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Guidelines to Improve Construction and Demolition Waste Management in Portugal

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1. Introduction

The construction industry is a major contributor to excessive natural resource consumption, depletion and degradation; waste generation and accumulation; and environmental impact and degradation. The amount of waste generated by the construction and demolition activity is substantial. Surveys conducted in several countries found that it is as high as 20% to 30% of the total waste entering landfills throughout the world (Bossink & Brouwers, 1996). Moreover, the weight of the generated demolition waste is more than twice the weight of the generated construction waste. Other studies compared new construction to refurbishment, and concluded that the latter accounts with more than 80% of the total amount of waste produced by the construction activity as a whole. The building activity at historical city centres tends to be an important waste generator because both refurbishment projects and new projects often include demolition (Teixeira & Couto, 2000). Construction site activities in urban areas may cause damage to the environment, interfering with the daily life of local residents, who frequently complain about dust, mud, noise, traffic delay, space reduction, materials or waste deposition in the public space, etc. Regarding this theme, an attempt was made to order each impact by the importance given to each one in scientific publications, being the following the most frequently mentioned (Couto, 2002; Couto & Couto, 2006):

- Production of waste;
- Mud on streets;
- Production of dust;
- Soil and water contamination and damaging of the public drainage system;
- Damaging of trees;
- Visual impact;
- Noise;
- Increase in traffic volume and occupation of public roads; and
- Damaging of the public space.

A recent research study carried out by the Instituto Superior Técnico da Universidade Técnica de Lisboa (Technical University of Lisbon) reveals that most of the construction and demolition (C&D) waste is not recycled in Portugal in opposition to what is happening in most European Countries. This study advances that Portugal generates around 4.4 million tones (Mt) per year of core C&D. However, in most construction sites the waste is selected

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but its destination is not controlled. Only a few local authorities require the promoters to make a plan for C&D waste (Couto & Couto, 2009).

This inappropriate management for long time has lead to the appearing of many disposals in green areas, adjoining roads and other sensible places.

On the other hand, there is not yet a market for recyclable materials. Most practitioners have been manifesting distrust and lack of information about this issue.

In the Historical City Centres (HCC) the negative effects of the construction projects have even a greater relevance, since they are urban areas with very particular characteristics. As they are touristic locations, it is necessary to maintain them as much as possible as pleasant places to live, work and enjoy. Furthermore, these areas frequently have significant restrictions regarding the available space, which brings about more difficulties for the construction projects. Therefore, the HCC, in view of their specificities, require a special attention from the intervenients of the construction sector in order to minimize the impacts of the construction projects.

The national inquiry carried out with the Portuguese Association of Cities with Historical Centers (Couto, 2002; Teixeira & Couto, 2002), of which 50% of members (56) answered, had the results showed in table 1 regarding the most common prevention attitudes towards the waste impact.

Common prevention attitude - waste	Answers (%)
Generally Compulsive Prevention - in the licensing of the construction project according to municipal norms/regulations	54
Sporadically Require Prevention - in the licensing of the construction project, in some circumstances	29
Eventually Require Prevention - during the work execution due to complaints from affected citizens	14
Without Prevention - considering the inconveniences caused by the normal execution of the construction project	3

Table 1. Common prevention attitudes towards waste production impact

The result shows that only about half of the respondents have expressed that preventive measures are generally required in the licensing stage, which is quite worrying due to the importance and sensibility of those places. The lack of a preventive attitude from both the authorities and the contractors, followed by an inefficient inspection and control by the authorities are the main causes for the majority of complains from neighbors and transients. This work presents a strategic actions set necessary to improve and promote the waste construction management in Portugal. An effort should be made in order to reduce waste production on site and to increase its recycling value. The reuse, based on deconstruction process, should be considered a good solution and an opportunity market.

2. Reasons to a good practice on Waste Minimisation & Management (WMM)

2.1 The main benefits of a WMM

Waste management involves identifying potential waste streams, setting target recovery rates and managing the process to ensure that these targets are met.

Adopting the principals of good practice waste minimisation on a project can demonstrate a firm commitment to sustainable construction and environmental management. Good practice in waste management when are well implemented, bring a number of benefits. The main benefits include (WRAP (a), 2009):

- Reduced material and disposal costs – less waste generated means that a reduced quantity of materials will be purchased, and less waste taken to landfill will reduce gate fees for disposal. Cost savings will stimulate the adoption of improved recovery practices and motivate a sustained change in waste management practice;
- Increased competitive differentiation – benefits both developers and contractors, particularly where this will help to meet prospective client's sustainability objectives;
- Lower CO2 emissions;
- Complementing other aspects of sustainable design; and
- Responding to and pre-empting public policy – those organisations responding to the thrust in public policy making for the increased sustainability of construction and the built environment will be in an advantageous position in comparison with those that wait until they are compelled to act by legislation.

With the implementation of good practice waste minimisation and management it is possible to be significantly more efficient in the use of natural resources without compromising cost, quality or construction programmes (WRAP (a), 2009).

Fully benefiting from good practice waste minimisation and management on a project will mean adopting its principles at the earliest possible stage, preferably mandated by the client through procurement requirements. The principles of good practice should then be communicated and implemented by the design team, contractor, sub-contractors, and waste management contractors through all project phases – from outlines design to project completion. This can be illustrated on the figure 1 in following page.

2.2 The costs of waste

The costs of waste are not limited to the cost of landfilling, as illustrated in figure 2.

The costs mentioned in figure 2 should also be added the following costs:

- The time taken by on-site sorting, handling and managing waste;
- Poor packing or overfilling of skips leading to double leading to double handling (this cost is very difficult to quantify); and
- The cost of material that have been wasted.

3. Strategies to mitigate the waste production: potencial uses for waste

3.1 Implementing a waste minimisation hierarchy

The waste minimisation hierarchy is an important guide to managing waste. It encourages the adoption of options for managing waste in the following order of priority (Morgan & Stevenson, 2005):

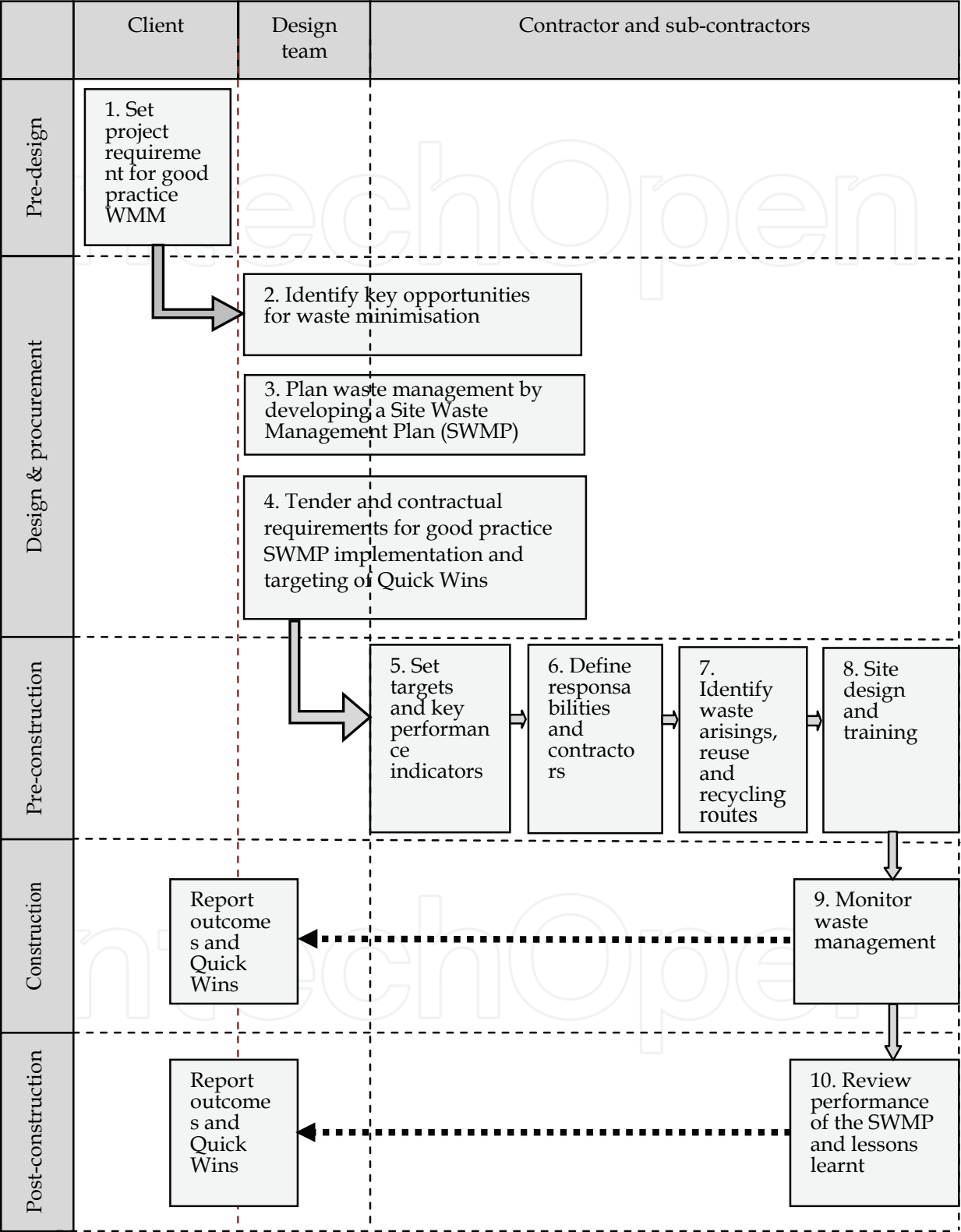


Fig. 1. Achieving good practice waste minimization and management. Source: Adopted from (WRAP (a), 2009)

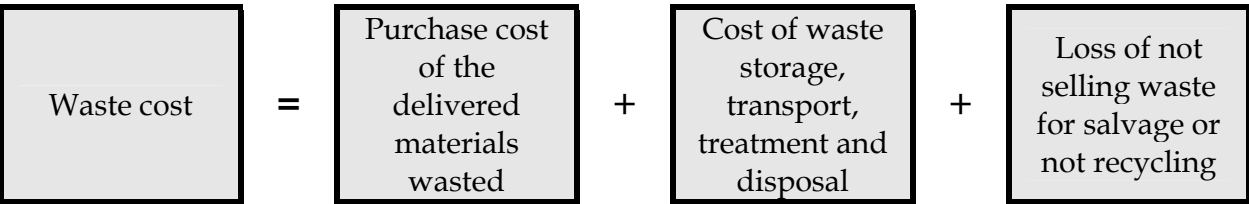


Fig. 2. The costs of waste. Source: Based on (WRAP (a), 2009)

- Waste should be prevented or reduced at source as far as possible;
- Where waste cannot be prevented, waste materials or products should be reused directly, or refurbished before reuse;
- Waste materials should then be recycled or reprocessed into a form that allows them to be reclaimed as a secondary raw material;
- Where useful secondary materials cannot be reclaimed, the energy content of waste should be recovered and used as a substitute for non-renewable energy resources; and
- Only if waste cannot be prevented, reclaimed or recovered, it should be disposed of into the environment by landfilling, and this should only be undertaken in a controlled manner.

In figure 3 is illustrated the waste hierarchies for demolition and construction operations. Construction waste management should move increasingly towards the first of these options, using a framework governed by five key principles promoted by the European Union (EU):

- The proximity principle;
- Regional self sufficiency;
- The precautionary principle;
- The polluter pays; and
- Best practicable environmental option.

Clearly, the reuse of building elements should take priority over their recycling, wherever practicable, to help satisfy the first priority of waste prevention at source.

The following section offers some advice on how to approach the project, so as to facilitate waste management of all stages of the project.

3.2 Avoiding waste

Avoiding generating waste in the first place is the best way to manage waste. Efficient, lightweight designs, which respond well to site characteristics, minimize not only waste, but also often result in cost savings in construction. Such buildings also often have significantly lower long-term operating costs. Identifying potential waste early in the design process decreases waste generated during construction.

3.2.1 Design stage

Recent research by WRAP (WRAP (b), 2009) has identified the important contribution that designers can make in reducing waste is through design. WRAP has developed a number of exemplar case studies on live projects, working with design teams to identify and build the business case for action around designing out waste. This work has improved current understanding of how to reduce construction waste and has led to the development of five key principles that design teams can use during the design process to reduce waste:

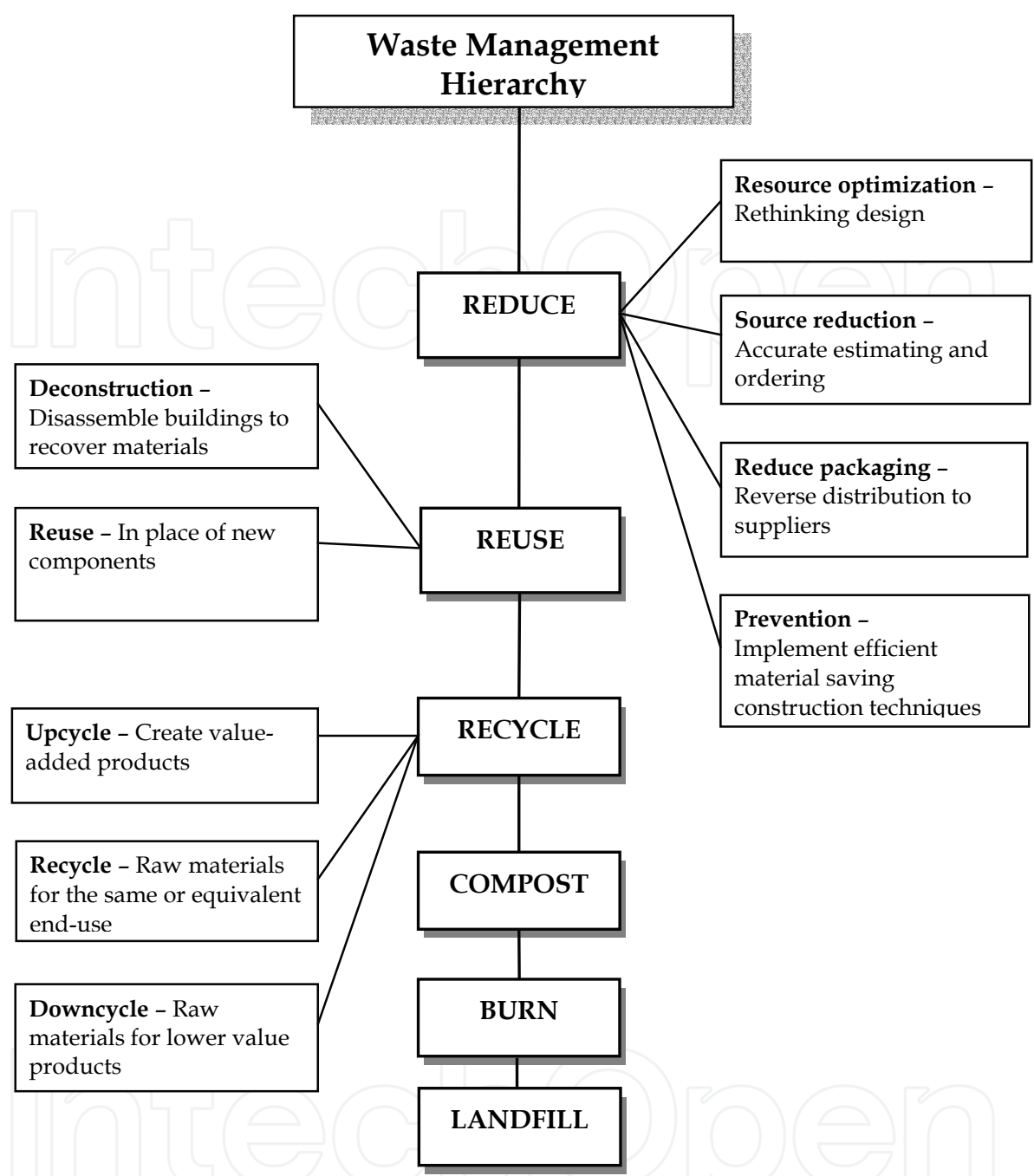


Fig. 3. Hierarchies for demolition and construction operations. Source: Adopted directly from (Kibert & Chini, 2000)

- Design to reuse and recovery - reuse of materials components and/or entire building has considerable potential to reduce the key environmental burdens (e.g. embodied energy, CO₂, waste, etc) resulting from construction;
- Design for off site construction - the benefits of off site factory production in the construction industry include the potential to considerably reduce waste especially when factory manufactured elements and components are used extensively;
- Design for materials optimization - this principle draws on a number of “good practice” initiatives that designers should consider as part of the design process. Good

practice in this context means adopting a design approach that focuses on materials resource efficiency (see figure 4) so that less material is used in the design (i.e. lean design), and/or less waste is produced in the construction process, without compromising the design concept. The figure 4 shows in the grey boxes the areas where designers can have a significant impact;

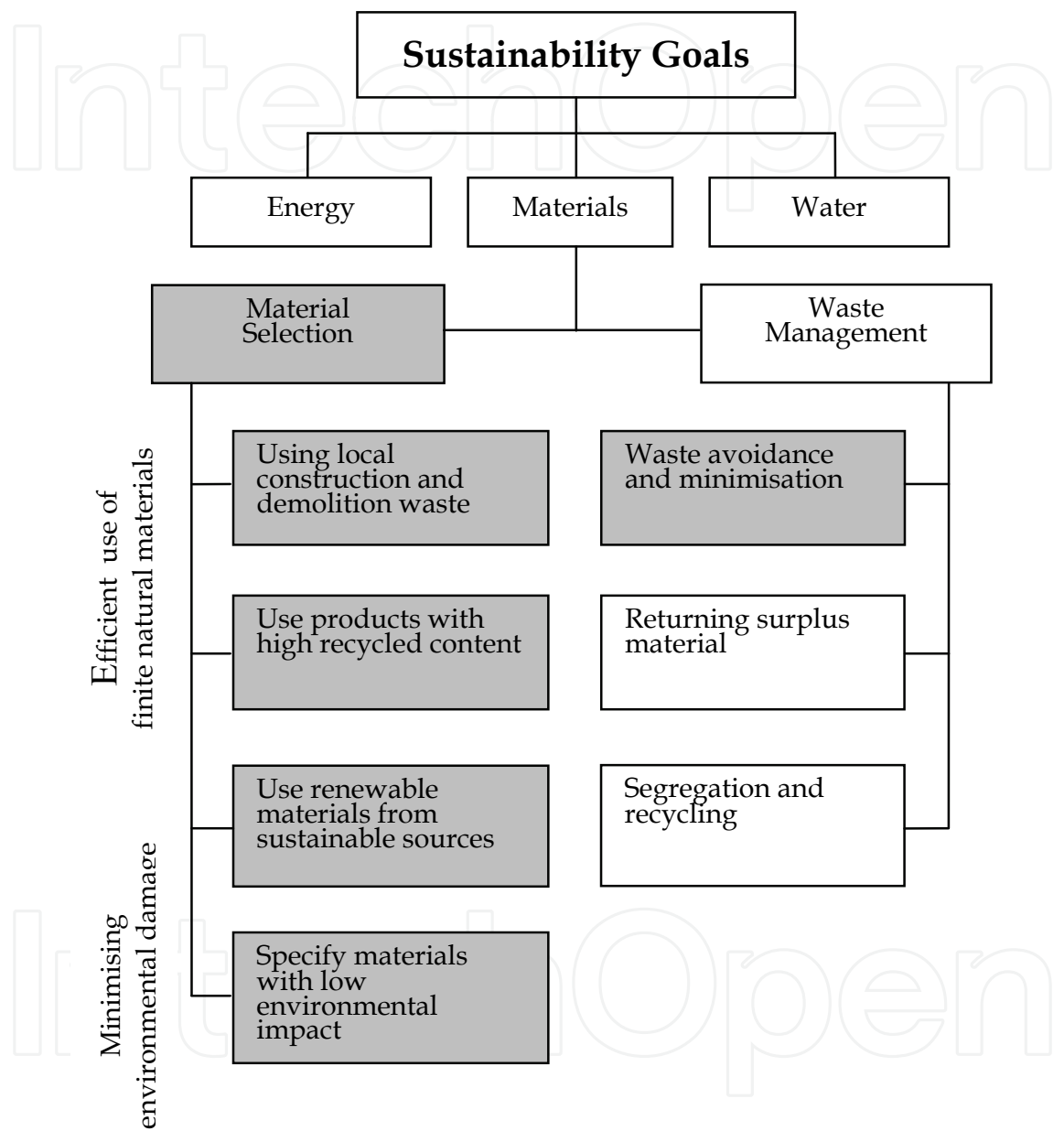


Fig. 4. Materials resource efficiency as part of sustainable construction. Source: (WRAP (b), 2009)

- Design for waste efficient procurement – designers have considerable influence on the construction process itself, both through specification as well as setting contractual targets, prior to the formal appointment of a contractor/constructor. Designers need to consider how work sequences affect the generation of construction waste and work with the contractor and other specialist subcontractors to understand and minimize

these, often by setting clear contractual targets. Once work sequences that causes site waste are identified and understood, they can often be “designed out”; and

- Design for deconstruction and flexibility – designers need to consider how materials can be recovered effectively during the life of building when maintenance and refurbishment is undertaken or when the building comes to the end of its life. Not to design with Design for Deconstruction and Flexibility in mind limits the future potential of Design for Reuse.

During the construction design stage there are several actions that could avoid waste generation, which may include:

- Designing to standard sizes, to modular and prefabricated construction, and requiring minimal earthwork;
- Incorporating recyclable, recycled and reusable products in construction;
- Designing for dismantling or deconstruction. Some of the principles include: the disentanglement of systems, materials bolted together instead of glued, a construction and deconstruction blueprint, built-in tie-offs and connection points for workers and machinery, no hazardous materials and highly recyclable materials (Resource Venture, 2005);
- Considering renovating or refurbishing an existing building, rather than demolishing and rebuilding;
- Designing to reduce future energy use, by orienting the building to use passive solar heating and natural ventilation;
- Co-ordination between designers and construction companies should be attended in the definition of materials and construction products; and
- Packing conditions should be discussed with suppliers in order to reduce the number of packs and the amount of packaging materials, especially those not possible to reuse or difficult to recycle.

3.2.2 Construction planning stage

During the construction planning stage there are several actions that could avoid waste generation, which may include (CIRIA, 1997; EnviroSense, 1996; Couto, 2002; Couto & Couto (a), 2007; Teixeira & Couto, 2000):

- Co-ordination between designers and construction companies should be attend in the definition of materials and construction products;
- Promoting adequate communication among owners, project designers and contractors. Lack of communication is often the cause of partial demolition and removal of applied material, contributing towards needless output of debris;
- Keeping the workers and concerned parties up to date, whether on the steps taken to minimize debris or the importance of such steps, as it easier to take action when one knows the motives for it;
- Before commencement of construction works, asses needed materials and make an effort to locate and acquire used materials beforehand, whenever possible;
- Arrival of materials and products should be planned, according to available place on site and to production flow, to avoid excessive stocks and possible deterioration of goods and packs;
- Stockpiles of sand, gravel, soil and other similar material should be located so that they do not spill and cannot be washed onto the adjacent street;

- Accident spills of those materials should be removed prior to the completion of the day's work;
- Quality control should reject defective materials at the time of delivery thus avoiding later disposal;
- Materials should be delivered packed on site so that cracking can be reduced during transportation and handling operations on site;
- Packing conditions should be discussed with supplies in order to reduce the number of packs and the amount of packaging materials, especially those not possible to reuse or difficult to have recycling waste;
- Orders to supplies of materials should respect sizing needs so that adjustments can be avoided during construction;
- Select products that output the least possible amount of waste or, at least, less toxic waste. A good example would be oil-based paint, which contain organic solvents that may render paint waste more dangerous. Water-based paint (latex) is safer to users and easier to handle. One should also try to use paints without metallic pigments, as these may also make the waste dangerous;
- Store vegetable soil on piles no higher than 2 meters, and handle it as little as possible, as this may damage its structure;
- Cut down as few trees and bushes as possible when cleaning out terrain to implant a construction site. Trees, trunks, branches and other vegetable matter, are solid waste that must be conveniently handled, at considerable cost; and
- Label packages of materials as it comes in, and record the date for reception of materials that deteriorate easily, so that the first to come in are employed first.

3.2.3 Construction stage

Most waste generated during the construction stage can be avoided. Ways to avoid waste are (Couto & Couto (a), 2007; Couto & Couto, 2009):

- Ordering pre-cut, prefabricated materials that are the correct size for the job;
- Reduce packaging by returning to the supplier, or requesting reusable packaging such as cardboard or metal instead of plastic;
- Bulk-buy to avoid excess packaging (however, ensuring site requirements are not exceeded, avoiding the environmental impact of transportation and excess storage)
- Orders to suppliers of materials should respect sizing needs so that size adjustments can be avoided during construction;
- Make sure storage areas are secure and weatherproof (where required);
- Keep the site tidy to reduce material losses and waste;
- Promote good practice awareness as part of health and safety induction/training for workers onsite;
- Protect materials from deterioration. Store them in sheltered areas if they are subject to degradation by rain or sunshine. Materials that can be degraded by mud or dust must be stored away from heavy traffic areas;
- Waste selection. Waste must be stored in segregated containers, according to the material origin; wood, metal, packages, aggregates, etc. Storing waste inconveniently has costs – the storage of dangerous waste is much more expansive than that of harmless materials – and may make the construction site unsafe. Piles of waste scattered throughout the site make accidents more likely; storing waste correctly not

only bolsters reuse and recycling as it contributes towards health and hygiene at the site. Waste selection involves room enough on site to dispose containers and allow for the operation of trucks and cranes and skill workers to the selection procedures, but these conditions are often difficult to achieve, especially in historical city centres. Some private companies already operate in the area of waste selection and possible reuse of materials in the construction industry;

- Cutting concrete due to lack of precision in design implementation shuttering and placement of holes should be avoided because it produces waste besides it is time consuming and involves noisy operations;
- Reusable shuttering materials with eventual wreck value should be preferred even if investment costs are higher; and
- Storing in safe areas using adequately labelled containers for chemicals and recycling.

3.3 Reusing waste

Reusing building materials prevents environmental impacts by reducing the need for virgin natural resources to be mined and harvested, while saving forests and natural areas from further degradation. Reusing waste is efficient, as it does not require further processing, thereby not requiring further energy use. Efficiency can be improved further by reusing materials on site, eliminating the need for transportation. There are several opportunities for waste reuse as following is described:

- Careful demolition can maximize the reuse value of materials, particularly fittings, floorings and timber linings;
- Sort demolition materials and identify the materials that can be reused, and grade accordingly to quality and re-usability;
- Reuse rock, soil and vegetation on site for landscaping;
- Stockpile the materials for removal and reuse off site, ensuring adequate provision for sediment and erosion control (ensuring minimal impact to the aesthetic quality of the surrounding environment);
- Reuse materials from the demolition stage;
- Buy used materials from reclamation yards where possible re-usable shuttering materials with eventual wreck value should be preferred even if investment costs are higher;
- Re-usable shuttering materials with eventual wreck value should be preferred even if investment costs are higher; and
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3.4 Recycling waste

Many waste products unable to be reused directly, can be reprocessed into new products. Successful waste minimisation requires the appropriate handling of waste on site at all stages of development. In particular:

- Sort waste according to type, use and quality. Several bins or storage areas should be provided, and should be clearly signed. Waste for disposal should be kept separate from recyclables;
- Ensure waste is kept clean and free of contaminants. This can be done by providing dry storage areas, clearly marked bins, and waste management information to contractors and staff; and
- Provide for ongoing waste management.

3.5 Disposing of waste

Disposal of waste should be considered a last resort, for materials that cannot be reused or recycled in the region. Unsorted loads may incur in a disposal penalty at landfills. Hazardous materials need to be disposed of correctly.

4. Deconstruction technique as alternative to traditional demolition

4.1 Factors affecting the choice of demolition method

According to what has been previously mentioned, the demolition is one of the main construction activities in concerning the production of waste. The demolition industry has undergone major transformations within the last 20 years. Traditionally it has been an intensive labor activity with low technology, low skills, and poorly regulated dealing mainly with the disassembly and demolition of simply constructed buildings. With the arising of new challenges, namely the increasing complexity in building design, the financial pressures from clients, health and safety issues, regulatory and legal requirements, it has followed the trend of all major industries and mechanized the process by replacing labor with machines (Hurley & Hobbs, 2004).

The older buildings often have several components with an aesthetic or antique value which results in them being salvaged. As the complexity and size of buildings has risen so have the technical demands placed on contractors taking them down safely. Research from the University of Salford (Bowes & Golton, 2000) reveals that demolition techniques are now not only numerous but also varied in their technology, application, cost and speed. Traditional methods such as the steel ball are being rapidly replaced by more modern methods as the emphasis changes from masonry and brickwork to concrete and steel structures.

Traditionally, factors are concerned with the physical aspects of the building to be demolished, its technology and materials, size, location, site, use and the scope of the demolition required, the safety of operatives, the public and the environment and the time period (Kasai & Lindsell, 1988). The incorporation of the time factor shows that the contractual conditions can have an effect on choice, whilst the inclusion of safety aspects points to the influence of wider issues such as legislation, and the environment. However, nowadays a new factor should be added to the initial group of factors:

- *The proposed fate of the building materials and components* once the structure is demolished will probably affect the choice to some extent. Some of the methods available, for example, explosives, merely reduce a building into manageable size pieces taking little

or no account of the separation of materials. Clearly such methods would be unsuitable for a project where a high degree of reuse of individual components was specified.

There are usually several methods of tackling a demolition, all of which have various advantages relating to the factors above. There are not 'right' or 'wrong' methods, just alternative options based on different assessment of the relevant factors in a case.

The choice for the best option for managing a project's waste, should take into consideration the value of the various materials. For instance, there may be materials on a project that have a greater value "as is" for salvage compared to their value as material for recycling. Some of these materials may be valuable to reuse on-site; others may be donated or sold to a used building material retailer or charitable organization. The initial costs for deconstruction services may be offset by returns from salvaged materials or reduced purchasing costs. Some deconstruction services may also give a tax deduction for materials that are donated (Resource Venture, 2005).

In some cases, reused materials may also provide functional or aesthetic features not available in new materials. For example, salvaged wood is often of a quality and a variety of species that is difficult to find in the market place.

There are two ways to recover materials for salvage and reuse: Deconstruct the building or conduct a selective salvage operation prior to demolition. Deconstruction involves the careful dismantling of a whole structure in reverse order of assembly, usually by hand, to re-harvest materials for reuse. Salvage is the removal of certain valuable reusable building materials before demolition.

4.2 Deconstruction technique

Deconstruction is a new term used to describe an old process. As its primary purpose, deconstruction encompasses a thorough and comprehensive methodology to whole building disassembly and seeks to maintain the highest possible value for materials in existing buildings by dismantling them in a manner that will allow the reuse or efficient recycling of the materials that comprise the structure (Moussiopoulos et al., 2007). For demolition projects that involve removing a large portion of a structure or an entire building, deconstruction may be the best option. Deconstruction is a specific type of demolition work that is growing in popularity in the United States and in other European countries and that poses the greatest potential for waste recovery on a wide range of construction projects. Deconstruction contractors take the entire structure apart, separating out resources that can be salvaged, recycled or reused.

The feasibility and cost-effectiveness of deconstruction is determined by how the building was constructed and what building materials were used. The building components, their condition and the manner in which they are secured to the structure can affect the cost-effectiveness of salvaged materials.

Another factor to consider is whether site conditions allow for mechanical versus manual demolition, which will add labor costs. To be cost-competitive with conventional demolition, the added costs of deconstruction (primarily, the extra labor of disassembly and removal) must be offset by the value of the salvaged building material and the avoided cost of disposal.

4.3 Salvage

Salvage is the removal of reusable building materials before demolition. In many cases, it may not be feasible or cost-effective to fully deconstruct a building, but there may be

materials on a project that can be salvaged instead of recycled or discarded. This is also a very good cost-saving strategy for a remodeling or tenant improvement project. Most demolition contractors are practicing some level of salvage on selected buildings. In many cases, demolition contractors will sub-contract with deconstruction contractors or specialty sub-contractors to conduct salvage operations before demolishing specific components or materials.

4.4 Barriers and advantages of deconstruction

4.4.1 Barriers and opportunities for deconstruction

There are a number of areas where the authorities may influence design and planning strategies at an early stage. These include fiscal incentives such as the maintenance of a fixed price for recovered products or increased costs for waste disposal through the landfill tax. Incorporation of deconstruction techniques into material specifications and design codes on both a National and European level would focus the minds of designers and manufacturers. Education of the long-term benefits of deconstruction techniques for regulators and major clients would provide the necessary incentive for the initial feasibility stage. Design for deconstruction is not, however, solely an issue for the designers of buildings. The development of suitable tools for the safe and economic removal of structural elements is an essential pre-requisite of the more widespread adoption of deconstruction (Couto & Couto, 2007).

A study carried out by BRE (Building Research Establishment) (Hurley et al., 2001) has shown what the industry has known for decades; that there are key factors that affect the choice of the demolition method and particular barriers to reuse and recycling of components and materials of the structures. The most factors are physical in terms of the nature and design of the building along with external factors such as time and safety. Future factors to consider should well include the fate of the components, the culture of the demolition contractor and the 'true cost' of the process. For the latter, barriers to uptake include the perception of planners and developers, time and money, availability of quality information about the structure, prohibitively expensive health and safety measures, infrastructure, markets quality of components, codes and standards, location, client perception and risk.

According Hurley and Hobbs (Hurley & Hobbs, 2004) the main barriers in the UK to the increased use of deconstruction methods within construction include:

- Lack of information, skills and tools on how to deconstruct;
- Lack of information, skills and tools on how to design for deconstruction;
- Lack of a large enough established market for deconstructed products;
- Lack of design. Products are not designed with deconstruction in mind;
- Reluctance of manufactures, which always prefer to purchase a new product rather than to reuse an existing one;
- Composite products. Many modern products are composites which can lead to contamination if not properly deconstructed or handled; and
- Joints between components are often designed to be hidden (and therefore inaccessible) and permanent.

Although the market for products from deconstruction to be poorly developed in Portugal can be noted that the interest in low volume, high value, rare, unique or antique architectural components it's much higher than the interest in materials that have high volume, low value, such as concrete.

Even though there are significant advantages to deconstruction as an option for building removal, there are still more challenges faced by this alternative:

- Deconstruction requires additional time. Time constraints and financial pressure to clear the site quickly, due to lost time resulting from delays in getting a demolition, or removal permit, may detract from the viability of deconstruction as a business alternative;
- Deconstruction is a labor-intensive effort, using standard hand tools in the majority of cases. Specialized tools designed for deconstructing buildings often do not exist;
- The proper removal of asbestos-containing materials and lead-based paints, often encountered in older buildings that are candidates for deconstruction, requires special training, handling, and equipment; and
- Re-certification of used materials is not always possible, and building codes often do not address the reuse of building components.

The main opportunities which require development include:

- The design of joints to facilitate deconstruction;
- The development of methodologies to assess, test and certify deconstructed elements for strength and durability, etc.;
- The development of techniques for reusing such elements; and
- The identification of demonstration projects to illustrate the potential of the different methods.

Modern materials such plywood and composite boards are difficult to remove from structures. Moreover, new building techniques such as gluing floorboards and usage of high-tech fasteners inhibit deconstruction. Thus, buildings constructed before 1950 should be ideally targeted for deconstruction (Moussiopoulous et al., 2007). In Portugal, it is expected a substantial increase in investment in rehabilitation of buildings. The deconstruction should have a relevant contribution in this process.

The greatest benefit will be achieved by incorporating deconstruction issues into the design and feasibility stage for all new construction. Each case can then be judged on its merits in terms of the potential cost of recovery and recycling or reclamation and reuse of construction materials.

The following in table 2 is an attempt to systematize the main barriers in the implementation of deconstruction in Potugal from the analysis of the barriers identified in the international literature (Storey & Pedersen, 2003):

Barrier	How this relates to PT	Solutions
Legislation		
Current standard specifications.	Standards give the impression that new materials must be specified.	- Development of standard specifications etc, which incorporate reused/recycled components. - Document and publish examples of the successful use of reused and recycled components. - Government and local council as examples in new development.

Markets		
The high cost of transport and storage of recycled components and materials.		<div>- Market networking.</div> <div>- Direct sales from site.</div>
Uses for some salvaged materials are undeveloped.	Finding uses for some recycled or salvaged materials is difficult.	<div>- Increased research focusing on problem materials.</div>
Designer/ public/ builder attitude: “new is better” and new buildings are permanent.	The majority of building materials specified and used in PT are new. Design for deconstruction is uncommon.	<div>- Education for architects in life cycle considerations and holistic design principles.</div> <div>- General education of public, designers and builders.</div> <div>- Easy to use guides in the use of salvaged materials/ design for deconstruction.</div> <div>- Publishing and compilation of research into quality aspects of reused goods.</div>
The lack of a grading system for reused components.		<div>- Development of a grading system.</div> <div>- Training in the grading of reused materials.</div> <div>- Liability issue addressed.</div>
Guaranteed quality /quantities of reused materials are difficult.		<div>- Increased networking of salvage.</div> <div>- Increased deconstruction.</div>
Lack of information and tools to implement deconstruction.	There is a lack of PT specific documents or information kits for the implementation of deconstruction and specific feasibility studies or clear PT examples cases.	<div>- Compilation of guides, development of implementation ideas.</div> <div>- Clear ways to implement PT Waste Strategy targets are needed.</div> <div>- Increased pilot studies and test cases.</div> <div>- Strategic planning to address barriers.</div>
C+D Industry		
Lack of communication and networking in the C&D industry.		<div>- Greater communication, networking and collaboration.</div> <div>- Increased conferences, email discussion groups, networking, professional articles publications, etc.</div>
Lack of design for deconstruction.	International research is not always applicable to PT. There is a lack of example cases built in PT. Design for deconstruction is	<div>- Education of architects and designers through conferences/ exhibitions/ case studies etc.</div> <div>- Education at architecture</div>

	not taught at architecture schools.	schools. - Development and sharing of teaching resources and case study examples.
Difficulty in securing funding for research.	Science and Innovation Policy.	- Governments and funding agencies need to make waste minimisation a priority.
Economics Factors		
The benefits of deconstruction are long term and collective.		-Increased education on environmental building impacts for developers.
Lack of financial incentive for deconstruction.		- Implementation of economic incentives and deterrents to encourage deconstruction.
Market pressures – the current climate of “as fast as possible”.	Limited time to salvage maximum materials in the demolition stage. Deconstruction takes longer.	- Salvage operations to work along side but independently of demolition contractors. - Share of environmental responsibility to developers.
It is difficult to access or apply economic assessment tools for deconstruction or LCA in some cases.	There are no PT specific deconstruction evaluation tools or national feasibility studies.	- Collection of existing tools in one place. Possibly website. - Development of non region-specific tools or more flexible parameters.
Deconstruction needs a more skilled workforce than demolition.	Unregulated demolition industry. Lack of case jobs to train on.	- Increased opportunities for training and transition from traditional demolition to deconstruction. - Cooperative between the construction and demolition sectors.
Technical Issues		
Lack of documentation.	Records of materials used in construction are not kept.	- Better recording of materials used. - Storage of records in the actual building.
Increased use of in situ technology, chemical bonds and plastic sealants, etc.	Commonly used in new buildings in PT. Most concrete structures have in situ components.	- Research viable alternatives to these techniques. - Development of ways to separate these bonds
Most existing buildings are not designed to be deconstructed.	This is true in PT.	- Research and development to find ways to effectively deconstruct these buildings. - Implementation of design for deconstruction techniques into learning establishments a priority.

Table 2. Main barriers to deconstruction in Portugal. Adapted from (Storey & Pedersen, 2003)

4.4.2 Deconstruction benefits

Deconstruction seeks to close the resource loop, so that existing materials are kept in use for as long as possible and the deployment of new resources in construction projects is diminished. The benefits from deconstruction are considerable. Deconstruction offers historical, social, economic and environmental benefits. Older buildings often contain craftsmanship, which have significant historical value. Deconstruction can carefully salvage these important historical architectural features because materials are preserved during removal. Deconstruction is more time consuming and requires more skill than simply demolishing a structure. Although the extra time required could act as a detriment, deconstruction provides training for the construction industry and also has the potential to create more jobs in both the demolition and the associated recovered materials industry. Deconstruction provides a market for labour and sales of salvaged material. More important, deconstruction puts back into circulation items which may be directly used in other building applications. Environmental benefits of deconstruction are essentially two fold. Primary, resource use is reduced through a decreased demand on new materials for building. This means that climate change gas emissions, environmental impact, pollution (air, land and water) and energy use are all reduced. Deconstruction also means that less waste goes to landfill because materials are salvaged for reuse. This means fewer new landfills or incinerators need to be built which reduces the environmental and social impact of such facilities, and environmental impact of existing landfills is reduced. Currently there are few incentives to break the historical practice of landfilling debris. The occasionally higher cost of selected demolition can be offset by the increased income from salvaged materials, decreased disposal costs, and decreased costs from avoided time and expense needed to bring heavy equipment to a job site (Couto & Couto, 2007).

Based on the review of international literature it is possible to categorize the main benefits of deconstruction as follows:

- Reuse and recycle materials: materials salvaged in a deconstruction project can be reused, remanufactured or recycled (turning damaged wood into mulch or cement into aggregate for new foundations) (Hagen, 2008);
- Foster the growth of a new market – used materials: recovered materials can be sold to a salvaging company. The market value for salvaged materials from deconstruction is greater than from demolition due to the care that is taken in removing the materials in the deconstruction process;
- Environmental benefits: salvaging materials through deconstruction helps reducing the burden on landfills, which have already reached their capacity in many localities. By focusing on the reuse and recycling of existing materials, deconstruction preserves the invested energy embodied in materials, eliminating the need to expend additional energy to process new materials. By reducing the use of new materials, deconstruction also helps reducing the environmental effects, such as air, water and ground pollution resulting from the processes of extracting the raw materials used in those new construction materials. Deconstruction results in much less damage to the local site, including soil and vegetation, and generates less dust and noise than demolition; and
- Create jobs: deconstruction is a labour-intensive process, involving a significant amount of work, removing materials that can be salvaged, taking apart buildings, and preparing, sorting, and hauling the salvaged materials.

Others benefits less obvious may also come from the deconstruction, but that depend on the specific characteristics of countries and regions.
The following (table 3) is presented an attempt to systematize the benefits that can come from the implementation of deconstruction in Portugal.

Benefits of Deconstruction in Portugal	
Environmental	Reduce primary resource use
	Reduce waste to landfill
	Increase opportunities for recycling
	Site impacts caused by demolition such as noise, compaction, dust, etc. are mitigated
Economic	Profit increased taking into account the sale of salvaged goods and reduction landfill costs
	Promotion of PT's green image
	Increase local market for the salvage and recycling industry
	Export opportunities for deconstruction related machinery and consulting
	Recycled goods may be of a higher quality and be of a more durable nature than new goods
Social	More jobs are created with deconstruction
	Deconstruction trains workers for the construction industry
	Deconstruction could provide low cost materials to low income communities
	Improve knowledge about the construction techniques applied
Health and Safety	Careful removal of hazardous materials
	Deconstruction means less new waste facilities
Legislative	Contributes to meeting local authority and central government obligations for waste targets, zero waste, kyoto targets and energy efficiency targets

Table 3. Benefits of deconstruction in Portugal

4.4.3 Cost of deconstruction

Deconstruction, as an environmentally-sound business practice, is not necessarily more costly than traditional demolition. Buildings can be often deconstructed more cost-efficiently than they can be demolished. There are many different factors involved, including the type of construction and the value of the materials that can be recovered. But overall, deconstruction can be more cost-effective than demolition. Not only can buildings be deconstructed more cheaply than they can be demolished, but deconstruction provides construction companies with low-cost materials for reuse in their own building projects. Deconstruction is also an ideal training ground for the construction trades. Preliminary results from pilot projects carried out in different parts of the USA by the US Environmental

Protection Agency (EPA) have indicated that deconstruction may cost 30 to 50% less than demolition (CEPA, 2001).

Deconstruction is labor-intensive, involving a higher level of manual work than there would be in a demolition project. But the higher labor cost can be offset by lower costs for equipment rent and energy usage, cost savings in the form of lower transportation and landfill tipping charges, and the revenues from sales of the salvaged material.

Research shows that the market value for salvaged material is greater when deconstruction occurs instead of demolition, because of the care taken in removing materials. Money made through salvaging can be used to offset other redevelopment costs. Lastly, disposal costs are lower with deconstruction because the process reduces the amount of waste produced by up to 75 percent.

Different studies carried out in Germany on deconstruction methods has showed that optimized deconstruction combining manual and machine dismantling can reduce the required time by a factor of 2 with a recovery rate of 97% (Kibert, 2000). In the Oslo region, Norway, it is estimated that between 25% and 50% of C&D waste stream is recycled or reused (Kibert, 2000).

In Portugal the construction waste management is now beginning its first steps, so that, its outcomes are not still known.

Previous research analysis to point out that from the clients' perspective the following are sound economic reasons for using deconstruction (Couto & Couto, 2009):

- To increase the flexible use and adaptation of property at minimal future cost;
- To reduce the whole-life environmental impact of a project;
- To maximise the value of a building, or its elements, when it is only required for a short time;
- To reduce the quantity of materials going to landfill;
- To reduce a future liability to pay higher landfill taxes;
- To reduce the risk of financial penalties in the future, due to changing legislation, through easily replaceable building elements; and
- To minimise maintenance and upgrading costs incurred by replacement requirements.

A key economic benefit of design for deconstruction is the ability for a client to "future proof" their building, both in terms of maintenance and any necessary upgrading, with minimum disruption and cost. The wider economic benefits to society include minimising waste costs at all levels.

Numerous projects have been costed, and while some have come in on budget, others have not. Much depends on the caniness of the design team and contractor, from the outset, with cost savings to be viewed as bonus rather than a given. Design for deconstruction should always be adopted for its wider economic, social and environmental benefits rather than any initial cost saving.

Current economic barriers to design for deconstruction and re-use of reclaimed materials and products include: the additional time involved for deconstruction and the difficulty of costing this against re-used materials which will be used on a different project, the damage caused by poorly designed assemblies and connectors as well as the limited flexibility of reclaimed elements. Reuse is not subsidised in the same way that manufacture is in terms of energy, infrastructure, transportation, and economies of scale, all of which have hidden environmental costs.

5. Establishing a conduct for successful deconstruction process

Advanced planning for deconstruction or salvage before demolition is crucial for its success. The first step is to assess the deconstruction potential:

- Conduct a walk-through with the owner's representative and a deconstruction contractor to determine the feasibility and level of salvage possible. Identify materials and job phases where recovery, recycling and salvage opportunities are the greatest. The walk-through also can identify materials that could be salvaged and reused on-site;
- To compare costs, require estimates for full deconstruction of the structure, targeted salvage prior to demolition, and traditional demolition; and
- Based on the walk-through and cost comparison, it should be determined if full deconstruction of the structure is an option or if salvage prior to demolition would be more effective.

After that, one should be establish goals for deconstruction salvage and recycling and include these goals in the specifications.

Based on the walk-through, a list of materials to be salvaged should be developed. Identify materials to be reused on-site. For materials that will be sold or donated off-site, salvage companies that accept reused building materials should be contacted.

It is important to use specification language in the construction waste management specifications to address deconstruction or salvage prior to demolition. The language should include goals or measurable standards for the level of salvage and/or a list of materials to be salvaged.

Deconstruction and salvage prior to demolition are usually more time-consuming than traditional demolition. It is important that sufficient time is allowed to dismantle the building or to salvage reusable items before demolition. For that, it is recommendable to take the following measures:

- Determine in advance how much time is available to complete the demolition phase of the project. The bid and contract process is the best place to assure that adequate time is available. Contracting mechanisms include decoupling demolition from the design/build phase of construction contracts. The demolition aspect of the project can be delayed while the terms of the larger design/build agreement are worked out, thus allowing time for deconstruction and salvage prior to completing demolition;
- Other alternatives to ensure enough time to complete deconstruction and salvage include issuing an early notice to proceed for the demolition phase of the project or creating a separate request for proposal or bid and contract for deconstruction and demolition.

It also is important for the architect to identify and remove barriers to salvage and reuse by eliminating language in contracts that prohibit rather than control activities such as on-site salvage, storage of salvaged materials, or processing operations that might create noise pollution like on-site concrete crushing.

Require the contractor to develop a reuse and salvage plan as part of the waste management plan for the project by including this requirement in the specification language. The reuse and salvage plan should include a list of items being reused in place or elsewhere on-site; a list of items for reuse off-site through salvage, resale or donation; a plan for protecting,

dismantling, handling, storing and transporting the reused items; and a communications plan describing the salvage plan to all players.

Finally, the contractor should be also required to provide clear and consistent communication at the job site to be sure the crew is informed of the salvage plans, procedures and expectations. Careful removal and handling of the reuse and salvage materials is crucial to their usability and marketability - the key to success is communicating the priorities, making detailed plans and carefully monitoring the progress to insure success.

6. Suggestions to impel the deconstruction process in Portugal

In Portugal the construction sector is still very traditional, so new practices and attitudes are difficult to implement. New challenges like refurbishment and waste management have been systematically prorogued. In order to improve the construction waste management by impelling the deconstruction process it will be necessary to implement some few strategic actions:

- To improve the efficiency of the authority control;
- Training all construction intervenients;
- Diffusion of benefits by workshops;
- To consider environmental factors in contractors selection;
- To increase the disposal taxes; and
- To increase the penalties.

7. Conclusions

Nowadays, few measures have been carried out to improve the relationship among construction site activities, the environment and the citizens. Maybe due to the mobility of the construction activity, it is difficult to make the construction companies - especially the smallest ones - keep the law. There are some good examples but they are still insufficient. The production of legal documents that encourages a more environmentally positive behaviour, that is, that arouse and force the construction industry to handle its debris and by-products more carefully, is of vital importance to the contribution of this sector for sustainable development for the which all must contribute. In this context, special mention must be made to the mandatory, in public projects, of a waste management plan, which must be made during the design stage. It seems to be a correct and effective way to highlight the importance of waste management and to get all the participants involved, from the design to the construction stage. This change, however, must be accompanied by public awareness campaigns. It is not enough to stress that the plan is mandatory. The plan's importance must be addressed too. It will be easier to reach our goals if all know the advantages and importance of such a plan.

Due to the need for adaptation and improvement of existing buildings taking into account the new standards of quality and comfort, the works involving demolition of buildings or parts of buildings are becoming increasingly frequent in Portugal. Thus, the study of practical solutions that point to the reuse of building materials and components, will contribute to decrease the urban problem created by illegal landfills - bringing

environmental improvement – and introduce new materials into the market which have potential for use. The deconstruction process appears as an adequate answer for these challenges and with a significant potential for exploitation in Portuguese building refurbishment. In this sense, it is very important to carry out an effort to overcome the barriers to the increased use of deconstruction methods as an option for building demolition.

Therefore, a greater engagement and a new attitude from all practitioners is absolutely necessary in order to implement new and more adequate waste management rules and new selection demolition processes so as to increase the results of the construction waste management.

It is very important that National authorities and construction practitioners understand the benefits of the deconstruction process and look at it as an advantageous way to improve waste management, thus following other European countries' practices.

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