METHODS FOR MEASURING THE "UNMEASURABLE": EVALUATING THE BENEFITS OF PRE-ASSEMBLY AND STANDARDIZATION IN CONSTRUCTION

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The decision to use pre-assembly and standardization is often not made early enough in the construction design process. If traditional designs have to be adapted at a later stage, this is clearly inefficient. There is a reluctance among clients and contractors within the construction industry to adopt recent government and industry initiatives and employ new technologies because they cannot see the "Pay Back". This paper describes the research being undertaken to develop a methodology for measuring the benefits of pre-assembly and standardization for construction projects from feasibility, through design and construction, to handover, operation and decommissioning. The paper describes and classifies the benefits of pre-assembly and standardization and then outlines the tools and techniques available in construction and other industries for measuring the benefits. While some benefits are measurable in monetary or non-monetary terms, other benefits have an influence on the success of the project or business, yet are not easily measurable. The work described forms part of the IMMPREST Research Project (Interactive Model for Measuring Pre-assembly and Standardization Benefit across the Construction Supply Chain).

Keywords: benefit evaluation, performance indicators, pre-assembly, standardization

INTRODUCTION

Recent government reports, including the Egan Report "Rethinking Construction" (1998), discuss the need for performance improvements in the UK construction industry. Egan (1998) identifies supply chain partnerships, standardization and pre-assembly as having roles in improving construction processes and also notes that the construction industry needs to learn from good practices within other industries, using similar tools and techniques for performance measurement and improvement.

In this context, research is being undertaken at Loughborough University to develop a methodology for measuring the benefits of standardization and pre-assembly for construction projects from feasibility, through design and construction, to handover, operation and decommissioning. The work described forms part of the IMMPREST Research Project (Interactive Model for Measuring Pre-assembly and Standardization Benefit across the Construction Supply Chain), which is funded for three years from October 2000 by EPSRC and DTI under the IMI LINK programme "Meeting the Clients' Needs through Standardization". There is a consortium of collaborating companies from across the construction supply chain.

The research follows on from a successful pilot study at Loughborough University, COMPREST (Cost Model for Pre-assembly and Standardization), which investigated

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the standardization and pre-assembly design and construction processes within the Mechanical Services sector.

DEFINITIONS

Standardization

In a client's guide and toolkit, Gibb (2000) defines standardization as "The extensive use of processes and components with regularity and repetition"; this toolkit covers standard processes and documentation and standard components, elements and sub-assemblies.

Gibb *et al.* (1999) describe the various types of standardization.

- Generic project standardization: international standards for the composition and performance of materials, international standards for processes, e.g. ISO 9000,
- National standardization: standards within a country or group of countries, e.g. the European Union, arising from legislation or codes of practice,
- Client standardization: standard elements, processes or procedures specified by a particular client, e.g. corporate logos, contractual procedures,
- Supplier standardization: standard components, sub-assemblies or products specified by a supplier or entire industry sector,
- Project standardization: the decision by a project team to use standard procedures or components for a particular project.

Pre-assembly

Gibb *et al.* (1999) and Gibb (2000) describe the various types of pre-assembly.

- Pre-assembled components and sub-assemblies: e.g. window frames or complete windows, including glazing and ironmongery,
- Non-volumetric pre-assembly: pre-assembled units that do not create usable space, e.g. building services ductwork or cladding,
- Volumetric pre-assembly: pre-assembled units that create usable space and are usually fully factory-finished internally, e.g. toilet pods, plant rooms or modular lift shafts,
- Modular building: a building comprising one or more volumetric units which form the actual structure and fabric of the building, e.g. motels or classrooms.

Benefit

Construct IT (1998) and Gibb (2000) have developed toolkits for measuring benefit in construction innovation, which use the concept of three categories of benefit:

- Efficiency – benefits which are financially measurable, e.g. by use of cost records, time sheets
- Effectiveness – benefits which are measurable but not always in monetary terms, e.g. greater certainty of cost and time estimating
- Performance – benefits which have an influence on the outcomes of a project or business enterprise but are not easily measurable in quantitative terms, e.g. better working relationships, improved health and safety.

The term "benefit" implies an increase in efficiency, effectiveness or performance but the use of standardization and pre-assembly for some elements of a construction project may be detrimental rather than beneficial and may produce decreases in efficiency, effectiveness or performance. In other elements, the use of standardization and pre-assembly may have a negligible effect.

A detriment in one phase of a construction project may give rise to a benefit in a later phase of the same project, or in a future project. Similarly, a benefit in one phase of a construction project may give rise to a detriment in a later phase. There is a need to develop measurement techniques which will allow evaluation of the effect of these trade-offs. There is also a need to evaluate any perceived detrimental effect which represents a barrier to the use of standardization and pre-assembly.

RESEARCH DESIGN AND METHODOLOGY

Research aims and objectives

The aim of this research is to identify the tools and techniques for measuring and comparing the benefits of standardization and pre-assembly against traditional construction and the data required for this evaluation. For "performance" benefits which are not measurable in quantitative terms, the research is investigating the performance measurement tools and techniques used in construction and other industries. The objective is to develop a robust measurement model which can be used to evaluate the benefits of using standardization and pre-assembly.

Methodology

The early research involved a survey of previous studies on applications of standardization and pre-assembly. A study is being carried out of the literature on performance measurement and analytical techniques used in construction and also in more general business and management disciplines; this includes documents and presentations on benchmarking and key performance indicators produced as a result of government initiatives. Primary research data will be obtained using case studies and questionnaires to investigate the use of measurement techniques in construction.

BENEFIT FACTORS

In addition to the COMPREST pilot study, described above, other research has identified factors which describe the benefits and detriments from using standard procedures, standard processes or pre-assembly. This includes the MEDIC (Modular Engineering Design Integrated Construction) research project at Nottingham University.

Publications which identify these factors include Gibb (1999, 2000), Gibb *et al.* (1999), Wilson *et al.* (1999) and Gibb and Isack (2001). The benefits cited by interviewees are not the same in all research exercises, because different construction projects have different priorities. For this reason, any benefit measurement model needs to include the flexibility for construction clients and contractors to specify their own priorities.

Benefit factors identified by previous research can be grouped together to assist with identifying the appropriate measurement technique. Where a factor could be categorized under more than one heading, care must be taken to ensure that there is no double counting when evaluating the benefit. Many of the benefits apply to more than one of standardized processes, standardized components and pre-assembly; these are categorized as general benefits. The lists below are not exhaustive.

Table 1: General benefits

Cost	Efficiency	Reductions in total project costs, transaction costs, overheads and preliminaries costs
	Effectiveness	Greater added value (better product for the same cost)
Time	Efficiency	Reductions in overall project time, design time, construction period, commissioning period and management time, faster response to change
People	Efficiency	Greater efficiency, smaller project teams, smaller design teams, fewer claims, reduced need for training
	Performance	Better working relationships, transfer of knowledge to subsequent projects
Risk	Effectiveness	Reduced financial risk because of greater certainty of cost and time estimating and completion date, greater predictability from using established solutions
Quality	Effectiveness	Better quality of final solutions, fewer defects
Health and safety	Effectiveness	Increased site safety, fewer on-site accidents
Environment	Efficiency	Reduced energy use, transport, waste, site damage

Table 2: Benefits specific to the use of standardized processes

Cost	Efficiency	Reduction in-house costs and fees
	Effectiveness	Facility for monitoring and limiting design costs
People	Performance	Improved knowledge and understanding, improved understanding of contract conditions, clarity of roles and responsibilities, better teamwork
Beneficial processes and operations	Effectiveness	Simplification of construction process, measurable productivity, better planning of work schedules and less disruption
	Performance	Increased facility to reproduce projects, increased buildability, centrally driven processes, fewer contracts, fewer design changes
Detrimental processes and operations	Performance	Additional costs if decision made at a late stage, difficulty in changing and improving existing processes

Table 3: Benefits specific to the use of standardized components

Cost	Efficiency	Reduced component design and production costs
Time	Effectiveness	Reduction in delivery lead times, off-the-shelf availability of components
People	Performance	The manufacturer having an input to the design process, better information about components, greater understanding of the finished product by client, increased familiarity with the finished product.
Quality	Effectiveness	Consistent quality of components, reduced need for quality assurance checks, better interfaces with other components
Beneficial processes and operations	Performance	Easier maintenance, secure supply chain, easier integration of design
Detrimental processes and operations	Performance	Dullness, lack of flexibility and responsiveness to client requirements, difficulty in conforming to urban planning requirements

Table 4: Benefits specific to the use of pre-assembly

Time	Efficiency	Reduced on-site time, reduced site and other management time
People	Efficiency	Fewer people on-site, reduced need for skilled site labour
Risk	Effectiveness	Reduced on-site storage, increased on-site security
Quality	Performance	Facility for off-site quality checks, earlier on-site weatherproofing, less snagging
Beneficial processes and operations	Performance	Removal of difficult operations from site to workshops, independence of off-site and on-site work, reduction in on-site interfaces
Detrimental processes and operations	Efficiency	Cost of setting up manufacturing facility, additional stage in supply chain, additional logistics costs in storage and handling of larger units

TOOLS AND TECHNIQUES

Pasquire and Gibb (1999) note that the decisions to use standardization and pre-assembly are still based on anecdotal evidence rather than rigorous data as there are no formal measurement procedures or strategies available. The COMPREST pilot study highlighted the poor availability of cost information and the need for improved data collection procedures. Some of the sources of data for evaluating benefits do exist, e.g. cost records, project time records and direct human resource costs. Other data may exist in an incomplete form; for example, records of time lost because of accidents give only a partial evaluation of health and safety benefit.

Assessing the benefits of standardization and pre-assembly, whether quantitatively or qualitatively, requires techniques such as those described below.

Benchmarking and key performance indicators

Ashworth and Hogg (2000) and Rossiter (1996) both comment on the importance of benchmarking in improving the performance of the construction industry. While Rossiter (1996) defines of benchmarking as ‘a process of collecting data on what makes different but comparable companies successful in specific areas’ he also states that it can be used to compare operations or functions within a company or between companies in the same or different industrial sectors. The essence of benchmarking is that it uses key performance indicators to evaluate processes. Similar techniques can be used to evaluate the benefits of standardization and pre-assembly by comparing operations with those of traditional construction methods.

A report on the use of key performance indicators (KPIs) from the KPI Working Group of the Department of the Environment, Transport and the Regions (DETR, 1999) describes measures of performance for construction within seven main groups. These are summarized below.

Table 5: Key performance indicators

Time	Time for construction, time predictability, time to rectify defects
Cost	Cost for construction, cost predictability, cost of rectifying defects, cost in use
Quality	Defects, quality issues on handover
Client satisfaction	Client satisfaction, including client specified criteria
Client changes	Change orders by client or product manager
Business performance	Financial and other measures of performance by the company or project
Health and safety	Accidents and fatalities

The report gives examples of KPI calculations, some involving monetary or other quantitative calculations and others involving weighted or normalized scores.

Wathey and O'Reilly (2000) list the performance indicators which may be used to evaluate the financial and non-financial environmental costs and benefits of a project or enterprise.

Health and safety

As one of the groups of KPIs described above, Health and Safety is also addressed in a document from the Movement for Innovation's Working Group on Respect for People (DETR, 2000). This group has developed a set of toolkits, with checklists and scorecards which are currently being trialled within companies and on projects to produce benchmarking performance data. The toolkits relevant to health and safety are: Health and Safety in Procurement and Design, Site Safety, On-Site Welfare, Off-Site Working Environment and Health.

Human resource management

While some human resource benefit factors can be directly measured using time sheets and personnel records, other factors are less easily measurable. The Movement for Innovation's toolkits, described above (DETR, 2000), also include measures of employee satisfaction, staff turnover, absence from work, safety, working hours, training and development and pay. The toolkits relevant to human resource management are: Off-Site Working Environment, Career Development and Lifelong Learning and Diversity in the Workplace.

Risk assessment

Risk assessment is covered by many texts including Smith (1999) and Koller (1999). Measurement of risk is obtained from a combination of impact and likelihood. Where hard data are not available, impact and likelihood may be measured on a multi-point scale, very low, low, … high, very high, and combined to produce a composite score. Where hard data are available, this measure may be calculated as:

Value of risk = Monetary value of outcome x probability of outcome (%).

Monte Carlo analyses and decision trees may be used to evaluate the risk where there are multiple options. Sensitivity analysis is a quantitative technique for exploring the effects of economic changes on a project.

Total quality management

Texts including Baxendale (1997) observe that quality costs comprise prevention costs, appraisal costs, internal failure costs and external failure costs. The costs involved in the first three of these, e.g. maintenance, inspection, reworking, wastage, can be identified and directly measured. Some external failure costs may be identified and measured, e.g. correction of errors, repairs, replacement of faulty materials and litigation; these are the known effects of customer dissatisfaction. There may also be unknown and unknowable effects of customer dissatisfaction, e.g. future lost business.

The principles of total quality management (TQM) include continuous improvement in quality, reliability and customer satisfaction by examining and improving processes, rather than results. The use of standardization and pre-assembly can be treated as an example of process improvement.

Lean construction

Following on from various texts on lean thinking in other industries, Flanagan *et al.* (1998) describe the application of lean principles to construction. Their four steps to achieving lean design and three steps to achieving lean supply, summarized below, include the use of standardization and pre-assembly, as in other lean production environments. The CALIBRE toolkits, developed by the Building Research Establishment, measure and classify construction activities as Added Value, Non Added-Value, Support or Statutory to enable non added-value time to be identified and reduced or eliminated.

Table 6: Lean principles in construction

Four steps to achieving lean design	**Three steps to achieving lean supply**
Focus on design	Process improvement
Maintain customer focus	Use technology to support the reengineered process
Eliminate non value-adding processes	Managing supplier relationships
Focus on the supply chain	

Value management

Ashworth and Hogg (2000) describe value management as comprising value planning, carried out in the earliest stages of a project, value engineering, used in the detailed design and construction phases, and value analysis, carried out following the completion of a project. Evaluation techniques used in value management include life cycle costing, which takes account of costs in use as well as during design and construction and functional analysis system technique (FAST).

Cost-benefit analysis

Ding (1999) describes the technique of Economic Cost-Benefit Analysis (CBA) to evaluate alternative options in construction projects, with the use of net present value (NPV) to measure financial benefits and resource costs over time. She notes the limitations of traditional CBA, where costs and benefits are always expressed in monetary terms and describes the use of Social CBA to evaluate projects according to their impact on the environment or community, where costs and benefits do not have a market value and are described as “intangibles”. She describes the technique of multiple criteria decision making (MCDM) which applies weights and scores, rather than financial measures to evaluate project options.

Logistics and supply chain management

The discussion of teamworking and partnership across the construction supply chain is developed in many texts, including Bennett and Jayes (1995) and Cornick and Mather (1999). The importance of supplier partnerships for the current “Building Down Barriers” initiative is explained in Holti *et al.* (2000). Christopher (1998) deals with this aspect of supply chain management in the wider business environment, citing the benefits gained from Efficient Consumer Response (ECR), a development of supplier partnerships within manufacturing and retailing.

Christopher (1998) describes a wide range of techniques for measuring and improving logistics and supply chain performance, including total cost analysis and strategic lead-time management. He describes the use of logistics performance indicators for benchmarking the logistics and supply chain processes. Holti *et al.* (2000) describe the use of target costing and involving cross-functional teams to manage project costs. The techniques of logistics and supply chain management are valuable tools for evaluating the benefits of standard processes and components and prefabrication.

FURTHER RESEARCH PROPOSED

The IMMPREST research project will apply these techniques to produce a benefit evaluation model, which will identify which individual techniques or combinations of techniques are most appropriate for the analysis of specific scenarios. To develop the model, the research uses interviews and questionnaires to investigate the factors affecting both traditional and standardization and pre-assembly design and construction processes and the sources of data available to measure these factors.

An iterative process, such as the Delphi method, will be used to refine the model. In order to achieve this, the model will be used to measure benefit in case studies in the Mechanical Services sector. It will also be made available electronically for use by selected collaborators, via a restricted access area of the project website, www.immprest.com

The refined model will be published and disseminated using a CD-ROM, which can be used to assist decision-making by estimating the potential benefit of future standardization and pre-assembly applications. The research will then be extended to Electrical Services, Frame, Envelope and Internals.

CONCLUSION

The value of this research is in identifying and evaluating opportunities for using procedures and products which will increase the efficiency and competitiveness of construction clients and contractors. It makes an important contribution to the agenda for improved construction performance set out in the Egan Report.

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