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The potential of integrating Design for Deconstruction as a waste minimization strategy into the profession of the architect

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Abstract
This paper focuses on the Design for Deconstruction (DfD) as a method of designing buildings with their end-of-life stage taken into account, by enabling their successful disassembly in order to reclaim their components and materials, either for reusing into new constructions or for recycling them. This aims at minimizing the overall future construction and demolition waste, as well as the need for extracting raw materials by extending the buildings' and materials' lives. The work focuses on the principles and context of DfD and the potential of integrating it into the architects' profession as a strategy for sustainable design. Their role as the 'first link of the chain' is discussed and a questionnaire survey reveals current practices in UK. Further implications and possible barriers for integrating DfD into the architect's profession are outlined as well as enablers and drivers for encouraging its use.

Keywords: design for deconstruction, waste, architect, questionnaire, assessment tools

Introduction
The contemporary way of living, characterized by the fast replacement of products and overconsumption, has led to the dependence on natural capital and consequently the improvident use of raw materials. The fallacy that natural resources are inexhaustible and free has brought us to the extraordinary threshold of today's waste society (Hawken et al. 2000). The linear industrial model of the last two centuries from extraction to demolition needs to be replaced by a cyclical one, which takes into consideration the end-of-life phase of materials. Reuse is preferable to recycling, due to the additional energy needed for the latter. Thus, careful dismantling of the building after the end of its useful life can facilitate the recovery and reuse of its materials without threatening their concurrent value. Design for Deconstruction is the means through which future buildings can be 'zero-waste', as they are designed to be deconstructed with the aim of reusing or recycling their materials.

Aims and methodology
The aims of the research include to understand and review the context behind DfD, to identify the importance of the role of the architect in the influencing of the waste stream of a project, to highlight the implications behind the existing gap between the extensive research and common practice, by analysing potential and existing barriers and outweigh

them with enablers and drivers. These are based on extensive literature review of previous and current research. Also in order to portray the applicability of DfD in current practices in UK, a questionnaire survey was undertaken.

Literature Review on Design for Deconstruction (DfD) concepts and principles

First it is important to clarify the position of DfD into the various end-of-life scenarios. Crowther (2001) has introduced the following hierarchy of these scenarios (with descending order of preference): 1. Reusing the construction: This includes the maintenance, refurbishment and adaptive reuse of the existing buildings, as most of them are expected to require either occupancy changes or replacement of technologically dependent components, before the end of their life. Therefore, constructions should be adaptable and flexible. 2. Reusing the components: Often the expected lifetime of components (non-structural elements and architectural features) is longer than the expected lifetime of the building, thus the components should be designed to be easily removed to be reused in new buildings. 3. Reusing the materials: This refers to all individual items that were used to assemble the components of the building and need careful dismantling so as to be reused in other components. 4. Recycling the materials: If the materials cannot be reused, recycling is the last resort before becoming waste. 5. Energy recovery: If none of the above scenarios is feasible then the best solution is incineration of the materials and collection of the recovered energy.

The "theory of layers" by Brand (1994) divides the parts of the building to six layers according to their expected lifetime. This can help DfD by designing the components of the same layer and their junctions with consideration to their life expectancies and making them separable and independent so that they can be easily accessed and removed (Isiadinso 2010): Site (eternal), structure (30-300 years), space plan (3-30 years), skin (20 years), services (7-15 years), staff (daily). The reusability of components and materials depends on their environmental impact, ease of recovery, quality and value after recovery and lifespan.

The difficulty of disassembly depends on the difficulty of assembly, as the former is the reversible process of the latter, therefore it is important to construct as easily and simply as possible to facilitate both processes. This is summarized in the term 'buildability', which contains three main principles: simplicity, standardization and independence for easy access. Buildability is also connected to modularity, prefabrication and standardization of assemblies and sizes, as principles for DfD (Crowther 2002).

The following table summarizes the general guidelines for DfD:

Table 1: Main principles organized according to main DfD categories (adapted from Macozoma 2002)

Category	Guideline
Design	Balance durability and adaptability Use buildability and theory of layers principles
Material salvage	Make decisions based on end of use hierarchy options
Material selection	Use minimum, reuse, conserve and avoid composites
Connections	Use minimum, standardize and reuse
Information	Keep records of all construction data in an "information library"

Role of the architect - conceptual barriers regarding DfD

The architect as the first link of the chain of the project delivery process is influential in adopting DfD from the design stage. He is responsible for a holistic perception of sustainability with the entire building life cycle taken into consideration and combined with other environmental design strategies. However, several misconceptions arise regarding the relation of DfD with architecture.

First, both the architect and the user tend to attach to the building a permanent character. Education and monumental architecture tend to cultivate the perception that buildings live for ever. For the client-owner, the very primitive sense of 'home' makes it difficult to allow the consideration of an end-of-life scenario. Thus, DfD may attach a more temporary character to the building, due to the idea of a predefined ending and an 'expiration date' rather than an ending left to the passing of time. However there is no real difference in the actual purpose of a DfD building compared to a conventional one. Their difference is that a DfD method measures the life expectancies of materials and provides flexibility for conversions. The actual life of it can be the same as a conventional building, or even more due to its adaptability. Nothing stays stable, even climate changes. Whether a building will be conceived as worthy preserving is dependent on future generations and DfD cannot stop an architect's brilliant idea.

Second, a sensible query is whether DfD questions the structural stability of a building, as built nowadays with provisions for earthquakes. Reinforced concrete structure is considered very inflexible and thus not easily disassembled. This is correct, as the last part after a soft-strip demolition process is the structure (Addis and Schouten 2004) and it is also the building layer with the longest life-span. This means that it is worth designing for durability, as it can withstand many changes and adaptations of the skin and inner layers. Adaptive reuse is then favourable against deconstruction. However, although a concrete reinforced structure cannot be disassembled without losing its performance, the materials can be recycled. Also alternative materials and flexible construction techniques can replace concrete with timber and metal frame. The second is favourable for DfD, as it is stable like reinforced concrete, it can span long distances with less mass and high tensile strength (Hurley 2002). Consequently DfD and structural stability are not actually contradictory.

Crowther (2002) underlines the standardization and repetition of design elements and details as buildability aspects. However, this can be further connected with restriction of the uniqueness of individual buildings and loss of 'architectural freedom' to design from scratch. Two scenarios are possible: either to first design and then produce the standardized elements or to design with particular elements in mind produced in standard dimensions to meet general demand (Isiadinso 2010, p. 70). Assuming that in a cyclical process future buildings will use reclaimed materials from other deconstructed buildings, the second scenario is more likely to happen. Then architects will face the uncertainty whether sufficient and appropriate components will be found to match the design and compromise may be inevitable. However, standardization did not stop Le Corbusier to be unique although he praised it, because he used a modular coordination and created many different combinations from standard components, hence not imposing any constraints on the architectural flexibility. Also, the concept of reusing items resembles the tangram, the Chinese puzzle whose pieces have standard geometries but multiple final solutions.

Innovative design of assemblies and sizing and dynamic configurations may be the key to combining standardization with architectural uniqueness (Durmisevic and Brouwer 2002).

Practical barriers and drivers

Undoubtedly, barriers exist in any innovation and they are inextricably linked with each other. One of them is cost implications. DfD is currently unable to give a clear picture, as it includes the cost of producing a deconstruction plan, the value of reused materials, the cost of production and purchase of assemblies, the training of all professionals and efficiency of deconstruction (labor costs). This unknown field creates prejudice and uncertainty, without being outweighed by the potential environmental benefits, which are not well established yet. According to Guy (2002), buildings may be designed with DfD in order to enable maintenance and reduce the deterioration of performance of technology-dependent components. The retrofit cost of a non-DfD building might be higher in the long term than that of a new DfD building, although this may have high initial cost. This concept is called 'Whole Life-Cycle Cost' and accounts for all costs from obtention to disposal of all resources needed for a building (Isiadinso 2010, p. 33).

The interaction with other professionals related to the building process, who must collaborate and be educated sufficiently consists also an important barrier. The driver would be appropriate training programs and integration of DfD in related studies. Also, other barriers include the lack of appropriate legislation, the clients' reluctance and the lack of a well-established market for reusing materials.

Current practices – Questionnaire survey

The questionnaire outlines the current practices regarding DfD. It was sent to architects based in UK with a response rate of almost 30%. The questions also outline the barriers that hinder the acceptance and use of DfD and discuss further enablers and drivers.

The results show that 74% of the participants consider the end-of-life stage of the buildings as important and that deconstruction stands for a viable alternative to demolition. A high proportion (71%) uses reclaimed or recycled content materials and most of them think that the main reasons for not using such materials are the cost implications and clients' reluctance. The majority thinks that their role is influential in adopting DfD in their practices. Also 68% is familiar with DfD, from which 23% states that they implement it in practice (Fig. 1) in industrial buildings, prefabricated and lightweight structures and refurbishment projects.

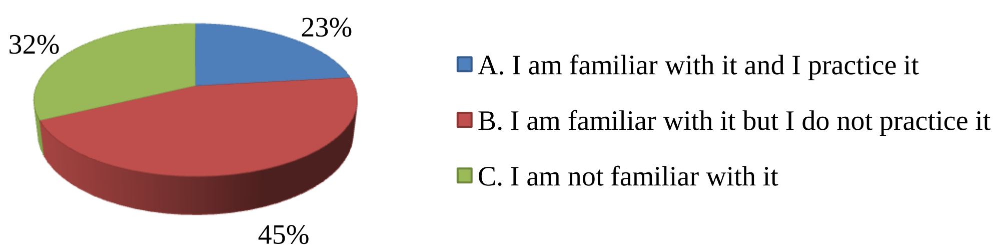

Figure 1: Familiarity and practice of DfD

Regarding the impact of DfD on architectural decisions, the majority answered that the materials' choices and construction techniques are mostly affected, while the initial concept, the form and the aesthetics had divergent views. Additionally, they listed the appropriate education- training as the most important barrier for using DfD, with clients' reluctance-unawareness and interaction with other professionals to follow. Costs and lack of appropriate legislation seem to be also highly important barriers (Fig. 2).

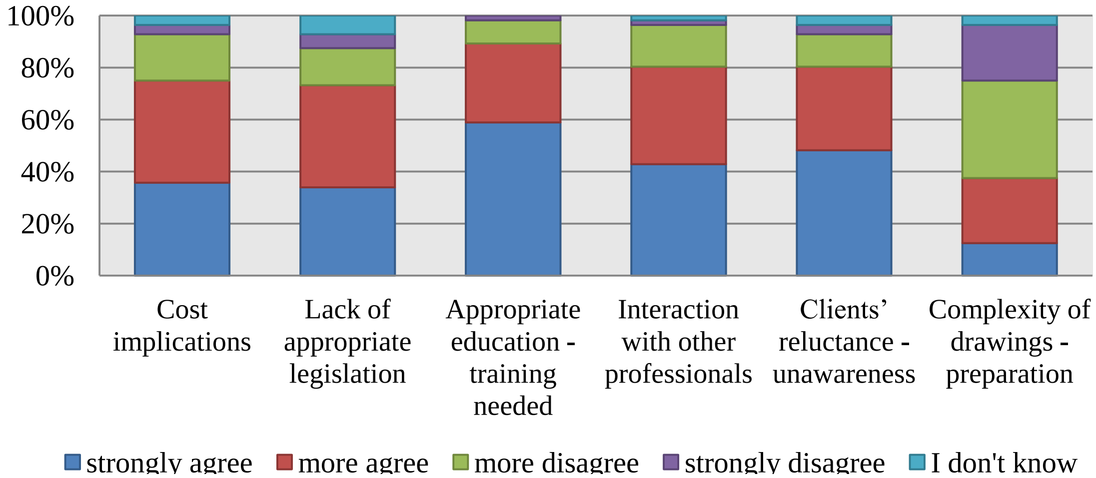

Figure 2: The main barriers for adopting DfD in the architect's profession

In the next question about whether standardization and prefabrication hinder the 'architectural freedom', the views were divergent; this shows that the query whether standardization affects architecture is reasonably raised. However they don't think that DfD assigns a temporary character to architecture. However 40% believe DfD does not assign a temporary character to architecture, although a considerable 28% believes it does. When asked which enabler-driver they think can make DfD more approachable to architects and clients, 90% lists the incentives by the industry of reclaimed – recycled materials as first, with training programs for all professionals and incorporation of DfD in assessment tools and legislation to follow.

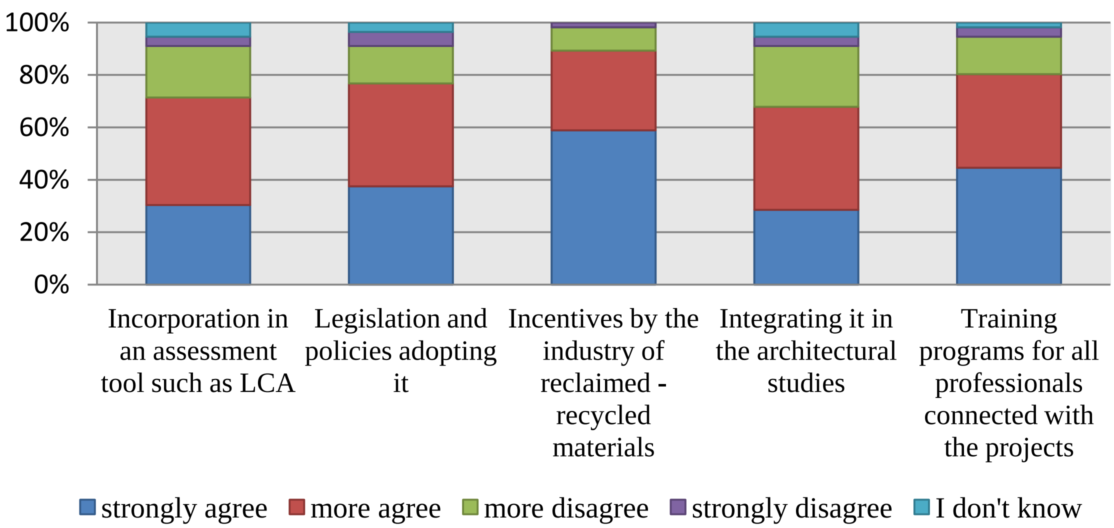

Figure 3: Possible drivers for making DfD more approachable to architects and clients

Finally, the results in the question whether they would like to integrate DfD in their future projects after answering the questionnaire are encouraging, with a large proportion of 82% being positive.

Recommendations and conclusions

Nowadays more practitioners and clients think about increasing their 'green status'- as financial incentives such as Environmental Performance Assessment and Life Cycle Analysis Tools give motivations. DfD could be included in BREEAM for UK in the future. There is a need for mainstreaming DfD in the building process, through high commitment of all related professionals, prioritization of 'Whole Life-Cycle Costs' against first investments, incorporation in legislation and raising awareness of clients with media campaigns and networking. Also DfD should be included in the targets of the next 2013 Global Summit of Sustainable Development in New Delhi.

Overall the questionnaire survey has shed light on current practices regarding DfD and has managed to stimulate a new way of thinking. It showed that architects are open to accept DfD as a strategy of waste minimization and as an environmental design aspect. However, DfD will gain ground more in the future, both because of the current barriers and because the evaluation of its use can only come after the end-of-life of the DfD buildings. This may be the reason for the existing gap between the extensive research and the limited application.

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