. This can be achieved through innovative work packages that focus more on products than functions, greater collaboration, better planning and computer modelling, improved logistics management, focused site organisation, performance measurement and learning from experience.

DETAILED PROJECT FEEDBACK

3.1 CHRIST CHURCH COURT

Christ Church Court is a £75 million, high specification, financial services office development in the City of London. The building provides 28 000 m^2 of office space on eight floors. Heat generation and electrical plantrooms are located in the basement. Chilled water plant and diesel standby generators are located on the roof.

The project was executed through a construction management procurement route with the nomination of numerous key specialist trade contractors. The site observation period focused on ductwork, and mechanical and electrical services, and the activities of the building management systems specialist trade contractor on the shell and core phase of the project.

Delays

Delays at Christ Church Court occurred in the key areas of materials, tools and equipment, information and workforce. However, there was a decrease in the magnitude of delays during the ten-week observation period due to feedback and continuous improvement. The percentage of available time lost to these key delays was 19%, which was significantly less that that the average of 35% recorded on the four UK study projects in the original BSRIA report on site productivity (see Table 3 opposite).

Table 3: An overview of delays on the Christ Church Court project.

Trade package	Delay type and magnitude (percentage of available time and total cost of delay[1])					
	Information	Materials, tools and equipment	Workforce time management	Total delay	Total potential saving	Average daily saving[3]
Mechanical period 27 August - 30 Nov 1999	5·6% £8636	12·9% £19 894	2·3% £3547	20·8%	£32 078	£471
Electrical period 20 September - 30 Nov 1999	5% £6053	5% £6053	1·9% £2300	11·9%	£14 407	£267
Ductwork period 16 August - 30 Nov 1999	5·3% £7493	17·6% £24 880	1·8% £2544	24·7%	£34 918	£453
	Average 5·3%	Average 11·8%	Average 2%	19·1%	£81 403	£1191
BSRIA benchmark[2]	7%	9%	19%	35%		

[1]Assuming an all inclusive site operative cost of £12.00/h times the number of workers involved in this trade.
[2]1997 BSRIA report: *Improving M&E Site Productivity.*
[3]Assumes all delays would be eliminated. This would be an ideal solution.

Installation performance

Each of the trades monitored demonstrated an ability to operate at best practice installation levels. However, a combination of factors within their control (and many that were the responsibility of the construction manager, suppliers or other trades) created an unstable production environment where performance and predictability levels were not high. There was therefore a marked variability in installation performance on this construction project.

The following table provides feedback on installation performance of the ductwork, pipework, and electrical trades for the observation period between the 16 August and 30 November 2000.

Table 4: The m&e installation performance (a percentage of self-imposed targets).

	Ductwork	Pipework	Electrical	Mean of all three trades
Best	100%	98%	90%	96%
Average	53%	62%	58%	58%
Worst	8%	12%	20%	13%

The use of a hoist at Christ Church Court enabled the site operatives to access all levels, including the basement and the roof.

Ductwork storage at basement level before elevation to point-of-installation on the upper floors.

Too much double-handling of ductwork components consumed site operatives' time.