

A design methodology to reduce waste in the construction process

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Abstract: This paper describes a conceptual tool to enable construction professional to identify where waste is generated during the construction of buildings and address how it can be reduced. It allows an improvement in the waste management practices on site by forecasting future waste types and volumes. It will reduce waste volumes on site through identification of wasteful design practices. The tool contributes to all stages of design and construction. At the Concept Stage of Design the proposed methodology provides a framework for reducing waste through better informed decisions. At the Detailed Design Stage it gives a methodology to address the areas of concern and provide focused information to aid the reduction of waste through informed design decisions. During construction it provides a tool to predict waste types arising on site thus allowing a system of proactive waste management that will aid skip segregation strategies leading to improved waste recycling and waste reuse.

Keywords: waste minimization, design management, modelling

1. Introduction

The UK produces over 435 million tonnes of waste annually [1]. Of this, approximately 17%, equaling, 70 million tonnes, is produced by the construction and demolition industries. This equates to 24kg per week for every person living in the UK – about four times the rate of household waste production [2]. In response to the growing burden of ‘waste’, and other related environmental pressures, the government have committed themselves to developing the theme of sustainable development as described and defined by the Brundtland Commission in 1987 [3]. i.e. “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

Subsequent Government statutes and policy documents [4-9] have endorsed sustainability in waste management, particularly ‘Making Waste Work’ [4] which, for the first time incorporated the ‘Waste Hierarchy’; Reduce, Reuse & Recycle. The Waste Hierarchy has now been widely accepted in industry. Within the hierarchy, waste reduction has the highest priority, followed by re-use, then recovery (recycling) and finally disposal; usually to landfill. The best management approach to waste however, is to manage affairs so that there is no waste to manage. This is, of course, very difficult but as Karbanda & Stallworthy suggest, we must begin with the question: can the

amount of waste being produced be minimised, if not totally eliminated? [10]

Designers, through their upstream position in the design construction process, have a unique opportunity to influence decisions to encourage waste minimisation and perhaps, total elimination of waste. As Lederberg suggests, ‘design is a unique point of leverage from which to address environmental problems. Design is the stage where decisions are made regarding the types of resources and manufacturing processes to be used, and these decisions ultimately determine the characteristics of waste streams’ [11].

The principle of designing products (or buildings) for the minimisation of wastes is the fundamental concept of Integrated Pollution Control (IPC) which was formerly introduced into UK legislation in the Environmental Protection Act (1990). Initially the concept was applied to clean up manufacturing processes to prevent both pollution and waste. In recent years however, research and practice has moved towards the re-design of products that consider environmental requirements in the design process [12,13]. The development began in the electronics industry with the German Environment Ministry drafting an electronic scrap regulation with the objective being to reduce the input of hazardous substances in household waste [14]. The legislation stimulated new product concepts which were aimed at environmental improvement.

The construction industry is now facing a similar transition. The trigger for the recent interest in waste minimisation in the construction industry can be explained by the introduction of the Landfill Tax. The tax has focused interest on the wastes hierarchy in the industry and as a result the industry has responded through exploring opportunities of wastes reduction. Whilst the reduction of waste, principally through design, forms the highest priority in the wastes hierarchy, its complexity has however placed it at the bottom of construction waste management research agendas.

The objective of the writers' recent research has been to examine the process of waste generation in the construction process and evaluate the most appropriate methods of waste reduction through designing out waste, i.e. waste reduction at source. This research has involved: the development of a better understanding of why wastes arise in the existing building design process through: an estimation of the common waste streams; an evaluation of waste volumes, weights and characteristics; an assessment of the hazardous vs. non-hazardous wastes; an evaluation of associated costs; and the identification of where wastes arise.

This paper focuses on the concept of a practical methodology for waste minimization and outlines how such a methodology may be used to provide: a tool for measurement and benchmarking of wastes; a model to focus priorities within waste management initiatives; and a method of designing out waste opportunities.

2. Construction waste

Defining 'what is waste' has been the subject of ongoing debate between the Environment Agency, industry and statute. For example, the Mayor Parry judgement (November 1998) where Mayor Parry, a major British scrap metal recycling merchant, was successful in its challenge to the Environment Agency over the definition of waste [15]. Defining what is or is not waste is a central theme in waste regulation. Someone's 'intention' is a good benchmark for those considering the applicability of waste regulation to a given situation. Material will become waste when it is discarded by its 'holder'. To avoid becoming waste, material must always be intended to be used, without first requiring treatment. Material will cease to be waste if it meets appropriately defined criteria and specifications, either without needing to go through a

'specialist recovery process' or having gone through such a process [16]. For the purpose of this research, we are addressing the 'wastes' arising on site, or those elements of a physical nature which are discarded from the construction process during site activities. There is no intention to design for re-use or re-cycling.

Determining the causative factors of construction waste in commercial and industrial buildings, which are almost always designed individually for client requirements, is not straightforward. Other sectors, including housing and retail all have the advantage of a degree of generic design which allows waste benchmarking on an agreed unit basis. It is not the purpose of this paper to discuss the units of waste measurement to be adopted, only to assume that units of measurement can be agreed. (However the topic is dealt with briefly in section 4.3 Feedback From Industry.)

A building design, or product design, is a process of synthesis in which decisions are made which affect cost, performance, buildability, safety and the level of wastes arising. Although there are exceptions buildings are generally developed without high regard for the environment and no regard for waste minimisation. This approach is outlined in below. Decisions are made at each stage of the design process including concept, detail and construction which create wastes. A concept of 'designing out waste' would address each decision throughout the process and influence actions to reduce waste. The sphere of influence of the designer and/or the construction manager will be dictated by the contract, which in turn is ultimately led by the Client. Different forms of contract present different opportunities, e.g. contractual arrangements which are based on Design, Manage and Construct (DMC) contracts have the advantage that designers and Construction Managers can form 'in-house' working groups to focus the design team's efforts on reducing wastes.

3. Waste minimization

For the purpose of this research waste minimisation is considered to be, "Any technique, process or activity that avoids, eliminates or reduces waste at its source or allows re-use of recycling of the waste" [17]. Sustainable waste management is, "Using material resources efficiently, to cut down on the amount of waste we produce, and where waste is produced,

dealing with it in a way that actively contributes to the economic, social and environmental goals of sustainable development.” (ref. Government waste strategy, 1999)

The focus on waste minimization is through source reduction which covers practices that reduce the use or generation of hazardous substances prior to recycling, treatment or control. Source reduction is generally achieved through one or a combination of the following: product reformulation, improved operating practices, chemical substitution, process re-design or in-process recycling. Source reduction does not include: designing for extended life; selecting materials which are compatible with recycling; designing for ease of disassembly; identifying materials for recycling purposes; the specification of recycled materials.

The second global scoping issue is one of ‘what level of challenge’ should be targeted for improving the building design process to reduce wastes. One of the ways of addressing this is to examine the hierarchy given by Stevels [18] which suggests improvements should be made on four levels, each level increasing in difficulty and degree of innovation required in the design process. The four levels include:

- Level 1: step by step improvement of the supply of existing products;
- Level 2: radical re-design based on existing concepts;
- Level 3: product alternatives (other concepts or replacement of products by services);
- Level 4: design for the fully sustainable society.

If we consider the ‘levels of difficulty’ in the context of the construction industry and the scope of this research, levels 1 and 2 will be targeted as opposed to the more radically innovative solutions of levels 3 and 4. The reason for this is the construction industry, although engaging in the environmental debate, still operates between stages 1 and 2. However, knowledge regarding potential areas of improvement is not enough to improve the design and construction process. It is also necessary to identify and devise a method to implement and prioritise the implementation of strategies to reduce waste. To achieve these two separate methodologies were devised that reflect the two distinct phases of design - concept and detail.

4. A methodology to reduce waste

4.1 Concept design stage

At the concept design stage decisions taken by the design team will have a crucial effect on the levels of waste produced. The design team will need to ask the client appropriate questions such as:

- ♦ How much of the existing construction works can be **retained** for the new use?
- ♦ Can any of the components within the existing construction works be re-used in the new building or elsewhere?
- ♦ To what extent can the new construction works, or any of its components or elements, be fabricated off-site in controlled conditions and is the client interested in considering options that may have a lesser impact on the environment?
- ♦ Could the client’s proposal be realized on an alternative site, giving the same results but with lower environmental impacts and levels of waste arising?
- ♦ Is the client prepared to recommend that the design team to look further into the future and “design for deconstruction”, for example, in specifying composite products that do not require adhesives so as to enable easier separation and consequently render both material available for recycling in a cleaner state?

The methodology described in this paper is not proposed to play a major role in this level of decision making although the data stored in the data base will enable more informed decisions at the briefing stage to be made.

4.2 Detailed design stage

The approach developed adopts three basic elements including design guidance, proactive construction waste management and future improvement (Fig. 1). The approach is centered around a database that provides: data to inform the designer of where wastes arise in work package; data to inform the designer which work packages create the most waste; data to inform where effort should be focused to reduce waste, and; Work Package design guidance.

The methodology relies upon **audit** data of construction waste to form the basis for benchmarking future performance. Audit data can provide average waste types and/or volumes per work package. These data can be used to predict likely wastes arising in future projects. By linking the waste profiles on existing projects with future construction programmes

we can generate a waste profile for future projects. These profiles can then be used as a basis for monitoring and control by site managers. This will allow proactive management of wastes on site by being able to predict when wastes will arise, therefore aiding reuse and recycling options. The process of benchmarking and targeting will identify areas where improvements can be made. The proposed tool will suggest where potential improvements may be identified. The benchmarking analysis system identifies areas of improvement for further consideration. It is intended to stimulate consideration of other waste minimization techniques such as modularization and standardization. The methodology includes waste auditing, constructing waste profiles and design guidance. It relies on a continuous process of design, proactive construction waste management, and the identification of future improvements.

4.2.1 Waste auditing

Waste Auditing enables organizations to understand the sources of waste and when waste occurs. The analysis of the data can provide a waste cause matrix that forms an essential part of the design review. This matrix will be developed for each works package. For each component data will be held on the main causes of waste. This provides the basis for reviewing the probable level of waste on the project. e.g. Waste in Ductwork results from Co-ordination (20%), Complexity (50%), and Buildability (30%). At the design review the Waste Cause matrix will illustrate the main reasons for wastes arising in each of the main areas of the project process, a checklist that reviews the areas of concern. Using ductwork complexity as an example, we could look at solutions for reducing ductwork complexity by company 2-3 options of ductwork layouts. The assessment will provide a 'high level' review of elementary ductwork layout design and suggest result levels of waste for each option.

4.2.2 Constructing waste profiles

Waste profiles can be constructed for total audited wastes and individual contractor's wastes against audit dates. These are simply a longitudinal analysis of which types of waste occur at which point in the construction process. They are used in analyzing alongside the construction programme to show at what point waste is generated and the quantity of waste produced. Average waste profiles can be produced and

maintained by averaging the waste types and waste volumes over time. The profiles allow a summary of the typical waste streams pertinent to a project package.

By linking the waste profiles with the construction programme it will be possible to encourage proactive waste management on site by being able to predict when wastes will arise and therefore aiding re-use and re-cycling options on site and reducing overall waste. The project and contractor programmes developed for the construction phase of projects will include several tiers of detail each of which help to build an accurate picture of the type of work being undertaken at any one time in a project.



Fig. 1 A method to encourage waste minimization within the design process

4.2.3 Design guidance

The designer may be the starting point for determining the final level of waste but this cannot be done without consideration of the construction process, hence detailed design should not begin without discussions with the construction team. Having identified the workpackages involved within the construction work and the construction processes should set targets for the key materials to be used after a review of previous audit information and waste benchmarks. It is these targets that the designer aims to meet through this design. This incorporates a waste monitoring policy for construction based on guidance from construction experts.

4.3 Feedback from industry

To ensure the approach addressed the needs of the designer the method was presented to two groups of multi-disciplinary chartered engineers as a validation exercise. A total of eight engineers were given the opportunity to comment on the methodology. They

were all supportive of the proposed method but considered that the quality of the database, the amount of data available and the flexibility of interrogation would be critical to its success. Also important would be its integration with other computer based tools. Careful consideration would need to be given to the user interface and supporting documentation. It was noted that waste is only one of many factors that is considered in design. Therefore the database must integrate with other factors, accessed via a common portal. It was noted that as most construction work is subcontracted, this may present difficulties in identifying waste in sub-contractor's scope. All considered that waste would need to be expressed in monetary terms if the issue was to be addressed seriously.

5. Conclusions

Within the construction process designers have a unique opportunity to influence decisions to encourage waste minimization. Waste minimization may be achieved through prevention, reduction at source, re-use of the existing product, quality improvements and recycling. The construction industry faces a transition from its historical approach with little if any consideration of the levels of waste to an approach based on environmental considerations. This transition is being prompted by cost savings not direct legislation.

The proposed methodology described in this paper will assist designers at the detailed design stage by providing audited data that may be used to evaluate probable and subsequently achievable levels of waste for the design solutions proposed. These data may then be used to assist the construction team plan for materials handling on site. Feedback from the construction team then provide new data which may be used by designers on new projects. We now seek to

validate the methodology through development and testing.

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