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DESIGN APPROACHES FOR CONSTRUCTION AND DEMOLITION WASTE MINIMIZATION GENERATED THROUGH THE BUILDING LIFE PROCESSES AND A MODEL SUGGESTION

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ABSTRACT

Increased construction activities along with the increasing population in Europe and the world leads to growing environmental problems, because buildings generate waste through the building life processes (construction, usage and deconstruction/demolition). Disposing of this waste into the environment causes soil, air and water pollution. The large volume of construction and demolition (C&D) waste strain waste sites and negatively affect living and nonliving environments. Moreover, it is more difficult to dispose of C&D waste than domestic waste since it contains harmful substances such as asbestos, and volatile organic compounds. Therefore, the fundamental task of C&D waste management, a top priority waste stream, is prevention/reduction. If the amount of waste that is collected, processed, and eliminated is reduced, environmental and economic costs can be reduced.

Preventing/reducing waste generation is the most effective method for stopping the depletion of natural resources and is an essential factor in environmental conservation and the sustainable use of natural resources. The greatest responsibility in preventing/reducing C&D waste belongs to designers, who make decisions directly in the design of the building and directly and indirectly in the construction, usage, and deconstruction/demolition phases. This study examines the ways that C&D waste can be prevented/reduced in the design phase, develops a design approach, and proposes solutions.

The study consists of eight chapters. The first chapter offers definitions for C&D waste, compares the amounts of such waste in different countries and describes how this waste is generated. Studies conducted in Europe and the world on preventing/reducing the waste generated in the construction, usage and deconstruction/demolition of buildings are examined. The importance, objectives, methods, and scope of the study are presented here. The second chapter examines the sub-phases of designing the building. The importance of the design phase in terms of the waste generated in construction, usage and deconstruction/demolition is also explained in this chapter, which determines the scope of the study.

In the third, fourth and fifth chapters, relationships between design and construction, design and usage, and design and deconstruction/demolition phases are described, considering the knowledge that waste is created in all these phases by design decisions. Suggestions are offered for managing the waste generated throughout the lifespan of the building during the design phase, and “designing out waste criteria” are presented.

In the sixth chapter, case studies around the world are examined and evaluated.

The seventh chapter of the study presents a model that designers can use to prevent/reduce C&D waste. The theoretical conclusions are presented here as a flow chart.

The eighth and final chapter of the study is entitled “Conclusion and Recommendations.” It evaluates this study’s design approach for preventing/reducing the waste stream generated in buildings’ construction, usage, and deconstruction/demolition phases.

Keywords: C&D Waste, C&D Waste Prevention/Reduction, Construction Phase of Buildings, Usage Phase of Buildings, Deconstruction/Demolition Phase of Buildings

ASTRATTO

L'aumento delle attività di costruzione insieme all'aumento della popolazione in Europa e nel mondo porta a crescenti problemi ambientali, perché gli edifici generano rifiuti attraverso i processi vitali degli edifici (costruzione, utilizzo e decostruzione/demolizione). Lo smaltimento di questi rifiuti nell'ambiente provoca inquinamento del suolo, dell'aria e dell'acqua. Il grande volume di rifiuti da costruzione e demolizione (C&D) sovraccarica i siti di rifiuti e influisce negativamente sugli ambienti viventi e non. Inoltre, è più difficile smaltire i rifiuti C&D rispetto ai rifiuti domestici poiché contengono sostanze nocive come amianto e composti organici volatili. Pertanto, il compito fondamentale della gestione dei rifiuti C&D, un flusso di rifiuti prioritario, è la prevenzione/riduzione. Se si riduce la quantità di rifiuti raccolti, trattati ed eliminati, è possibile ridurre i costi ambientali ed economici.

La prevenzione/riduzione della produzione di rifiuti è il metodo più efficace per fermare l'esaurimento delle risorse naturali ed è un fattore essenziale per la conservazione dell'ambiente e l'uso sostenibile delle risorse naturali. La maggiore responsabilità nella prevenzione/riduzione dei rifiuti C&D spetta ai progettisti, che prendono le decisioni direttamente nella progettazione dell'edificio e, direttamente e indirettamente, nelle fasi di costruzione, utilizzo e smantellamento/demolizione. Questo studio esamina i modi in cui i rifiuti C&D possono essere prevenuti/ridotti nella fase di progettazione, sviluppa un approccio progettuale e propone soluzioni.

Lo studio si compone di otto capitoli. Il primo capitolo offre definizioni per i rifiuti C&D, confronta le quantità di tali rifiuti nei diversi paesi e descrive come vengono generati questi rifiuti. Vengono esaminati gli studi condotti in Europa e nel mondo sulla prevenzione/riduzione dei rifiuti generati dalla costruzione, utilizzo e decostruzione/demolizione degli edifici. L'importanza, gli obiettivi, i metodi e la portata dello studio sono presentati qui. Il secondo capitolo esamina le sottofasi della progettazione dell'edificio. L'importanza della fase di progettazione in termini di rifiuti generati durante la costruzione, l'utilizzo e la decostruzione/demolizione è spiegata anche in questo capitolo, che determina l'ambito dello studio.

Nel terzo, quarto e quinto capitolo sono descritte le relazioni tra le fasi di progettazione e costruzione, progettazione e utilizzo, e progettazione e decostruzione/demolizione, tenendo conto della consapevolezza che in tutte queste fasi si creano rifiuti dalle decisioni progettuali. Vengono offerti suggerimenti per la gestione dei rifiuti generati durante l'intero ciclo di vita dell'edificio durante la fase di progettazione e vengono presentati "la progettazione dei criteri di smaltimento".

Nel sesto capitolo vengono esaminati e valutati casi di studio nel mondo.

Il settimo capitolo dello studio presenta un modello che i progettisti possono utilizzare per prevenire/ridurre gli sprechi C&D. Le conclusioni teoriche sono qui presentate come un diagramma di flusso.

L'ottavo e ultimo capitolo dello studio è intitolato "Conclusione e raccomandazioni". Valuta l'approccio progettuale di questo studio per prevenire/ridurre il flusso di rifiuti generato nelle fasi di costruzione, utilizzo e decostruzione/demolizione degli edifici.

Parole chiave: Rifiuti C&D, Prevenzione/Riduzione dei Rifiuti C&D, Fase di costruzione di Edifici, Fase di Utilizzo degli Edifici, Fase di Decostruzione/Demolizione degli Edifici

PART I
Introduction

Found in solid, liquid and gaseous form in nature; any substance that arises as a result of production, use and destruction activities and which is undesirable to be given directly or indirectly to the environment as it will harm the living and non-living environment is defined as "waste".

The largest share among the waste types grouped as medical, domestic, industrial, agricultural, mineral and structural [1] belongs to the C&D l wastes generated by the activities of the building production sector in terms of both the area they cover and the amount.

Various definitions of C&D waste are made in the literature. Menegaki and Damigos [2] defined construction and demolition waste (CDW) in general, as a mixture of different material, including inert waste, non-inert non-hazardous waste and hazardous waste, generated from construction, renovation, and demolition activities. According to Yuan & Shen [3], construction waste is building debris, rubble, earth, concrete, steel, timber, and mixed site clearance materials, arising from various construction activities including land excavation or formation, civil and building construction, site clearance, demolition activities, roadwork, and building renovation.

It is seen in the definitions that C&D waste originate from construction products. It emerges in various processes of the building product or structure. In this context, C&D waste is considered as waste that occur in various types and amounts in the life cycle of building products – raw material acquisition, product production, sale, application to the building, use, recycling, destruction – or during the construction, use and dismantling / demolition processes of the building.

Currently, the European construction sector produces 500 million tones of construction and demolition waste (CDW) every year, 36% of the total amount of total waste generated according to Eurostat [4]. As can be seen from the data, the amount of CDW is high, and it covers a larger area compared to the same amount of various types of waste. CDW has negative effects on the natural/artificial environment and the health of living things due to reasons; construction, use of the building and leaving it indiscriminately to nature after the processes of demolition, accumulating in the natural environment, not carrying out the CDW management with appropriate action steps, not taking the hazardous wastes under control, etc.

The reasons for the formation of C&D waste, which have various damages on the natural/made environment, living health and economy, are classified in various ways in the sources. Gavilan and Bernold [5] associated the causes of the formation of C&D waste with the design process, the process of obtaining building products and the use of building products. The Building Research Establishment (BRE) has addressed the causes of C&D waste generation in the context of the design process, contracts, and delivery process [6]. Shah [7] discussed this classification under six headings as planning and design, purchasing, product supply, storage, construction/repair, and running out of products.

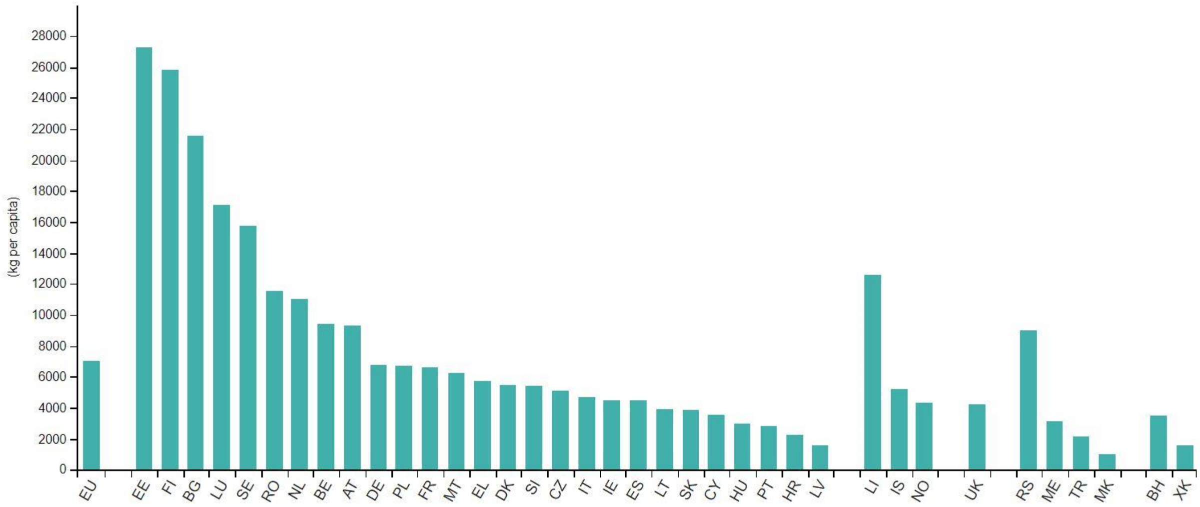

Table 1.1 The amount of C&D *waste generated in European Union countries [4]*

In the studies conducted by Bossink and Brouwers [8], Faniran and Caban [9], Ekanayake and Ofori [10], and Chandrakanthi [11], it is agreed that most of the C&D waste is caused by the wrong decisions made by the architects during the design process. Innes' [12] study states that 33% of the C&D waste generated during the construction process are caused by design errors. Studies by Coventry and Guthrie [13], Greenwood [14], Poon and colleagues [15] and Baldwin colleagues [16] emphasize that the most important task in the prevention and reduction of C&D waste belongs to the architect. In this context, the greatest responsibility for the prevention/reduction of s C&D waste falls on the designers who make direct decisions during the design process of the building, and directly/indirectly during the construction, use, dismantling/demolition processes of the building. The starting point of this study is that buildings that are not designed in accordance with the principles of preventing/reducing waste generation create significant waste problems in the construction, use and dismantling/demolition processes.

1.1 Literature Review

Preventing/reducing waste generation is the most effective way to prevent the consumption of natural resources and is the main factor in protecting the environment and using natural resources in a sustainable manner. For this reason, waste prevention/reduction is determined as the first priority in all regulations. The European Union's Waste Environment Directive also obliges member states to take measures to encourage waste generation and reducing the level of hazardous wastes [17].

Considering the importance of the subject and the size of the problem, it is seen that there are studies by researchers and institutions examining the relationship between the design process of the building and the C&D waste prevention/reduction issue. When selecting studies by institutions Dow, and C2C have been selected and examined because they are studies aimed directly at C&D waste management, LEED and BREEAM have been selected because of current and active uses in the world, Green Star and IGBC Green Homes have been selected because they are at the local level.

● According to the study of Coventry and Guthrie [13], the tasks of the architect in the design process to prevent/reduce waste in the construction, use and dismantling/demolition processes are defined as followings:

- Making suggestions to the employer on C&D waste reduction,
- Developing the design by considering the wastes that may occur.

● According to Keys, Baldwin, and Austin [18], the causes of C&D waste generation in construction, use and dismantling/demolition processes depend on the complexity of the products selected in the design process and the construction setup, and the lack of coordination and communication in the design team. In this context, the prominent decisions within the scope of the thesis for the design without C&D waste have been defined as followings:
- Choosing pre-made products,
- Selecting standard products,
- Choosing the appropriate size and feature product,
- Selecting recycled products,
- Detachable design,
- Identifying products that may produce waste,
- Establishing effective communication between teams.

● In the study of Polat and Ballard [19], the main reasons for the formation of C&D waste arising from design are listed below:
- Deficiencies in the type and size information of the products to be used,
- Errors in the type and size information of the products to be used,
- Determining the types and sizes of the products to be used, regardless of waste generation,
- Changes to the design.

Lean Design for waste prevention/reduction

● In the study by Ballard and Zabelle [20]; various losses (time, product, money, etc.) occur during construction, use and dismantling/demolition processes. The use of LPDS (Lean Project Delivery System) approach is considered important to prevent/reduce these losses. Accordingly, in the first step of LPDS, data on environmental factors and requirements should be collected, design decisions should be made, and back-and-forth feeds should be made to control the decisions (Figure 1.1). After all the decisions are defined correctly, the lean design should be shaped in line with these decisions.

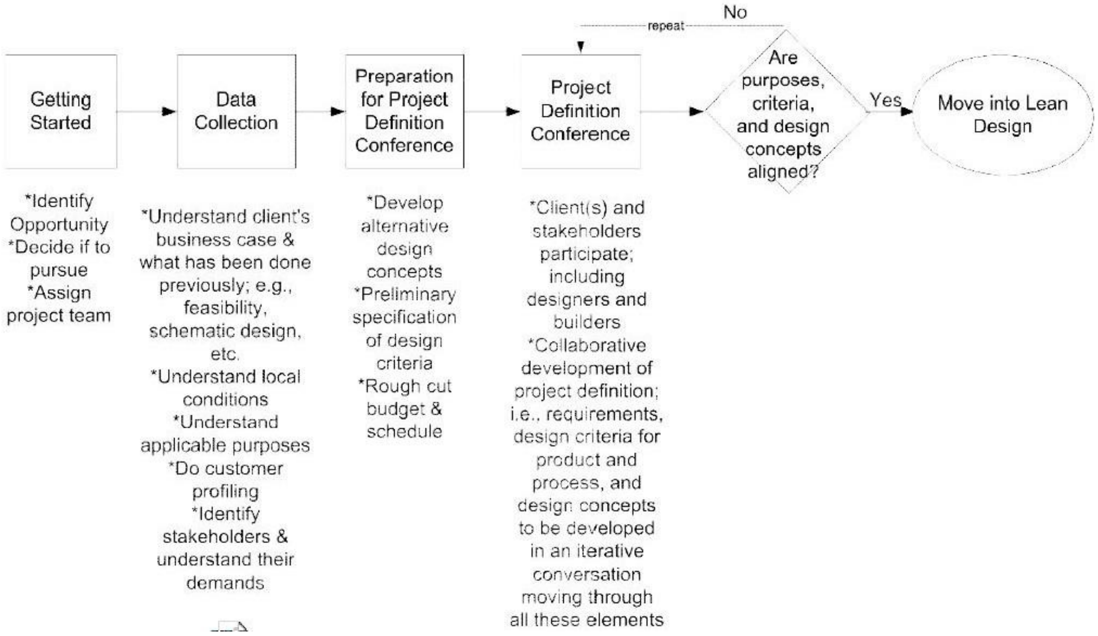

Figure 1.1 Project definition process in LPDS approach [20]

● In the study by Dorsthorst and Kowalczyk [21], the ICM (Integral Chain Management) approach, which aims to make the most use of the material to reduce C&D waste, is discussed (Figure 1.2). Major issues related to the use of building products in ICM are defines as following:
‘○ Level of reuse
- Construction
- Construction materials
- Building products
○ The way of reuse
- Recycling the substance to be used for the same purpose
- Downcycle of the substance to use it for a lower purpose than its original use
- Upcycle the substance for higher-purpose use than its original use
○ All actors involved in the construction, use and dismantling/demolition processes plan all processes with this awareness, not using non-recyclable products.

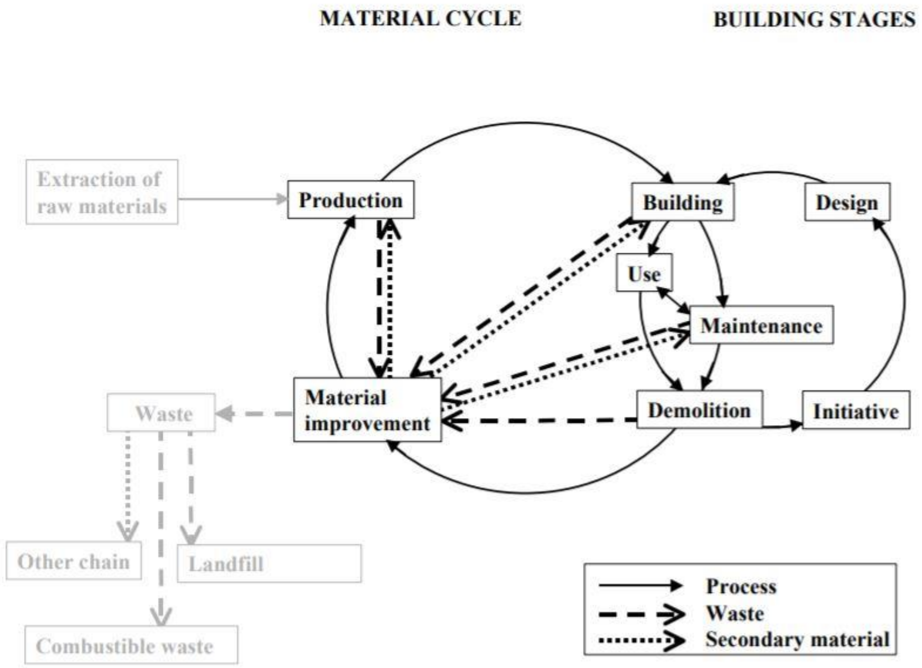

Figure 1.2 ICM approach [21]

However, it is emphasized that decisions regarding reuse should be taken during the design process of the building. Design for Recycling decisions that will contribute to the prevention/reduction of C&D waste through the recovery of construction products are defined as followings:
- Design for Adaptability: Making designs that can adapt to the new function when functional changes are to be made in buildings where the functional periods and the building lifespan are not equal,
- **Design for Dismantling:** Not to use non-recyclable products or to distinguish these products before the demolition process,
- Design for Deconstruction: Designing building products as demountable in order to reuse them,
- **Application and Dismantling Techniques:** To prevent damage as much as possible while dismantling the building products in order to be able to use them for the second time.

● **DoW** (Designing out Waste) approach consists of five different design decisions. These are determined as the following:
- Design for Reuse and Recovery;
- Design for Off Site Construction;
- Design for Materials Optimisation;
- Design for Waste Efficient Procurement
- Design for Deconstruction and Flexibility

In addition, a guide for designers has been created. The guide defines what needs to be done to prevent/reduce waste. The "Preliminary Design" and "Detailed Design" steps, which constitute the first two steps, indicate the suggestions for the design process [22].

● **The C2C** (Cradle to Cradle) approach was developed by architect William McDonough and chemist Michael Braungart, who wanted to completely eliminate the concept of "waste." Instead of designing "cradle-to-grave" products that are dumped or buried on land at the end of their life, McDonough and Braungart [23] argues that it is possible to use "from cradle to cradle" by producing products whose contents are constantly circulated in closed loops. For this purpose, the C2C approach is used to certify the product or system that complies with the "Cradle to Cradle" principle. It has been seen that the use of recycled products is supported in the C2C approach.

● **LEED** certification system (Leadership in Energy and Environmental Design), developed by USGBC (The US Green Building Council) contains information to evaluate environmental performance, aims to prevent/reduce C&D waste in the design process. Within the scope of LEED, there is no special section for the prevention/reduction of C&D waste in the design process, the subject is discussed under the heading of 'Materials and Resources'. There are suggestions at the product selection level to prevent/reduce the wastes that will occur during the construction, use and dismantling/demolition processes during the design process. Although recycling or reuse of building products is not always positive for the environment, it has been seen that recycling or reuse is supported regardless of waste type [24].

● **BREEAM** (BRE Environmental Assessment Method) is a building certification system contains information on the prevention/reduction of C&D waste in the design process of the environmentally friendly building which was started to be used in England in 1990 and later adopted in many countries of the world. Within the scope of BREEAM, there are no recommendations under the headings of 'Resources', 'Waste' and 'Materials' to prevent/reduce C&D waste in the design process. It includes suggestions at the product selection level to prevent/reduce the wastes that will occur during the construction, use and dismantling/demolition processes during the design process. There are decisions regarding the design decisions-waste relationship under the Resources subheading. As in LEED, it has been seen that the recycling or reuse of building products is supported in BREEAM, regardless of waste type [25].

● The certification system developed by GBCA (Green Building Council Australia), known as **Green Star**, in 2003 for buildings in which the cooling system and sun shading systems are important in hot climates is a comprehensive, national and voluntary environmental impact assessment system that regulates the design and construction of buildings. Within the scope of Green Star, there is no special section for the prevention/reduction of C&D waste in the design process, the subject is discussed under the headings of 'Management' and 'Materials'. There are suggestions at the product selection level to prevent/reduce the wastes that will occur during the construction, use and dismantling/demolition processes during the design process. For this purpose, it is seen that the reuse of building products is supported and the disassembly-targeted design approach is emphasized [26].

1.2 Purpose of the Thesis

Although studies have been carried out to prevent the C&D wastes that will occur during the construction, use and dismantling / demolition processes in the design process of the building; it is observed that there are inadequacies in integrated studies in which the design process is associated with the waste generation, the duties and responsibilities of the designers regarding the wastes generated during the construction, use and dismantling/demolition processes are defined. In this context, the main purpose of the study is to create a model that can be used by designers in the design process in order to prevent/reduce C&D waste.
It is known that a significant part of the decisions taken in the first steps of the design process directly affect the resulting building performance. Designers often cause environmental problems due to their design decisions, but sometimes they are not aware of this. In this context, the sub-purpose of the thesis is to ensure that the C&D waste prevention/reduction in design is understood by designers and other relevant experts.

1.2 Hypothesis

Design to be made by considering or ignoring the situations related to the formation of C&D waste is determined as followings:
● It will affect the natural and artificial environment and the health of living things positively or negatively,
● It will determine the costs of construction, use (maintenance, repair, replacement) and dismantling/demolition.
With the creation and use of a model that defines the principles to be considered in the design process of the building, following steps can be achieved:
● Designers will be conscious,
● Healthy natural and artificial environments will be formed,
● Environmental pollution will be prevented,
● Natural and artificial resources will be protected,
● Economic development will be supported.
This work is based on the assumption that the decisions taken during the design process can prevent/reduce the type and amount of waste that will occur in other processes, by creating a model that is easy to understand and includes information and design approaches for designers.
This study is limited to followings:
● Selection of C&D waste, which is one of the waste types,
● Identification of the design process of the building,
● Examining the design process in terms of wastes that will occur during construction, use and dismantling/demolition processes,
● Identification of construction, use and dismantling/demolition processes and examining these processes in terms of C&D waste generation,
● In a model where the building design process- C&D waste relationship is established, the duties and responsibilities of the designers who are primarily responsible for the prevention/reduction of C&D waste are revealed, and the design decisions are determined.
Although the model, which was created as a result of the study and can be applied for every building type, is operative, it is impossible to test it within the scope of the thesis study. Because in order to test the functionality of the model, a building must be designed with this model, and

then it must complete the construction, use and dismantling/demolition processes. Although the life span of the building varies according to the type of building; 10 years for temporary structures, 25-49 years for medium-life structures, 50-99 years for long-lived structures and at least 100 years for permanent structures [27]. In this context, in order to test the full functionality of the model, a temporary structure must be designed and the construction, use and dismantling/demolition processes must be completed, and a minimum of 10 years is required for this purpose. However, it is impossible to carry out this study due to the time and economic constraints in the thesis study. However, it is possible to test the model in the direction of preventing/reducing the wastes that will occur during the construction process, which is a part of the model, with a research project after the thesis work is completed.

As a method; in line with the purpose and scope of the study; the topics covered in the thesis were investigated by examining sources such as C&D waste management, C&D waste prevention/reduction and building design related articles, books, thesis, internet resources, building evaluation systems, requirements, design guide and checklists etc. The studies conducted in the world and in Europe on preventing/reducing the C&D waste that will occur during the construction, use and dismantling/demolition processes in the design process have been examined. In the light of the knowledge that the wastes are formed during the construction, use and dismantling/demolition process depending on the design decisions of the building, the relations between the design process-construction process, the design process-use process and the design process-dismantling/demolition process have been established. Suggestions have been developed on how to manage the C&D waste that will occur during the construction, use and dismantling/demolition processes during the design process, and "design decisions that do not generate waste or reduce waste" are presented. While creating a model that designers can use to prevent/reduce C&D waste; the obtained results are explained theoretically and also presented in the form of a flow chart.

PART 2
The design process of the building and the CDW relationship

In this section, first of all, the design process of the building will be defined, the sub-processes of the design process and the decision levels in the sub-processes will be examined. In the continuation of the section; based on the assumption that the C&D waste generated during the construction, use and dismantling/demolition processes result from incomplete/wrong decisions in the design process, in the context of C&D waste generation, which is discussed in detail in the 3rd, 4th and 5th chapters of the thesis, the relationship between design process-construction process, design process-use process and design process-dismantling/demolition process will be discussed.

2.1. The design process of the building and sub-processes

According to many researchers, design is considered as a problem-solving process, while according to some researchers, it is a decision-making process. Design, which is handled and evaluated with different aspects in various fields, such as "knowledge generation", "intellectual action", "problem solving process" can be defined in different ways. There are different definitions and approaches regarding the concept of design. Accordingly, the design can be defined as followings:

● A decision-making process in the face of uncertainty [28], for which large penalties are paid for mistakes,

● The act of reaching a solution is a process that includes decision-making stages of different nature [29],

● A purposeful problem-solving action [30],

● The act of producing a very complex and multivariate knowledge [31],

● Selection, decision making, responsibilities phase [32].

However, in the most general definition, design is "creating a concept about the non-existent and constructing the planning that will enable its formation" [33].

As stated in the definitions, the design action refers to a process. It can be defined as an information-intensive process that starts with the definition of the design problem and continues in a certain time-space relationship until the appropriate solution is reached [34].

According to Broadbent [35], the design process is "the time from the beginning of a design to its completion". Obtaining information, interpreting how this information will be used and applied in the face of different design problems, developing the design by acting with a certain decision-making method in the decisions that the designer has to make in the process within the framework of the determined purposes, evaluating the extent to which the design obtained as a result of the design action meets the expectations are included in the design process [36].

The architectural design process, which is one of the basic design areas, finds its place in the literature with different definitions. Accordingly, the architectural design process is defined as followings:

● A systematic decision-making process where information is stored, organized, acted upon and decisions are made [36],

● Interpretation, determination and documentation of the conceptual, functional, formal, structural and operational characteristics and qualities of the whole of the building that will fulfill the functions determined to meet the requirements [32],

● A series of processes that the designer develops from the first step where he encounters the problem to the last step where he presents the solution [37],

● All of the decisions of guiding and evaluating architectural activities in order to create, methodically combine and integrate architectural data related to planning functions in architecture [38].
As noted; the design process of the building is a multi-participant and successive process that starts with a building requirement, decisions regarding the whole building that will fulfill the functions and meet the requirements, expresses these with drawings, defines the time until the start of the construction.
In the study called A Green Vitrivius, which was prepared jointly by the European Commission, Directorate General XVII. For Energy and Architects' Council of Europe, architectural design process consists of following sub-processes [39]:
● Briefing,
● Initial studies,
● Concept design,
● Preliminary design,
● Developed design,
● Detailed design.
According to the RIBA, the institution that regulates the organization of the architectural profession in the UK, the Building Acquisition Process is defined by a "Plan of Work/PoW" consisting of eight sub-processes. These sub-processes are defined as followings [40]:
● Strategic definition,
● Preparation and briefing,
● Concept design,
● Spatial coordination,
● Technical design,
● Manufacturing and construction,
● Handover,
● Use.
According to this plan, the strategic definition, preparation and briefing, concept design, spatial coordination, technical design sub-processes of the "Building Process", which consists of five sub-processes, are related to the design process.
According to the work plan prepared ACE (Architects' Council of Europe) scope of services for the building are defined respectively as followings [41]:
● Initiative,
● Initiation,
● Concept design,
● Preliminary design,
● Developed design,
● Detailed design
● Construction
● Building use
● End of life.
As stated in the definition, the design process consists of sub-processes. These sub-processes are also included in the studies of various institutions or researchers. In the study of RIBA [40] international plans of work are compared (Figure 2).

	Pre-Design		Design				Construction	Handover	In Use	End of Life
RIBA (UK)	0	1	2		3	4	5	6	7	
	Strategic Definition	Preparation and Brief	Concept Design	NOT USED	Developed Design	Technical Design	Construction	Handover & Close Out	In Use	NOT USED
ACE (Europe)	0	1	2.1	2.2	2.3	2.4	3		4	5
	Initiative	Initiation	Concept Design	Preliminary Design	Developed Design	Detailed Design	Construction	NOT USED	Building Use	End of Life
AIA (USA)			-		-	-	-			
	NOT USED	NOT USED	Schematic Design	NOT USED	Design Development	Construction Documents	Construction	NOT USED	NOT USED	NOT USED
APM (Global)	0	1	2		3	4	5	6	7	
	Strategy	Outcome Definition	Feasibility	NOT USED	Concept Design	Detailed Design	Delivery	Project Close	Benefits Realisation	NOT USED
Spain			-			-	-	-		
	NOT USED	NOT USED	Proyecto Básico	NOT USED	NOT USED	Proyecto de Ejecución	Dirección de Obra	Final de Obra	NOT USED	NOT USED
NATSPEC (Aus)		-	-	-	-	-	-		-	
	NOT USED	Establishment	Concept Design	Schematic Design	Design Development	Contract Documentation	Construction	NOT USED	Facility Management	NOT USED
NZCIC (NZ)		-	-	-	-	-	-		-	
	NOT USED	Pre-Design	Concept Design	Preliminary Design	Developed Design	Detailed Design	Construct	NOT USED	Operate	NOT USED
Russia			-	-	-	-	-			
	NOT USED	NOT USED	AGR Stage	Stage P	Tender Stage	Construction Documents	Construction	NOT USED	NOT USED	NOT USED
South Africa		1	2	3	-	4	5			
	NOT USED	Inception	Concept and Viability	Design Development	NOT USED	Documentation	Construction	Close Out	NOT USED	NOT USED

Figure.2 Comparison of international plans of work [40]

As stated in all studies that include sub-processes, the architectural design process starts with a preliminary study in which environmental factors and requirements are determined. After the preliminary studies are completed, the design is started with the available data, general decisions are made, and the design is shaped at the upper scale. This sub-process is followed by the sub-process where the final decisions regarding the design are taken. After making final decisions regarding the design setup, system and products, the details of their production are discussed. In this context, the design process within the scope of the research is defined respectively,

● Concept design
● Preliminary design
● Developed design
● Detailed design

It is a holistic process that includes substages, which are composed of steps that affect each other in the period from the emergence of the building requirement to the start of the construction.

Concept design Sub-process: It is the process that started with a structure requirement, which is determined by environmental factors and requirements, and planning for the design and construction of the structure. The function of the structure is to respond to the needs of their users. User requirements are determined depending on the environmental factors.

When the project first gains a temporary direction, decisions made at this early stage in the design process are critical. Alternative floor plans are considered; a site planning and/or building organization strategy is devised; and a concept for the structure's parts, as well as materials, is considered - however none of these details are likely to be finalized. The costs are calculated in a general way. To attain comprehensive design integrity, the architect uses informed intuition to make decisions that combine experience, training, and imagination, as well as interdisciplinary input from design team members and external consultants.
The most important participant in the concept design process is the user. In cases where the user is not specific, it is the employer that targets the user. The most intense participation of the user/employer in the process is in the preparation of the requirements program. If the user/employer can convey their requests and requirements to the design team in the most accurate way, and if the design team interprets these requests and requirements in full, encountering problems affecting cost, time and quality in the future processes can be minimized. When this sub-process is completed, if all the information is not collected sufficiently, there may be continuous feedback to the concept design sub-process due to the obstacles and problems that arise during the construction process. The decisions, constraints and requirements program created at the end of this sub-process constitute the inputs of the design processes and the control criteria of the construction process [42].

Preliminary design Sub-process: The provisional direction previously sketched is revised and developed through models, plans, sections, and elevations at the preliminary design stage. Previously made decisions are either confirmed or amended. The structure takes on its final form, layout, construction type, and maintenance approach. Materials have been suggested. Simplified evaluation tools and numerical studies should now confirm the initial investigations of comfort and environment. It becomes progressively difficult to make significant adjustments after receiving consent from administrative authorities [43]. After the site selection is made and the environmental factors and requirements are determined, the preliminary design sub-process, in which the building is shaped, is started. The design studies carried out in this sub-process; It aims to reflect the information determined, interpreted and evaluated in the preliminary design sub-process to the project. In order to realize the structures that respond to the requirements and are compatible with the environment, the requirements program, the function chart, land, infrastructure, climate, zoning status, natural and built environment data, user/employer requests, etc. the inputs and the decisions taken by the architect must be finalized.

Developed design Sub-process: This sub-process contains more detailed and finalized information/studies on the form, construction technique, product and system decisions to be used in the building. Since the most basic decisions of the project are shaped, mistakes made cause problems that are much more difficult to correct later. Data that cannot be adequately evaluated or reflected in the preliminary design are evaluated in the developed design. In addition to the information to be provided in the preliminary design regarding the final design, it is necessary to provide the information of "determination of water, heat and sound insulation properties, determination of heating, cooling, air conditioning, ventilation principles and their reflection in the design, reflection of the measures against fire in the design, and the finalization of the materials to be used in the building" [44].

Detailed design Sub-process: It is the sub-process in which all the details are handled in order to transform the architectural product designed in the developed design sub-process into an output that can be applied. This sub-process covers the finalization of the decisions taken at the end of the developed design sub-process, the determination of the details of the systems to be installed throughout the building (structure system, flooring systems, etc.), the preparation of the detail drawings of the connection of a selected product with another product, and the calculation of the quantities of the selected products.

2.2. The relationship between the design process and CDW generation in construction, use, dismantling/demolition processes

As stated in the Introduction Section of the study, the form, system, and product decisions taken during the design process directly affect the construction, use and dismantling/demolition processes; as a result of erroneous decisions, various types and amounts of C&D waste are formed in these processes. It is stated that C&D waste increases during and after the construction process due to various reasons such as design errors, insufficient design data, lack of detail and complexity, mistakes in product selection, unforeseen ground conditions, design changes made at the last moment, lack of coordination and communication between the parties [45]. In this context, the design process is of great importance in order to prevent/reduce waste generation during construction, use and dismantling/demolition processes.

Through the relationship to be established between the design process and the construction, use and dismantling/demolition processes, all kinds of activities will be supervised, and waste prevention/reduction targets will be achieved. For this purpose, the reasons for the formation of C&D waste in the construction, use and dismantling/demolition processes will be discussed in detail in the following sections: the relations between the wastes generated and the design process will be established, and information will be given on how to manage them during the design process.

PART 3
Construction process and CDW generation

In this section, first of all; the construction process will be defined, the sub-processes that creates the process will be revealed, the reasons for the formation of C&D waste during the construction process will be examined, and the relationship between this situation and the design process will be established. Suggestions for design decisions will be developed with the assumption that the wastes that may occur during the construction process will be managed during the design process.

3.1 Construction Process

In researched resources, there are various definitions of the concept of construction. In the work of Gökhan and Baytin [46]; they defined the construction as a process involving the actions of creating/forming a certain object by bringing together various building parts according to a completed design. According to Türkçü [47]; construction is a whole that includes the methods, actions and processes applied or utilized for the emergence of the final product, which is called the structure. According to Izgi [32], achieving concrete results after the completed design process is realizing the building. Mutluay [48] defined the construction of a building as the activities of transforming the resource inputs into the architectural product, which is the output of the process. According to Güler and Coşgun [49], they are the activities of realization of the building and making it ready for use according to the application project. It is important to add to these definitions that the construction process is an integrated process that includes sub-processes that interact with each other. In this context, the definition of the construction process within the scope of the study; It is an integrated process that starts after the completion of the design process, includes sub-processes where the building is physically realized using capital, labor, and natural resources, and ends with the use of the building.
The construction process consists of sub-stages. According to the work plan prepared by ACE (Architects' Council of Europe) in 2014, the stages of a construction of the building is defined respectively, pre-construction, inspection, commissioning, and handover [41].

Pre-construction Sub-process: contract administration is prepared, and contracts and project objectives are reviewed.

Inspection Sub-process: the execution of the building contract is overseen. Construction progress and compliance with plans are monitored. Contractors' activity and execution of the works are inspected. Contractors' drawings are considered. Random inspection of materials and quality of workmanship are undertaken. Final clarification of design details prior to implementation is undertaken. Changes required by the client and issue relevant instructions to contractors is processed. Requests for payment issued by contractors are checked and approved.

Commissioning Sub-process: All works are checked that have been carried out in accordance with the contract, permits obtained, and that the building is fit for use and compliant to regulations. If necessary, statutory procedures required to open the building is organized. Preparation of as-built documentation is overseen**.**

Handover Sub-process: After final checks for workmanship and compliance with contract documents, handover to the client and building users as start of guarantee periods is supervised. Issue of as-built documentation and final accounts are overseen.

According to the plan of workplan prepared by RIBA in 2020, the "Process of building structure" consists of eight sub-processes. Manufacturing and construction, and handover sub-processes are associated with the construction process [40].

Manufacturing and construction:
- Finalize Site Logistics
- Manufacture Building Systems and construct building
- Monitor progress against Construction Program
- Inspect Construction Quality
- Resolve Site Queries as required
- Undertake Commissioning of building
- Prepare Building Manual

Handover:
- Hand over building in line with Plan for Use Strategy
- Undertake review of Project Performance
- Undertake seasonal Commissioning
- Rectify defects
- Complete initial Aftercare tasks including light touch Post Occupancy Evaluation

In the work of Anderson [50], the construction process divided into two sub-processes which are construction, and after construction. The construction sub-process itself is handled as the management of the construction, pre-construction activities and construction. The post-implementation sub-process includes the legal completion and delivery of the building.

According to Lepel [51], the construction process consists of following sub-processes; preparation of the building area, excavation, creation of the building foundation, creation of the structural system of the building, completion of interior and exterior fine structure works, testing/inspection of the structure, delivery of the structure.

In the studies examined; the sub-processes of the construction process took place in the context of C&D waste without being detailed at the desired level, and in some studies, the works that had to be completed in the design process were handled during the construction process. For this reason, sub-processes were redefined according to the content of the thesis study. Construction process starts with the approval of the employer to start the construction and continues with the preliminary preparation and organization sub-process. After the preliminary preparation and organization are completed, the building area is prepared, excavation works are carried out, and the building products are transported and stored in predetermined areas. While the product supply continues, the application starts; the application of the products to the structure and the supervision of the application are carried out simultaneously. With the completion of the application, the temporary structures are demolished, the building area is cleaned, the structure is handed over to the employer and the construction process is terminated. Accordingly, the sub-processes that creates the construction process within the scope of the thesis work can be listed as followings:

● Approval of the start of construction,
● Preliminary preparation and organization,
● Preparation of the building area,
● Excavation works,
● Transporting the products to the building area,
● Storage of products,
● Application of products to the structure,
● Controlling the application,
● Cleaning the building area,

● Delivery of the building to the employer.
It is considered important to examine each sub-process in order to understand the activities that make up the construction process.

Approval for the Start of Construction Sub-Process: With the completion of the design process and the final approval by the employer, the process in which the necessary preliminary preparations and organization will be made begins.

Preliminary Preparation and Organization Sub-Process: In this process, necessary permits are obtained for the building. Contracts are prepared with the contractor-subcontractors selected during the design process, taking into account the requirements of the application. Agreements are made with the teams that will undertake the architectural and technical inspections of the construction process.

Preparation of Building Area: Building area Sub-Process: It is an enterprise established for a temporary period in which the necessary equipment and people work in coordination in order to complete the construction, repair or demolition safely within the stipulated time [52]. Building area consists of four parts: production, management, storage areas and social facilities [53]. This sub-process requires followings; establishment of structures to serve in management and storage areas, preparation of the infrastructure, providing the necessary security measures in the building area and surrounding the building area.

Excavation Works Sub-Process: After the preparation of the construction site, excavation works begin in the construction area. Excavation covers the actions of followings:
- Taking security measures at the excavation site,
- Protection and support of excavation surfaces,
- Keeping the excavation area dry,
- Removal of the removed soil and all kinds of materials from the excavation pit,
- Accumulation and protection of the extracted soil [54].

With the completion of all these processes, the ground is made suitable for starting construction.

Transporting the Products to the Construction Area Sub-Process: In this sub-process; The building products selected, evaluated, and approved by the employer during the design process are taken from the suppliers and brought to the building site.

Storing the Products in the Building Area Sub-Process: The products brought to the building area are stored under appropriate conditions in the open/closed storage areas determined in the building area layout scheme.

Application of the Products to the Building Sub-Process: This process includes the activities of bringing together the selected products in accordance with the project and brought to the building site in order to physically realize the building [55].

Supervision of the Application Sub-Process: This process, which covers the supervision actions during the construction process, takes place with the participation of legal supervisors. In field inspections, it is inspected that the construction works are carried out in accordance with the requirements and the design, and that the workmanship and application methods are carried out within the scope of the standards in the contract documents [56].

Cleaning of the Building Area Sub-Process: Upon the completion of the construction works, the structures established to serve temporarily in the building area are dismantled/destroyed. The established structures are removed, then the infrastructure is cleared, and the land is organized as much as possible [57].

Delivery of the Building to the Employer Sub-Process: After the construction works are completed, the project is examined whether it has the required qualifications, if the errors that will significantly affect the use cannot be determined, a temporary acceptance is made with a report and the completed architectural product is delivered to the employer for use [48].

3.2. C&D Waste Formation in Sub-Processes of the Construction Process and Recommendations for Preventing/Reducing C&D Waste in the Design Process

Although the construction process started after the end of the design process, there is a tight bond between the two processes. For this reason, the effects of the decisions made during the design process continue during the construction process, and wrong decisions may cause the formation of C&D waste.

In order to create the infrastructure for what needs to be done in order to control the C&D waste that will occur during the construction process, the studies and obligations of the institutions at the national and international level have been examined. Among these studies, DoW, and C2C aimed to prevent/reduce C&D waste directly, LEED, BREEAM certification systems were selected and examined due to their current and active use in the world.

● In the DoW approach, approaches to the design process to reduce waste in the construction process are explained under the following headings [58]:

- Reusing the excavated soil: The balance of the excavated and filled area should be ensured in the building area, that is, the filled area should be created as much as the excavated area.
- Simplifying the building form: Considering the construction process, it is necessary to know that simple building forms will cause less waste than complex forms and to design the buildings with this awareness. The designer should design by considering the waste load that each different surface will create.
- Iteration of the structure form: The number of variables can be reduced by iterating through the structure. Thus, the type and amount of C&D waste that may occur can be prevented/decreased.
- Choosing contemporary construction methods: The choice of construction method has a direct effect on the type and amount of waste that will occur in the construction area. It is stated that the production carried out in controlled environments outside the building area, in other words, pre-construction techniques reduce the C&D waste by 90%.
- Iteration of the building components: The approach of iteration of the variables in the structure form should also be taken into account in the product selection. Repetitively using products that will provide the same function (the products to be selected for the floors of all wet areas in the building are the same size/shape/color etc.) will reduce the product variety. In addition, the use of a product that has a certain function in other places will ensure the sustainability of the products, and the product leftover from one place will be used in another place and will be removed from the waste state.
- Coordinate design with product dimensions: The designer should coordinate between the space which will be created and the product which will be used. For example, choosing a gypsum board with a width of 1200 mm to be used on the walls of a room measuring 5000x5000 mm means that 200 mm of waste will be generated in each direction. Considering the example, it is important to design the room dimensions by considering the product dimensions. However, considering that the element size determined according to the size of a selected product is also

effective on other building elements, different product options should be considered. Coordination should be ensured throughout the building.

●C2C (Cradle to Cradle) is based on the approach that products must be re-entered into the cycle (such as production, reuse, recycling) in order to reduce resource consumption and waste production as a result of the end of their useful life, and these decisions are taken during the design process [59]. In this context, the approach developed for waste prevention/reduction in the design process is based on followings:

- Determining how each product will be evaluated at the end of its life-cycle during the design process,
- While making product decisions for designs, it is based on not choosing products that do not enter the production cycle at the end of their life cycle [60].

● In the LEED Certification System, suggestions developed to prevent/reduce the C&D waste that will occur during the construction process are included in the "Materials and Resources" category. Approaches to the design process are discussed under the following headings:

- Preserving and reusing the existing structure (walls, floors, roof, etc.) at certain rates,
- Reusable or with recycled content,
- Choosing local/regional products [24].

● Recommendations developed in the BREEAM Certification System to prevent/reduce construction waste during the design process; It is included in the 'Waste' and 'Materials' categories. Approaches to the design process are discussed under the following headings:

- To prepare a “Site Waste Management Plan”,
- Preserving and reusing the existing structure (facade, carrier elements) at certain rates [61].

● Recommendations developed in the Green Star Certification System to prevent/reduce construction waste during the design process are discussed in the 'Management' and 'Materials' categories. Approaches to the design process are following:

- Preparing a waste management plan,
- Reusing or recycling some of the C&D waste,
- Making designs that require contemporary construction methods,
- Preserving and reusing the existing structure (facade, carrier elements) at certain rates,
- Choosing building products that are reusable or have recycled content [26].

● Recommendations developed in the IGBC Green Homes Certification System to prevent/reduce construction waste during the design process are discussed in the "Materials" category. Approaches to the design process are following:

- Selecting reusable building products,
- Choosing building products with recycled content,
- Choosing local/regional building products [62].

Studies Reviewed	Critique of Studies and Aspects That Can Contribute to the Model
DoW	-It was important to choose a contemporary construction method. However, choosing a modern construction method alone may not be enough to reduce waste generation. -Coordinated design with product dimensions is suggested. However, sometimes it is important to choose the right size product for the design.
C2C	-The stated recommendations are acceptable, but it is important to develop a more detailed and holistic approach to the waste prevention/reduction goal.
LEED	-The stated recommendations are acceptable, but it is important to develop a more detailed and holistic approach to the waste prevention/reduction goal.
BREEAM	-It was considered important to prepare a "Construction Area Waste Management Plan". However, the waste management plan to be prepared does not provide support on waste generation, but on what to do after waste is generated.
Green Star	-It was considered important to prepare a waste management plan. However, the waste management plan to be prepared does not provide support on waste generation, but on what to do after waste is generated.
IGBC Green Homes	-The stated recommendations are acceptable, but it is important to develop a more detailed and holistic approach to the waste prevention/reduction goal.

Table 2.1 Evaluation of the studies examined for the purpose of preventing/reducing the C&D *waste that will occur during the construction process in the design process*

It is thought that the substances mentioned in C2C, LEED, IGBC Green Homes will help prevent/reduce the C&D waste that will occur during the construction process. In addition to these, the correct calculation of the required product quantities should be taken into consideration in terms of waste prevention/reduction. No information on this subject was found in the studies.

In the studies, the construction process was handled as a whole. However, based on the knowledge that the construction process is an integrated process that includes sub-processes, no evaluation has been made about what should be done in which sub-process. For this reason, sub-processes will be discussed separately in order to understand the problems that may be encountered in the construction process and solution proposals will be developed for the problems to be experienced in each sub-process.

While developing suggestions for sub-processes followings are excluded from the scope:
- Confirmation for start of the construction
- Preparation and organization

because the build activity of its subprocesses is not started,
- Delivery of the building to the employer

As the sub-process construction activities are completed,
- Preparation of the building area,
- Storage of products,
- Checking the application

- Cleaning the building area

Since the designer is not responsible for the C&D waste generated in the sub-processes. Assuming that the designer's responsibility is completed at the end of the design process, the wastes generated in these sub-processes and waste prevention/reduction suggestions are not included in the thesis study.

3.2.1. CDW generation in the subprocess of excavation works and recommendations for preventing/reducing CDW during the design phase

Soil and any other material removed from the excavation area are considered as wastes that may occur during the excavation works. In the DoW [58] approach to prevent/reduce this waste; it is suggested that the excavated soil should be evaluated primarily for filling or landscaping works within the building area. In this context, what needs to be done in the design process are suggested as followings:

- Calculating the amount of excavation soil to be excavated by taking into account the relationship of the building with the ground, providing a balance between the excavated and filled area so that the excavated soil to be excavated can be used in filling works,
- It is recommended to determine whether the extracted vegetable soil can be used in landscaping works or in what amount.

3.2.2. CDW generation in the subprocess of transporting products to the construction site and recommendations for preventing/reducing CDW during the design phase

In the sub-process of transporting the products to the construction site, there are risks of breaking, spilling and losing its quality depending on the distance from which the product is brought, and as a result, C&D waste is observed. According to the results of the studies carried out in five different construction areas between 1992-1993 and in 69 different construction areas between 1996-1998 in Brazil, it is stated that a significant part of the C&D waste formed during the construction process was formed during the transportation activities [63].

It is important to choose local/regional products in the vicinity of the building site, as stated in LEED [24] and IGBC Green Homes [62] in Chapter 3.2, in order to prevent and reduce waste due to transportation distance-related causes. While the definition of local/regional product is considered as products produced within 500 miles (805 km) of the building site in the LEED certification system, this distance is specified as 400 km in the IGBC Green Homes certification system. Within the scope of the thesis study, the products supplied from the provincial borders where the building area is located were accepted as local products, and the products obtained from the same geographical region were considered as regional products.

3.2.3. CDW generation in the subprocess of application of products to the building and recommendations for preventing/reducing CDW during the design phase

In the sub-process of applying the products to the structure, C&D waste is formed depending on the following reasons:

-The lack of dimensional coordination between the dimensions of the structure and the dimensions of the products,
- Miscalculation of the required amount of product,
- Wrong application method selection,
- Production on site,
- No decision to recycle/reuse at structure or product scale.

In this chapter; for the reasons stated above, waste generation and what needs to be done during the design process to prevent/reduce this generation are discussed and examined under sub-headings.

3.2.3.1. CDW generation due to failure to provide dimensional coordination between the dimensions of the building and the product dimensions and recommendations for preventing/reducing CDW during the design phase

The fact that the selected products are not in a size/form compatible with the building elements/components to which they will be applied causes compulsory cuts in the construction site and the remaining parts become waste. This issue is also explained in detail in the studies of Gavilan and Bernold [5], Craven, Okraglik and Eilenberg [64], Osmani, Glass and Price [45]. Similar to the example in the DoW approach in Section 3.2; if a ceiling height of 290 cm is created with a 50 cm high gypsum block standard, 10 cm of gypsum block waste will be generated in the vertical direction.
However, depending on the diversity of construction activities, the productions do not repeat each other and the dimensional coordination cannot be achieved in the whole building, which may result in the formation of C&D waste [18]. For example, while the structural system of the structure is created, if the dimensions of the carrier component are not repeated, the mold workmanship will diversify, and in case of making different molds for the different structural components, C&D waste will occur due to the compulsory cuts in the molds [65]. To prevent this situation; methods of making coordinated design with product dimensions or selecting products in appropriate size and form for a design whose dimensions/shape have been determined should be used.

Coordinating Design with Product Dimensions: Dimensional coordination in building production; It is defined as the selection of the most suitable dimensions in the design of spaces in order to be able to bring together the building products without changing their sizes [66].
As stated in the DoW approach, since the dimensions in the design will derive from the product dimensions; It is necessary to know exactly the joint dimensions and the way of coming together with the product. Product selection; it is appropriate to make it among pre-made products, since precise information about the specified features can be accessed [58].
While it is important to provide coordination between the dimensions of the building element/component to which the product will be applied and the product dimensions, it is also important to provide dimensional coordination throughout the building. In this context, modular coordination can be mentioned as a technique that allows dimensional coordination throughout the building.
Modular coordination is that the dimensions of the building products and the dimensions of the modules in the modular design are interconnected by a common unit [67], [46], [68]. According to a report published in the Journal of Industrial Ecology, it is stated that the negative environmental impacts of structures produced with modular coordination are low compared to other construction activities [69].

Choosing the Products in the Appropriate Size and Shape for the Design: When choosing the product that will create the least waste for a completed design, following two methods can be applied:
- Special ordering and production of the product in a size/form suitable for the design,
- Choosing the most suitable size/shape for the design among the ready-made products

In the first of the specified options, the dimensions/shape of the required product can be precisely determined during the design process and specially produced. Thus, in practice, there is no size/form mismatch between the products and the building element/component to which they are applied. Therefore, the C&D waste that occur due to compulsory cuttings are prevented.

3.2.3.2. CDW generation due to failure to calculate the amount of required product correctly and recommendations for preventing/reducing CDW during the design phase

If the required amount of product cannot be determined precisely during the design process, more or less product will come to the building area than necessary, and in both cases, C&D waste may occur. Gavilan and Bernold [28], Craven et al. [5], Ekanayake and Ofori [70], Poon, Yu and Jaillon [15], Polat and Ballard [19], Poon, Yu, Wong, and Cheung [71], Tam, Shen, Fung, and Wang [72], Wang, Kang and Tam [73] are also included in the studies. The fact that the incoming products are more than the requirement and cannot be returned may cause the products to turn into waste in the field. Similarly, if the products are less than the requirement, the application will not be completed. If the same product cannot be found, the risk of changing the application made until that time may arise and will result in the formation of C&D waste. In this case, in order to prevent/reduce the C&D waste that will occur, it is important that the quantity take-off, which is defined as the job of determining all the product quantities required for the building, is done without errors and in accordance with the requirements. The quantities required for each product should be calculated exactly while calculating the quantity, and the waste and spare product rates should be added to these calculations.

3.2.3.3. CDW generation due to not choosing the application method correctly and recommendations for preventing/reducing CDW during the design phase

If the appropriate application method is not selected for the product, the product may be damaged, lose its quality and become a waste. A similar approach is also found in studies by Pheng and Tan [74], Ekanayake and Ofori [70], Polat and Ballard [19], Poon, Yu, and Jaillon [15]. In order to prevent this situation, it is important to know exactly the features of the selected products and to choose the appropriate application method in line with the catalog information of the product.

3.2.3.4. CDW generation due to the production of products with on-site construction and recommendations for preventing/reducing CDW during the design phase

The most distinctive feature of on-site production is that all of the production takes place on-site and with intense manpower. However, the human-oriented nature of production activities can increase the error rate and cause waste generation. In the study conducted by Poon, Yu and Jaillon [15], it was stated that the preference of on-site production instead of pre-made products causes waste generation. In this context, choosing pre-made products in the design process is considered important as waste generation will be prevented/reduced.

Pre-production activities include the production and assembly of the products that will form the building in controlled environments outside the building area. The product brought to the building area is completely or partially finished. Therefore, the need for product storage in the building area is reduced. Since the assembly process is carried out in controlled environments, errors arising from workmanship are prevented [75]. According to the studies of Dainty and Brooke [76] and Baldwin et al. [16], it can be said that the structures created with pre-made products (pre-made flooring, wall panels, etc.) will reduce the formation of C&D waste, since they do not require production in the building area.

3.2.3.5. CDW generation due to lack of reuse or recycling decisions at building and product scale and recommendations for preventing/reducing CDW during the design phase

The absence of reuse or recycling decisions regarding the C&D waste that will be generated during the implementation process increases the C&D waste generation and the damage to the environment by the generated wastes. A similar approach is also found in studies by Gavilan and Bernold [5], Craven, Okraglik and Eilenberg [64], Polat and Ballard [19], Osmani, Glass and Price [45], Jaillon, Poon and Chiang [77]. If the "0 Waste" target cannot be achieved within the scope of waste prevention/reduction policy, it should be decided at the design stage what to do with the wastes that may arise. In this context, in the design process, it was considered important to take reuse or recycling decisions at the scale of the building and product.

Preserving and Reusing the Existing Building at Certain Rates: As stated in LEED, BREEAM and Green Star Certification Systems, if there is a building in the area, instead of demolishing it all and producing a new one; Decisions must be made whether the building can participate in the new design, to what extent it can participate, and how much of the building can be preserved. As the entire existing building can be preserved, its carrier system / facade / walls / floors / roof can also be protected to a certain extent. Thus, the C&D waste that will arise with the demolition of the existing structure will be prevented/reduced.

Choosing Reusable or Recycled Products: As stated in C2C, LEED, Green Star, IGBC Green Homes, products that have been used as waste can be used by selecting products with reusable or recycled content. Thus, waste will be a useful product in a new cycle.

Making Reuse Decisions for Possible Wastes in the Construction Area: The amount and types of wastes that may occur in the implementation sub-process can be determined during the design process. As stated in Green Star, reuse decisions can be made regarding possible waste. For example, the possible amount of concrete waste generated in the building area can be predicted and the decision to reuse this waste in filling works in the building area can be revealed during the design process. Similarly, reuse decision can be made for metal products such as molds removed in the building area or nails coming out of the molds. In this case, even if waste is generated, reuse actions will allow the products to go from waste to usable. It is important in terms of waste prevention/reduction that the decisions about the conditions under which the wastes will be reused in the production of the same building are made during the design process.

3.3. Examination of recommendations for preventing/reducing CDW occurring in subprocesses of the construction process during the design process

In Section 3.2, the sub-processes in which C&D waste are generated during the construction process and the causes of waste generation in these sub-processes are discussed. Suggestions regarding the design process have been developed to prevent/reduce these wastes. In Section 2.1; the sub-processes of the design process, which are defined as concept design, preliminary design, developed design and detailed design, and the sub-processes that generate waste during the construction process and suggestions for prevention/reduction are overlapped. In Section 3.2 following suggestions are developed:

- Calculating the amount of excavation soil to be excavated by taking into account the relationship of the building with the ground, providing a balance between the excavated-filled area so that it can be used in filling works,
- To determine whether the extracted vegetable soil can be used in landscaping works or in what amount,
- Selecting local/regional products,
- Coordinate design with product dimensions,
- Selecting the products in the size and shape suitable for the design,
- To make the quantity take off works without any mistakes,
- Choosing the application method suitable for the product,
- Designing with pre-made products,
- Reusing the existing structure by preserving it at certain rates,
- Selecting products that are reusable or have recycled content'
- Making reuse decisions in the building area regarding possible wastes

It is emphasized in which sub-process of the design process and in what way the above suggestions should be taken into account, and these suggestions are considered as a design decision for the goal of waste prevention/reduction.

Figure 3.1 (C1) was formed by overlaying the decisions developed to prevent/reduce the wastes that will occur in the sub-processes of the design process and the sub-processes of the construction process. When creating Figure 3.1, the Sub-Processes of the Design Process (SODP) are shown in concept design: purple, preliminary design; orange, developed design: blue, detailed design: green. Information on which sub-process of the design process will be handled by the decisions is expressed with the colored box in the decision line. Design decisions developed for the purpose of waste prevention/reduction in Sub-Processes of the Construction Process (SOCP) sometimes only concern one of the sub-processes, sometimes the same decision can be reconsidered in another sub-process according to the level of detail of that sub-process.

In Figure 3.1, a code number is also assigned for each decision. Codes refer to the following:
- [C1] the way in which the sub-processes that generate waste during the construction process (depending on the design decisions) and the design decisions regarding waste prevention/reduction in the sub-processes of the design process overlap,
- X given in [C1.X] is the sub-process that generates waste during the construction process,
- Z given in [C1.X (Z)] represents the improved design decision for waste prevention/reduction.

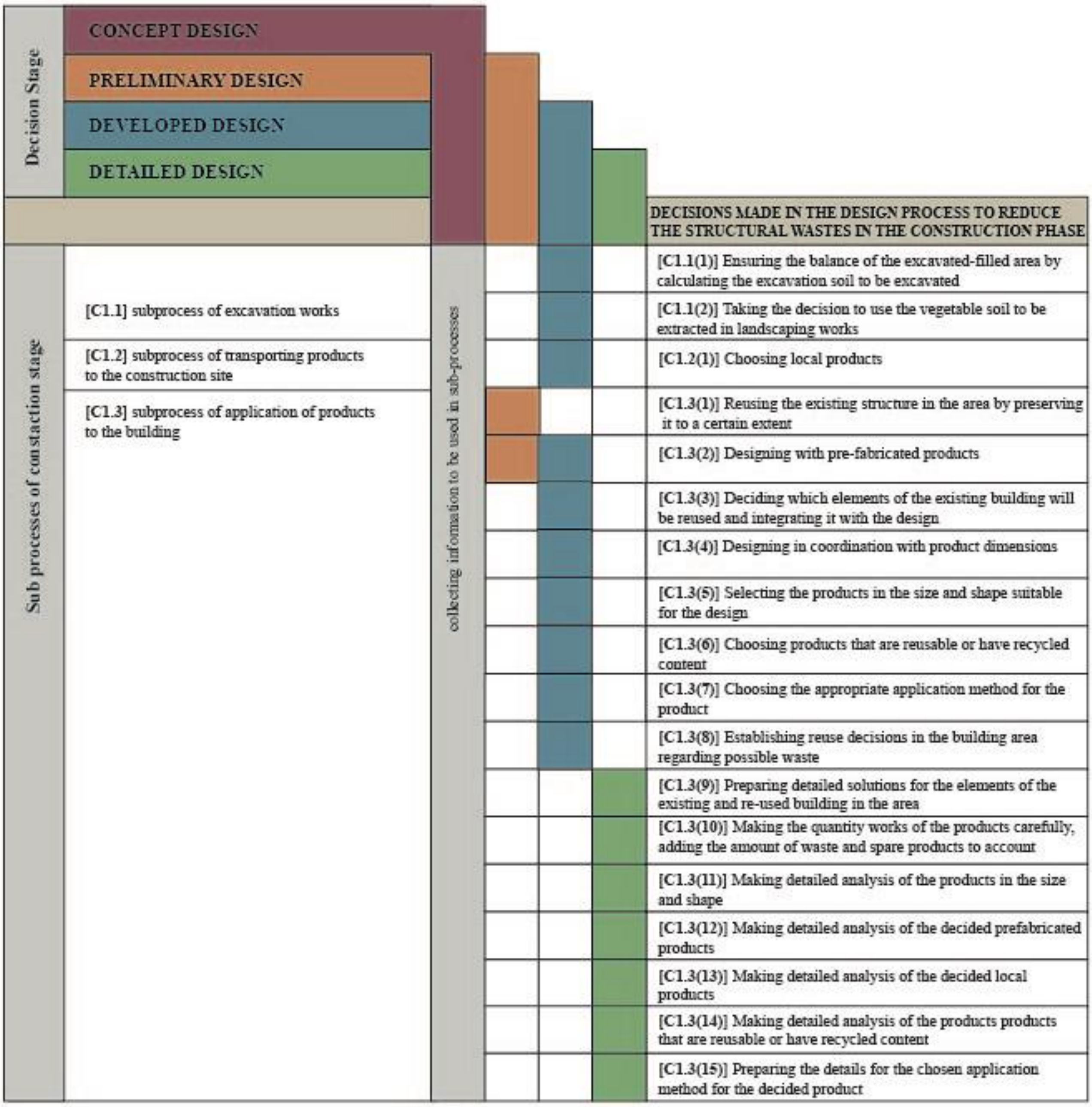

Figure 3.1 Overlaying the waste prevention/ reduction recommendations in the construction process with the design process of the building

PART 4
Usage process of the building and CDW generation

In this section, first of all, the usage process of the building will be defined, the sub-processes that make up the process will be revealed, the reasons for the formation of C&D waste in the usage process will be examined, and the relationship between this situation and the design process will be established. Suggestions for design decisions will be developed with the assumption that the wastes that may occur during the usage process can be managed during the design process.

4.1. The Use Process of the Building

There are various definitions regarding the use process of the building in the researched sources. According to Gültekin [78], use is the process in which the completed building is used and maintenance-repaired (cleaned-worn out, damaged parts are renewed) when necessary. Güler and Coşkun [49] described the use process; as the process in which the contractor delivers the work after all construction activities are completed, the building is made ready for use upon completion of the certificates of suitability for use, and the operation, maintenance and repair activities of the building upon starting use. It would be appropriate to add the information that the usage process consists of sub-processes to these definitions.

In this context, the definition of use process within the scope of the study is "an integrated process that includes sub-processes that starts with the completion of the construction process and the delivery of the building by the employer and continues until the end of the life of the building."
As stated in the definition, the usage process consists of sub-processes. These sub-processes have also been included in various studies.
According to the "Work Plan" prepared by RIBA in 2020, the last step of the "Building Acquisition Process", which consists of eight sub-processes, is stated as the use process [40]. In the work plan, the sub-processes of the use process are discussed as followings:
- Provisional acceptance,
- Giving the information about the structure to the user,
- Evaluation of the performance of the design in the usage process [79].

In the study of Güler and Coşgun [49], the usage process is divided into the following sub-processes:
- Transition phase
- Usage process.

In the 4th of the papers prepared with the participation of CHOA (The Condominium Home Owners Association), the use of the building is likened to the life process of a person and divided into five sub-processes. Possible maintenance, repair and renewal requirements for each sub-process are specified as followings [80]:
- Prenatal (0-2 years): It is the process in which the structure is completed and delivered to the user. Maintenance requirements are focused on cleaning activities and periodic inspections.
- Childhood (2-16 years): This sub-process includes low-cost repairs and renewals caused by both the low quality of the construction products used and the faulty productions. The maintenance of the building continues.
- Adolescence (17-29 years): Assuming that the construction products used have a life of 20-25 years, repair and renewal processes are carried out depending on aging and deterioration in

this period. These processes are more costly than those performed in the second sub-process. The maintenance of the building continues in this sub-process as well.
- Adulthood (30-49 years): In this sub-process, products that have been changed before can be changed for the second time. Maintenance operations are carried out in this sub-process as in other processes. Repairs and renewals to be made in this sub-process include changes made due to changes in function, preferences, and legal obligations.
- Old Age (50 years and above): It is the last sub-process of the use of the building. Maintenance, repair, and renewal requirements are as in the fourth sub-process. The owners must now prepare for the next cycle of asset renewals as the building moves beyond its 50th anniversary and embarks upon the next 50 years of operations.
In the study of RIBA in 2020, the use process, as the last of the sub-processes of the building production process, is discussed and is divided into provisional acceptance, informing the user and evaluating the performance of the building. However, the actions of making provisional acceptance and informing the user about the structure express short time intervals and do not include a sub-process expression. In the study of CHOA [113], the usage process of the building is divided into sub-processes with only the maintenance-repair focus of the building. In the studies of Güler and Coşgun [49], acceptable definitions were made within the scope of the thesis study. However, these sub-processes were renamed within the scope of the study.
The usage process starts after the completion of the construction process. The work is delivered by making inspections, and the process that the user experiences in the building begins until the end of the building's life. Accordingly, the sub-processes that make up the usage process are following:
● Sub-process of transition to use,
● The sub-process of the user living in the structure
In order to understand the usage process, it is important to examine the sub-processes.

Sub-process of transition to use: A building occupancy permit/operation license is required for the building produced in accordance with the design decisions. For this, the compliance of the projects of the building with the laws, the positivity of all the reports, all the permits and the landscaping must be done. In this context, the transition to use sub-process is the phase in which the documents for building's suitability for use are completed, specified conditions are met and then the contractor delivers the work as ready for use.

Sub-Process of the User Living in the Building: It is the longest sub-process of the building's life, in which the building is operated by the users. In this sub-process, the user effect is seen intensely. It covers maintenance-repair and replacement activities in building products.

4.2. CDW generation during the subprocesses of use process and recommendations for preventing/reducing the CDW during the design phase

In order to create an infrastructure for what needs to be done in order to control the C&D wastes that will occur during the design process, studies of institutions at the national/international level have been examined. Among these studies, DoW and C2C have been selected and examined because they directly target C&D waste prevention/reduction, LEED and BREEAM certification systems are current and widespread, and Green Star and IGBC Green Homes are local-level studies. As a result of the examinations, no suggestions were found regarding the prevention/reducing of the C&D waste that will occur in the use process in the C2C during the design process.
● **In the Dow approach**, approaches to the design process to reduce C&D waste in the use process are explained under the following headings [58]:

◦ Making flexible design: Functional changes that may occur during the design process should be considered, and flexible designs that can allow different uses should be made. Thus, waste generation will be prevented/reduced while the building is adapted to its new function. In the DoW approach, flexible design means dismantling the products and adapting the building to its new function. In this context, product-scale suggestions are offered with the following headings for flexible design:
- Using mortars that will allow products such as bricks to be easily dismantled,
- Avoiding applying products by sticking them together,
- To care about the reuse of products rather than their recycling,
- To design the structural system as demountable.

In addition, is also recommended to include flexible design in the work plan of the RIBA [81].
◦ Designing with user participation: It is important to establish communication between the user and the design team, and to involve the user in the design process in order to fully determine the needs and tastes of the user during the design process. With the exact determination of the user's wishes, changes to be made in the usage process can be prevented. Accordingly, the formation of C&D waste can be prevented/reduced.

● **In the LEED Certification System**, suggestions developed to prevent/reduce the C&D waste that will occur during the use process are included in the “Materials and Resources” category. Approaches to the design process are considered as followings [82]:
◦ With the selection of durable products, there is no need for frequent changes in the usage process,
◦ Choosing 75% of durable products from recyclable or reusable products.

● **In the BREEAM Certification System**, suggestions developed to prevent/reduce the C&D waste that will occur during the use process are included in the “Materials” and “Waste” categories. Approaches to the design process are discussed under the following headings:
◦ Designing with a focus on durability; for this purpose, to take precautions against damage caused by pedestrian or vehicle movements inside and outside the building, thus reducing the frequency of change of products [61],
◦ In the structure designed for a particular user, having the user choose the floor covering or agreeing with the designer for the selected product, thus preventing subsequent changes [83].

● **In the Green Star Certification System**, suggestions to prevent/reduce the C&D waste that may occur during the use process are included in the "Materials" category. Approach to the design process; designing the load-bearing system, roof or facade of the building with detachable products, thus preventing the waste that will occur by using the dismantled building products in other areas in case of need for change or renewal [26].

● **In the IGBC Green Homes Certification System**, suggestions on preventing and reducing the C&D waste that may occur during the usage process during the design process are included in the “Site Selection and Planning” and “Materials” categories.
Approach to the design process; It is to prepare design guides that will help prospective users to maintain green design features, which include the principles to be considered when making interior arrangements [62].
In order to prevent/reduce the C&D waste that will occur in the usage process and which are mentioned in the studies examined, the decisions regarding the design process that will be utilized while constructing a new model are given in Table 3.1, and the studies are criticized.

Studies Reviewed	**Critique of Studies and Aspects That Can Contribute to the Model**
DoW	-According to this study, the idea of flexibility means simply disassembling the products and adapting to their new function. The way flexibility is handled is insufficient.
C2C	-According to this study, the idea of flexibility means simply disassembling the products and adapting to their new function. The way flexibility is handled is insufficient.
LEED	-The stated recommendations are acceptable, but it is important to develop a more detailed and holistic approach to the waste prevention/reduction goal.
BREEAM	-In the Breeam Certification System, user participation is achieved with the title of 'To have the user choose the floor covering in a structure designed for a specific user or to make an agreement with the designer for the selected product' However, in a certain structure, it will not be enough to compromise with the user only on the choice of flooring. It is important to make interviews in line with the needs and tastes of the user, and to ensure user participation in the design and selection of products. Therefore, it is important to consider user participation in more detail.
Green Star	-It is suggested to 'design the carrier system, roof or facade of the building with removable products'. However, it is important to consider the need for maintenance/repair/replacement as a whole.
IGBC Green Homes	-The stated recommendations are acceptable, but it is important to develop a more detailed and holistic approach to the waste prevention/reduction goal.

Table 3.1 Evaluation of the studies examined for the purpose of preventing/reducing the C&D *waste that will occur during the use process in the design process*

In the studies examined, the usage process was handled as a whole. However, based on the knowledge that the usage process is an integrated process that includes sub-processes, no evaluation has been made about what should be done in which sub-process. For this reason, sub-processes will be handled separately in order to understand the problems that may be encountered in the usage process and solution proposals will be developed for the problems to be experienced in each sub-process.

4.2.1. CDW generation in the subprocess of transition to use and recommendations for preventing/reducing CDW during the design phase

In case the user's needs cannot be determined at a complete/near-all level, there may be various levels of adding, removing or changing activities in line with the user's needs/tastes in the transition to use sub-process. The survey study conducted by Esin and Coşgun [84] with the participation of 180 users also supports this situation. It was learned that 26% of the participants had made changes in the sub-process of transition to use in the interior of the house (before they moved to the building). However, with these additions/removals and changes, new products become unusable and C&D waste may occur.
Reasons why user needs/likes could not be determined during the design process;

- Ineffective communication between the user and the design team,
- Inability to establish a user-designer relationship (mass housing designs, etc.) because the user is not known for certain.

In this case, in order to prevent/reduce the waste that will occur, it may be suggested to provide user participation in the design process or to design the shell in the structures designed for the possible user, to develop more than one proposal for the interior by the design team, and to make the selection by the real user.

Designing with User Participation: In order to prevent/reduce additions/removals or changes by ensuring that the structure overlaps with the user's needs/likings, it is important to determine user needs/likes during the design process and to ensure user participation in the design for this purpose.

With Lang's quote, Eaton (1969) states that the most successful examples of architectural structures realized throughout the century are private residences with specific users, and attributes these designs to be considered successful by user participation in the design process. Lang also attaches importance to this close relationship between the architect and the user, emphasizing the decisive effect of the relationship between the user and the architect on the final product, and states that the act of architecture cannot achieve very successful results in cases where values are diversified, differences increase and there is no close working relationship with the user [85].

In the study developed by the Dutch architect Habraken in 1961, a structure was proposed that allows the users to shape their living spaces in line with their individual needs, and this study has inspired many designs with user participation [86]. A place where the user can express his power to change and influence.

Habraken, who proposes a design method, understands the structure on two basic distinctions as support and infill units, and defines support units as unchangeable and infill units as variables that the user can intervene.

(Fig. 4.1). According to this proposition, infill units that allow the space to be reconstructed by the user and to create different usage options bring the idea of participation into existence [87].

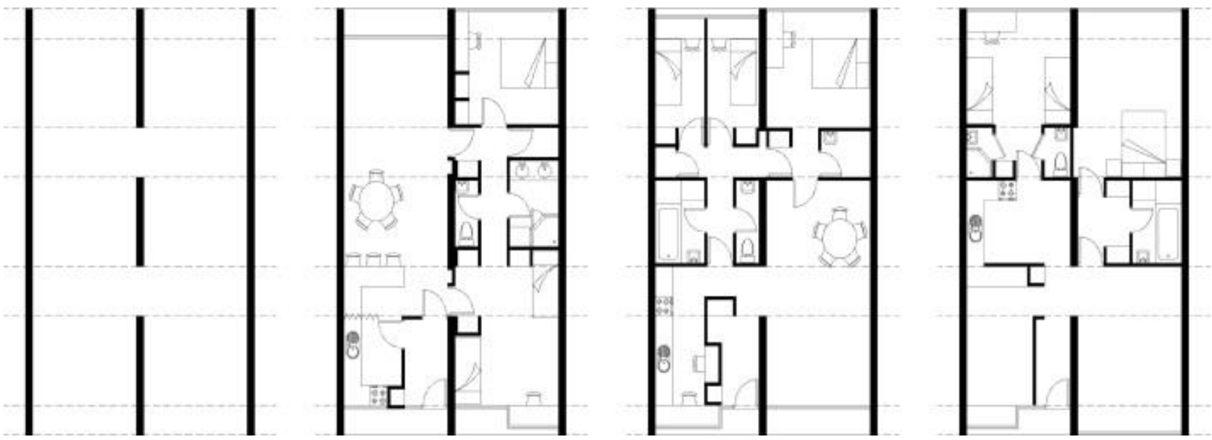

Figure 4.1 Habraken's support and infill units and space arrangement options [88]

Cedric Price's Fun Palace proposal and Herman Hertzberger's Centraal Beheer design can be listed as interesting examples in terms of interpreting the idea of user participation in this spectrum. In Fun Palace, Price separated fixed and mobile spaces with technology and structural emphasis and gave importance to the user in a changeable and transformable space setup. Hertzberger, on the other hand, gave importance to the interaction and adaptability between

users with the suggestion of continuous and undivided space organization by giving importance to user-space harmony [87].
Ensuring user participation in the design is related to the design approach. User participation is low in the standard design approach. Because standard design is a linear process. Participants consisting of architect, consultant, employer's construction manager, society and user participate in the design when deemed necessary. Communication between these participants is either non-existent or very limited. The integrated design approach, on the other hand, is an efficient approach for all participants, especially the user. This approach is a closed process that operates in a circular fashion. Participants work face-to-face, and each participant can have a say at every stage of the process. In particular, the user can express his needs and wishes within the team [89].
According to Wandersman [90], the user's participation in the design should be as followings:
- Designing his own environment without being influenced,
- Choosing one of the designs realized up to that time,
- Choosing one of the design proposals made by the designer,
- Informing the designer about the suggestions developed by the designer is in the form of creating the design with feedback in line with the user suggestions.
It is thought that, especially if the 4th article is put into practice among the options mentioned, the needs/likes of the user can be determined exactly/nearly, thus contributing to the prevention of C&D waste generation.
According to Friedmann, where the user is known for certain, a simple notation format should be produced in which the user can create his own requirement program. In Friedmann's technique, the need for space is expressed in buttons, and users are asked to tie these buttons together with ropes and attach a label to each button indicating its feature. This combined and labeled schema of interconnected buttons reveals the requirements program in such a clear way that the user does not need to explain to the architect [91].
In cases where the user is not known for certain, following steps can be taken [92]:
- future users of a residential project directly participate in the design process,
- Make a design or impact analysis from the community and evaluate several design options,
- Involvement of future resident or similar users in the design process or construction process by designers.
In both cases where the definite user or the potential user participates in the design process, it is thought that the architectural product obtained will be adopted by the user and the change requests will decrease, thus supporting the C&D waste prevention/reduction.

Designing the Shell, Offering Different Solutions for the Interior: In cases where the user cannot be determined definitively, a two-stage design process can be suggested. In the first stage, the empty shell (with the structural system) can be designed. It is possible to develop several different suggestions for the possible user for the interior setup. Thus, it is possible to finish and deliver the building at certain levels instead of delivering it in a ready-to-move condition. When the building meets the real user, one of the different proposals developed during the design process can be selected and the building can be completed. Thus, C&D waste that will occur due to subsequent changes will be prevented.

4.2.2. CDW generation in the subprocess of the user living in the building and recommendations for preventing/reducing CDW during the design phase

In the sub-process of the user's living in the building, it is necessary to make changes in the product scale for various reasons. Esin and Coşgun [84] determined the reasons for the changes made in the use of the building as follows:

- Wear-deterioration,
- Aesthetic reasons,
- To increase product quality,
- To eliminate the difficulty of use,
- To eliminate the inadequacies in space,
- Security,
- To increase the quality of workmanship,
- Using products suitable for changing tastes,
- Reaching healthy building conditions (Fig. 4.2).

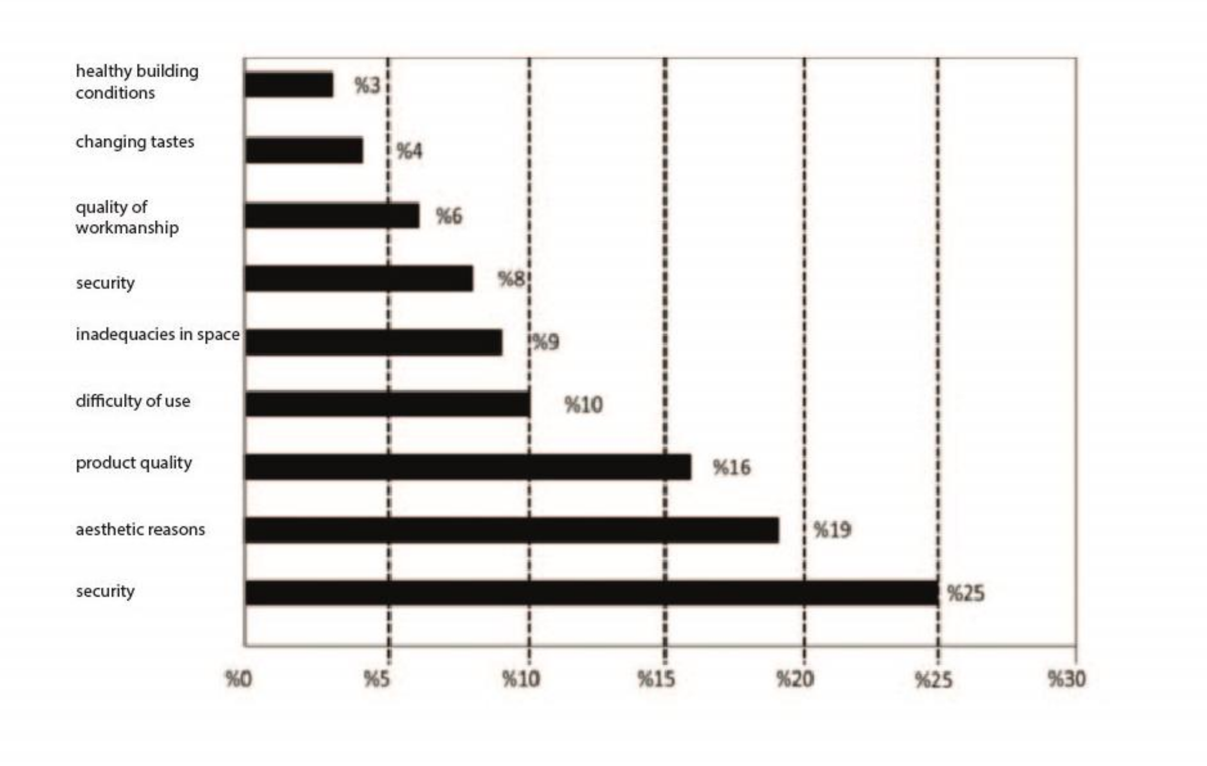

Figure 4.2 Reasons and rates of changes made during the use of the building [84]

According to Limoncu and Biçer Özkun [4], the reasons for the formation of C&D waste in the usage process specified as followings:

- User requests,
- Aging-deterioration,
- Function change

The reasons for the change in the usage process by the information given occur due to following:

- Physical aging of the products
- Change in user requirements,
- User change,

● Change in structure function,
● Change in legal obligations,
● Change in preferences depending on the innovations in the building sector.
As a result of these changes, the formation of C&D waste is inevitable. In this section, waste generation and what needs to be done in the design process to prevent and reduce this generation are discussed and examined under sub-headings.

4.2.2.1. CDW generation due to physical aging of product and recommendations for preventing/reducing CDW during the design phase

The structure enters the physical aging process from the moment it is put into use. Ulusarac [93] defines physical obsolescence as "the deterioration and wear of the whole or components of the building system, which occurs over time due to external effects within the structure". Alemdar [94], on the other hand, defined physical obsolescence as "the elements that make up the structure wear out over time as a result of internal and external factors and lose their usefulness...". The internal and external factors that cause aging are due to the following reasons:

- Natural events (wind, precipitation, humidity, radiation, temperature changes, etc.),
- Misuse (friction, torsion, impact, etc. mechanical effects),
- Environmental (air pollution, dust, biological effects, etc.) [66].

With the passage of time, the physical aging of the structure negatively affects its performance depending on its qualities, causing it to not be able to fulfill the tasks expected from it and gradually decreasing its usefulness. Building products that lose their usefulness as a result of physical aging need to be replaced, in which case C&D wastes are formed.
As stated in the study by Milani [67], the average healthy life of the building is 50 years, 20 years for the exterior cladding, 7-15 years for the heating, water and electrical flooring systems, and a few years for the floor coverings. Similarly, in the study of Bosma et al. [68], it was reported that the building underwent user intervention and changes were made in 50 years for exterior cladding and joinery, 15-20 years for heating, water and electrical flooring systems, and eight years for floor coverings. Gow [69] gave the information that maintenance-repair and renewal is required for 30 years for heating, water and electrical flooring systems, 20 years for window and door joinery, roof and floor coverings, and 10 years for exterior cladding.
In order to prevent/reduce the C&D waste that will occur due to changes to be made due to physical aging, it is important that the designs offer maintenance, repair or modification possibilities and that durable construction products are selected.

Making a Design that Offers Maintenance-Repair or Change Opportunities: In case of physical aging, maintenance-repair or replacement is carried out. In both cases, there is C&D waste generation. In order to prevent/reduce this situation, the maintenance-repair evaluations in the usage process should be made during the design process.
During the design process, measures should be taken to reduce the problems that may occur in the sub-process of the user living in the building and to facilitate maintenance-repair. When product changes are required, vertically accessible service shafts, horizontally raised floors or removable suspended ceilings will provide convenience.
In addition, during the design process, checklists can be created showing possible malfunctions in the structure and their possible causes. These lists should include a solution proposal for each situation. These checklists should be given to the user of the building, and the first things to be done in case of a malfunction should be easily seen. Thus, problems can be solved before they grow. In addition, maintenance and repair plans for building products should be prepared. These

plans should include information on the weekly, monthly and annual maintenance required for the products.

Choosing Durable Products: It is important to choose durable products with a long service life, taking into account the durability of the building product, in order to prevent frequent renewals that will be encountered in the sub-process of the user in the building, and to maintain the service life of the structure and the service life of the building products simultaneously. The service life intervals that the structures must provide are determined by various standards. The service life of the building types specified in BS7543:1992 [99] British and ENV 1991-1:1994 [100] European standards is as in Table 4.1. Table 4.2 shows the service life according to the building types in CSA S478-1995 [27] Canadian standard.

Class	Service Life of Structure (Years)	Structure Type
1	1-5	Temporary structures
2	25	Structures created with replaceable elements
3	50	Public or private structures
4	100	Monumental structures, bridges, etc.

Table 4.1 Targeted service life for building types according to BS7543:2003 and ENV 1991-1:1994 [134], [135]

Class	Service Life of Structure (Years)	Type of Structure (Examples)
Temporary	0-10	Non-permanent construction site structures
Short term	10-24	Temporary classrooms
Medium term	25-49	Industrial structures, multi-floor car parks
Long term	50-99	Health and education structures, basements parking lots
Permanent	At least 100	Monumental structures, buildings with historical value

Table 4.2 Targeted service life for building types [54]

The service life of products of structures that must have a service life in the ranges determined by the requirements may also differ from each other and from that of the structure. If the service life of the product is longer than the service life of the structure, it is not possible for the structure to be adversely affected by this situation. However, if the service life of the product is shorter than that of the structure, replacement/refurbishment is required, which activities can result in the generation of C&D waste. Therefore, the products must have certain standards. The service life that construction products must provide is given for the first time in the New Zealand standard adopted in 1992 [101]. Accordingly, products of structures with a service life of at least 50 years, under conditions of adequate maintenance; it should provide the performance to meet the requirements during the following periods:

● at least 50 years for the carrier system,

● at least 50 years for hidden connection components and parts applied to flooring systems, outer shell and carrier system where access is difficult,

● 15 years for other building envelope and structural system fastening products, building envelope coating products and other structural elements that are easy to access but difficult to replace,

● 5 years for easy-to-reach coatings, renewable protective coverings, fittings and other structural elements [95].

According to the ease of repair or replacement and the service life of the structure, the time interval during which the building products must achieve the level of performance that meets the requirements is determined by the requirements. Table 4.3 shows the useful life of building products accepted by the European Union. In this context, it is recommended that the product selection be made in the design process, taking into account the service life of the structure and the specified standards.

Default Service Life of the Structure (years)		Default Service Life of Building Products (years)		
Structure Class	Year	Product Class		
		Repairable/Easy to Replace	More Difficult to Repair/Replace	May Serve Lifetime *
short	10	10	10	10
Medium	25	10	25	25
Normal	50	10	25	50
long	100	10	25	100

* Building products that are economically impossible to repair or replace

Table 4.3 Useful service life of construction products [137]

4.2.2.2. CDW generation due to change in requirement/user/function/obligations/preferences and recommendations for preventing/reducing CDW during the design phase

As stated in Section 4.2, the sub-process of the user's living in the building is the longest period of the building's life. Although the structure is sufficient for the user when it is started to be used, after a certain period of use, inadequacies may arise with the change of needs, user, function, obligations, or tastes. These changes have been tried to be explained in detail.

- Change in User Needs: User requirements may change over time for various reasons (such as the inadequacy of the house they live in in terms of spatial size due to having the 3rd child of a family, or the change in the physical needs of the user due to the aging of the user over time, etc.).

• Change of User: Sometimes the requirements change due to the change of the user. User change can be explained as the replacement of the existing user with a different user. This change may occur with followings:
- The building has changed hands (a different person starts to use the same functional building),
- The change of the user depending on the reasons for the change of function (conversion of the kindergarten structure to high school structure, etc.). In both cases, even if they have a technical life due to the change in requirements, the structures cannot be used because their useful life has expired.
• Change of Building Function: Another reason for change that can be encountered in this sub-process is functional changes and generally occurs before physical aging. Because the social, technological and economic features in the social area change over time and differentiate. In this case, the change of the function, which can be defined as suitability in terms of use and operation, is inevitable. The structure, which should work in a unity, may become useless as a result of the deterioration of its harmony and the failure to provide the order required for use. This may lead to a change in function, which can be defined as a change in use and functioning [102]. According to Sarp [95], changing the function during the usage process may be caused by the following reasons;
- Problems in the operation of the structure due to programming and design errors,
- Change of user requirements,
- Change in the external environment,
- Structure owner or user request,
- Development of technology.

During programming and designing, another function suitable for the structure can be given as a solution to the problem that the structure is not useful as a result of not establishing good relations within the structure [95].

Changes in the needs of the user may cause functional changes in the structure.

Changing the physical or social characteristics of the external environment may cause a new function to be assigned to the structure.

The function (usage of a building with a residential function as a residence and office, etc.) can be changed at the request of the owner or the user, for purposes such as providing economic benefit from the building [95].

The development of technology may cause the structure to become obsolete by failing to function (if new mechanical arrangements are needed in a factory structure due to the change/development of production systems and machinery, but if the structure cannot adapt to these regulations, etc.). The function may change as a result of the decision that its function is not efficient for the structure due to the aforementioned reasons.

Changes made for the stated reasons include the following actions:
- Removing existing but outdated functions from the places where they are located,
- Leaving the function of a certain place to another function due to the change in needs,
- The space that will allow the necessary new functions to the existing structure [102].

• Change of Obligations: Another reason for change in this sub-process may be in terms of obligations. Necessities including the rules to be followed by the institutions around the building and the building production system [66]; Laws, regulations, regulations, standards, directives, special documents, testing, measurement and evaluation techniques can be listed in order of importance . If the structure designed and produced according to the acceptable values determined within the framework of the obligations cannot provide the new values determined due to the change in the requirements in this sub-process, changes may be required. Therefore, when requirements change, it is necessary to evaluate the compatibility of existing building features with the new rules [95].

• Change in Likes: Changes in user tastes occur due to the introduction of products whose technical quality is increasing day by day, and the reflection of the same development and change on the visual characteristics of the products. Although the building does not get old physically or functionally, sometimes users want visual innovation. In this case, changes in the structure are inevitable.

In order to prevent/reduce the C&D waste that will occur as a result of the changes to be made for the stated reasons, it is recommended to make a flexible design.

Making Flexible Design: The level expected from a successful architectural design is to be able to adapt to the change when it is necessary to make renovations in the building depending on the change of user needs / user / function / requirements / tastes. Adapting to change is possible with the flexibility approach. Instead of designing the unknown with predictive approaches, 'flexible planning' is important for structures to adapt to changes. Flexibility as a concept is the changeability of other conditions by keeping a basic system constant [92].

One of the first determinations about flexibility in architecture was made by Gropius. According to Gropius; architects should consider buildings not as monuments or works of art, but as structures that serve the flow of life, and should create a flexible ground that can cover the dynamic features of modern life [140].

Norberg-Schulz uses the concept of flexibility in architectural design in two senses. In the first use, flexibility is defined as the growth or shrinkage of the structure without losing its integrity by adding or removing, and in the second use, the elements and relations can be changed [104].

Musgrove [105] explains flexibility as the fact that the partition walls are interchangeable, and the making of spatial arrangements that do not require the variability of the dividing walls.

Douglas [106] explains flexibility as the ability to change and transform the plan in order to reorganize the space organization and make it more effective.

Flexibility in design allows the architect to decide on the project before construction that can meet different requirements within the same basic framework. Provided that the building envelope and the structural system remain the same, flexibility is provided by the approaches that create a single space or space zones inside [107].

When designing a flexible structure; it is necessary to see the structure as a whole of replaceable and detachable parts according to the changing needs of the user. For example, it should be considered that some spaces that may be needed over time can be added to the building later, or that some products need to be changed in order to extend the technical life of the building [108]. In cases such as eliminating the deficiencies and adding a new system needed, the demolition and rebuilding of the building, albeit partly, can be prevented only in this way.

Flexible design is an approach that helps prevent/reduce C&D waste even when function changes. Although functional change is seen as a situation that will increase the generation of C&D waste; it helps to extend the useful life of the structure that serves a new use and user. While changing the function, it is important that the building allows different uses in terms of functionality and volume in the plan plane and in the 3rd dimension. For this purpose, load-bearing systems, flooring systems and dividing walls should be designed to adapt to different spatial configurations. Thus, since the building can be adapted to new uses without being completely/partially demolished, effective use of the land and building products is possible.

4.3. Examination of recommendations for preventing/reducing CDW occurring in subprocesses of the use process during the design process

In Section 4.2, the sub-processes in which the C&D waste occur during the use of the building and the reasons for the waste generation in these sub-processes are discussed. Suggestions regarding the design process have been developed to prevent/reduce these wastes. In this section; in Section 2.1, the sub-processes of the design process, which are defined as concept design, preliminary design, developed design and detailed design, and the sub-processes that generate waste in the use process and suggestions for prevention are overlapped. The following recommendations have been developed in Section 4.2:

- Designing with user participation,
- Designing the shell, offering different solutions for the interior,
- To design that can offer maintenance-repair or replacement opportunities,
- Choosing durable products,
- Making flexible design.

Emphasis is placed on which sub-process of the design process and how these suggestions should be taken into account, and these suggestions are considered as a design decision for the purpose of waste prevention/reduction.

Figure 4.3 (U1) was formed by overlaying the decisions developed to prevent/reduce the wastes that will occur in the sub-processes of the design process and the sub-processes of the usage process. While creating Figure 4.3, the Sub-Processes of the Design Process are shown as concept design: purple, preliminary design: orange, developed design: blue, detailed design: green. Information on which sub-process of the design process will be handled by the decisions is expressed with the colored box in the decision line. The design decisions developed for the purpose of preventing/reducing the waste that will occur in the Sub-Processes of the Usage Process sometimes concern only one of the sub-processes, sometimes the same decision can be reconsidered in another sub-process according to the level of detail of that sub-process.

In Figure 4.3, a code number is also assigned to each decision. The codes refer to the followings:

- [K1] the form that overlaps the design decisions regarding waste prevention/reduction in the sub-processes of the design process and the sub-processes of the design process,
- X given in [K1.X] is the sub-process that generates waste in the usage process,
- Z given in [K1.X (Z)] is the improved design decision for waste prevention/reduction.

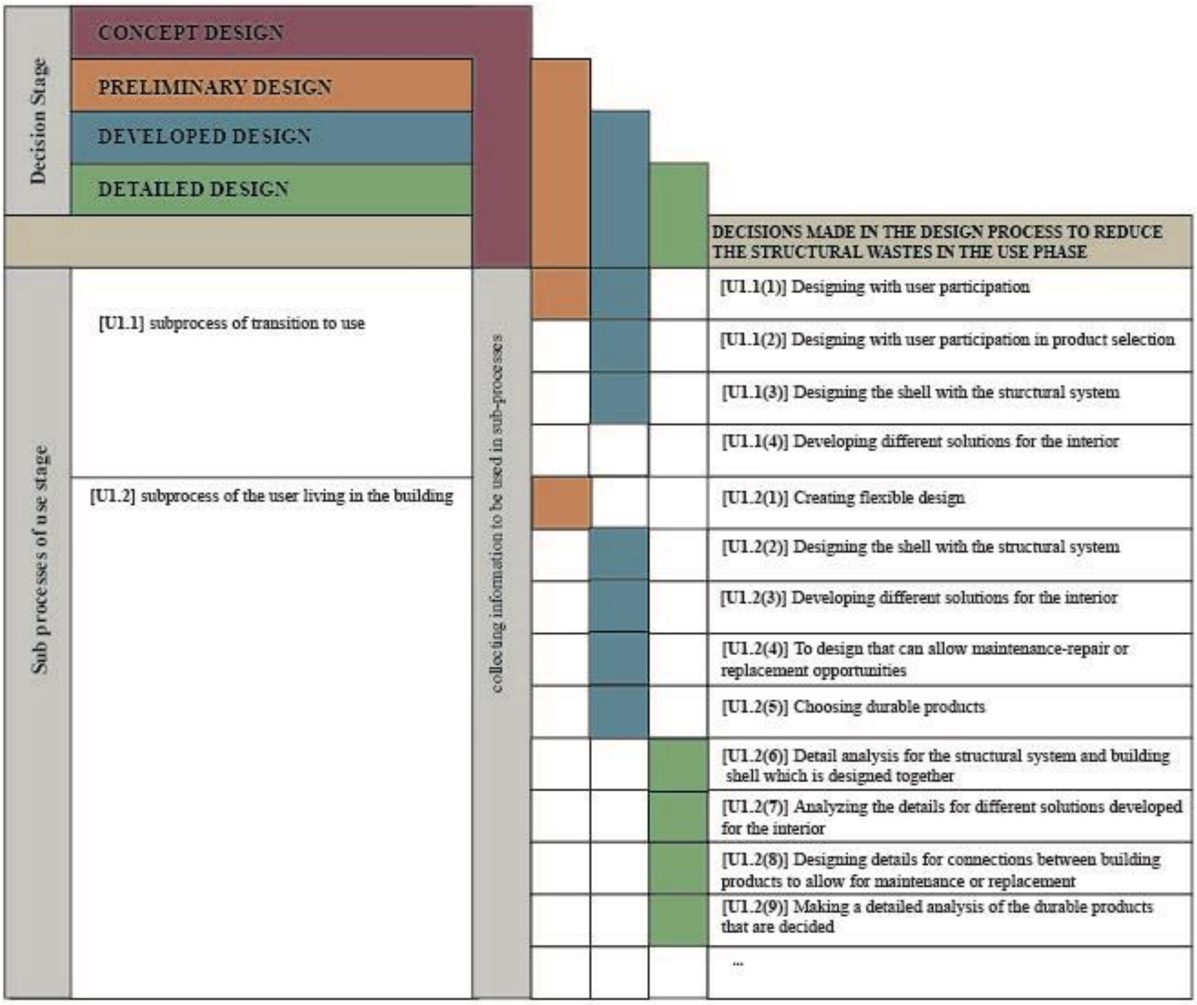

Figure 4.3 Overlaying the waste prevention / reduction recommendations in the use process with the design process of the building

PART 5
Dismantling/Demolition process of the building and CDW generation

In this section, first of all; the dismantling/demolition process will be defined, the sub-processes that make up the process will be revealed, the reasons for the formation of C&D waste in this process will be examined, and the relationship between this situation and the design process will be established. Suggestions for design decisions will be developed with the assumption that the wastes that may occur during the dismantling/demolition process will be managed during the design process.

5.1. The Dismantling/Demolition Process of the Building

Buildings are dismantled/demolished due to reasons such as completing the useful life of the buildings, losing their function by not meeting the user's needs, becoming unusable due to damage after disasters such as fire and earthquake, decisions to eliminate building/building groups within the scope of urban transformation projects in cities undergoing change and transformation.

In the resources researched, there are various definitions of the concept of dismantling/demolition. While demolition is the process of separating the building products from the building without damaging them for recycling and reuse, demolition is the process of voluntarily destroying the building [109]. According to Macozoma [110], deconstruction is a method that is employee-oriented and uses very little mechanical equipment, allows the recycling of disassembled products and non-reusable products. Building demolition, on the other hand, is a process that reduces the reusability of building products and increases the amount of waste that needs to be destroyed by bringing the building to the ground, in contrast to dismantling [110]. In case the buildings complete their lives, the dismantling/demolition method is decided. There are three methods used in the dismantling or demolition of structures. These can be listed as followings:

- Dismantling of the structure,
- Partial dismantling of the building,
- Demolition of the structure.

The dismantling, partial dismantling or demolition processes of the building consist of various sub-processes. These sub-processes are also included in the studies of various institutions or researchers. In the report prepared by Symonds Group [111], the dismantling/demolition process of the building includes following sub-processes:

- Identifying building products,
- Dismantling/destroying,
- Processing the resulting C&D wastes,
- Storage of the resulting C&D wastes,
- Evaluation,
- Prepare the area for the appropriate target.

In the study conducted by NDA (2012), the destruction process divided into four sub-processes:

- Taking security measures,
- Installation of explosives required for demolition,
- Performing the destruction,
- Recycling of C&D waste.

According to the report prepared by Symonds Group [111]; After the sub-process of determining the building products, the sub-process of performing the dismantling/demolition is started. However, it is important to decide whether to use dismantling, partial dismantling or demolition methods between the two sub-processes. The study by NDA [112] considers only demolition, not dismantling or partial demolition. In this case, after the demolition takes place, the whole building becomes a waste and only recycling decisions are taken. However, it is seen that the reuse of building products is not considered.

In the studies examined; the sub-processes of the dismantling/demolition process are discussed in the context of C&D waste without any detail at the desired level. For this reason, sub-processes were redefined according to the content of the thesis study. Period starts with the decision of dismantling/demolition of the building and continues with the determination of dismantling/demolition targets. The structure should be evaluated and the dismantling/demolition method should be determined by conducting analysis studies on the surrounding of the building and the structure. Because every building cannot be dismantled or demolished with the same technique and technology, the dismantling/demolition method differs according to the type of building; While some structures that have been decided to be dismantled/demolished are completely demolished, some structures are partially dismantled/demolished. Then, a dismantling/demolition permit should be obtained, the building area should be prepared, and the dismantling/demolition should be carried out. The products to be reused and recycled together with the dismantling/demolition of the structure should be separated, transported to predefined areas, and stored. After all these processes are completed, the building area should be cleaned, and the process should be terminated.

The dismantling/demolition process within the scope of the thesis study considered as a process that includes following sub-processes:

- Decision of dismantling/demolition of the building,
- Determining the dismantling/demolition targets of the building,
- Evaluation of the building
- Determination of the dismantling/demolition method,
- Obtaining the dismantling/demolition permit of the building,
- Preparation of the area,
- Performing the dismantling/demolition of the building,
- Processing, transport and storage of C&D waste
- Cleaning the area.

And it is important to define sub-processes.

Sub-Process of Decision for Dismantling/Destruction of the Building: Buildings can be dismantled/destroyed for reasons such as the following:

- Completion of his life,
- Damaged as a result of disasters,
- Having a disaster risk,
- Having negative effects on the environment,
- Staying within the scope of urban transformation,
- Inability to meet user requirements,
- User change,
- Completing the function of the building in the area,
- Desiring to separate a part of the building from the building.

The dismantling/demolition process of the buildings starts with the decision of the owner of the building or certain institutions to terminate the life process of the building, regardless of the reason for the dismantling/demolition of the building.

Sub-Process of Determining the Dismantling/Destruction Targets of the Building: It is important to determine the targets of the deconstruction/demolition project in terms of living/non-living environmental health and economy. For this purpose, attention should be paid to the following issues:

- Recovering the building products that can be reused during the dismantling / demolition process, and realizing the highest level of recovery,
- Carrying out the dismantling / demolition in a safe way without harming the environment and human health, ensuring work and worker safety,
- Dismantling / demolition as soon as possible,
- Minimizing the dismantling/demolition cost,
- Evaluation of products that are salvaged and reused during dismantling/demolition with methods suitable for the conditions of the country (marketing, donation, use in another field, etc.).

Structure Evaluation Sub-Process: In order to determine the method of dismantling/demolition of the structure, the type and quantity of products to be reused, the structure must be evaluated at various levels:

- Evaluation of the physical condition of the building [113],
    - ◦ Construction type.,
    - ◦ State of use of the building: used, abandoned, etc.,
    - ◦ Location of the building: in the city, outside the city, etc.,
    - ◦ Physical condition of the building: fire damaged, earthquake damaged, flood damaged, etc.,
    - ◦ Condition of products in construction: proportion of products to be reused and recycled,
- Evaluation of the structural system of the building,
- Identifying products to be reused and recycled.

Sub-Process of Determination of Dismantling/Demolition Method: In this sub-process, method determination and dismantling/demolition planning are made. The re-use possibilities of the products after dismantling are at a very high level, in the case of partial dismantling, they are at medium level, and in the case of deconstruction, they are at very low levels. However, the deconstruction method; In cases such as the structure is not designed for disassembly, the building products are not selected for disassembly, the dismantling takes more time, and the cost increases, the building is partially dismantled or demolished [114].

Sub-Process of Obtaining Dismantling/Demolition Permit of the Building: It is the sub-process in which official institutions are informed about the dismantling/demolition of the buildings.

Site Preparation Sub-Process: The site must be planned in accordance with the conditions to ensure that the dismantling/demolition work is done and completed safely, on time, in accordance with the agreements. Working area must be planned in order to minimize the problems of circulation, transportation, storage, environmental and safety [115]. In this planning, there is a need for areas where cleaning, disassembly, separation, repair, temporary storage, permanent storage can be done for the C&D waste formed after dismantling / demolition.

Sub-Process of Performing the Dismantling/Demolition of the Building: The dismantling/demolition sub-process of the building includes the implementation of the techniques determined within the framework of the dismantling/demolition plan in accordance with the planned schedule, after the necessary site preparations have been made and the building support process has been carried out. It is possible to define the dismantling/demolition sub-process as the reverse of the application of products to the structure. Because, the products added last in the sub-process of applying the products to the structure are removed first. In general, the dismantling/demolition of the building starts with the separation of the building products containing harmful chemicals (asbestos-containing products, etc.). The products separated from the building should be removed from the building according to their properties and destroyed according to the relevant regulations. Building products that can be reused later (doors, windows, cabinets, sinks, bathtubs, radiators, suspended ceilings, etc.) are dismantled. After these operations, the dismantling/demolition of the structural system of the building is carried out with the appropriate method. In this sub-process, it is important to carry out the necessary building support operations to ensure safety and to keep the sub-process under control by the contractor and responsible public institutions.

Sub-Process of Processing, Transporting and Storing C&D Waste: C&D waste generated after dismantling/demolition actions can be contaminated, mixed and in quite different sizes. For this reason, it is necessary to process the C&D waste in facilities inside or outside the building area in order to make them ready for recycling, disposal and other works. Processing of C&D waste consists of following steps:

- Separation of the mixed ones,
- Separation into parts,
- Cleaning,
- Sizing.

Transport and storage of processed C&D waste should be carried out in accordance with the relevant regulations.

Area Cleaning Sub-Process: The last sub-process of the dismantling/demolition process is the cleaning of the area. All contaminants must be properly removed from the area.

5.2. CDW generation during the subprocesses of dismantling/demolition process and recommendations for preventing/reducing the CDW during the design phase

Institutional studies (DoW, C2C, LEED, BREEAM, Green Star, IGBC Green Homes) have been examined in order to establish the infrastructure for what needs to be done in order to control the C&D waste that will occur during the dismantling/demolition process. In addition to these, Pulaski et al.'s (2003) study has been scrutinized since it directly relates the design process to the dismantling/demolition process in terms of C&D waste generation. As a result of the examinations, no recommendations were found in the LEED, IGBC Green Homes Certification System to prevent/reduce the C&D waste that will occur during the dismantling/demolition process during the design process.

The Demolition Protocol implemented in the United Kingdom in 2008 was reviewed. Similarly, the LEED certification system does not evaluate this part of the study in its current situation, but in current scientific studies, there are suggestions that can be added to LEED versions in order to prevent / reduce the C&D waste that will occur during the dismantling / demolition process. In the study of Webster and Costello [159], it is suggested that a separate credit should be opened under the title of "Design for the Reusability of Construction Products". In Saleh's [160] study, in addition to the credits under the "Materials and Resources" category in LEED-New Buildings, two new credits are proposed under the titles of Detachable Design and Design for Adaptive Reuse.

● **In the DoW approach** there are five basic design principles [58]:
◦ Design for reuse and recycling,
◦ Design with pre-built systems,
◦ Design for targeting appropriate product use,
◦ Design for efficient waste generation,
◦ Deconstruction-oriented design and flexibility.
Design principles that can be used to reduce waste in the dismantling/demolition process are design for reuse and recycling, deconstruction targeted design and flexibility.
The following key questions are given in the design approach for reuse and recycling:
- Can the waste generated when the building is demolished be reused to realize a different design?
- Can these wastes be reused to produce a more valuable product?'
It has been stated that the answers to these questions have an important role in preventing/reducing the waste that will occur in the dismantling/demolition process.
The key questions to be answered in the deconstruction-targeted design and flexibility approach are given below:
- Has the structure been designed with reusable/recyclable products?
- Can the building products be easily dismantled?
- Is there a "Building Information Modeling/BIM" or "handbook" in which data on which products are designed to be removable?
It has been stated that the answers to these questions have an important role in preventing/reducing the waste that will occur in the dismantling/demolition process.

● **In the C2C approach**; approach to the design process to reduce waste in the dismantling/demolition process is based on followings [60]:
◦ Determining how each product will be evaluated at the end of its life,
◦ While making product decisions for designs, products that do not enter the production cycle at the end of their useful life should not be selected.

● **Recommendations developed in the BREEAM Certification System** to prevent/reduce disassembly/demolition wastes during the design process is in the "Resources" category. Accordingly, points are earned when five basic design principles in the DoW approach are followed [25]. Principles can be used from the five key design principles to reduce waste in the dismantling/demolition process as stated in the DoW approach are design for reuse and recycling, deconstruction targeted design and flexibility.

● **The suggestions developed in the Green Star Certification System** are in the "materials" category. The approach to the design process is to design the load bearing, roof and facade systems of the building in a removable way [26].

● **In the study of Pulaski** [116], suggestions were developed to prevent/reduce the disassembly/demolition process wastes in the design process and associated with the sub-processes of the design process (Table 5.1). According to this study, the decisions regarding the design process were determined as the following:
-Design for prefabrication, preassembly, and modular construction,
-Simplify and standardize connection details,
-Simplify and separate building systems,
-Consider worker safety during deconstruction & construction,
-Minimize building components and materials,

-Select fittings, fasteners, adhesives, and sealants that allow for quicker disassembly and facilitate the removal of reusable materials,
-Design to accommodate deconstruction logistics,
-Reduce building complexity,
-Design to reusable materials,
-Design for flexibility and adaptability,
The extent to which the sub-processes of the design process are related to these decisions is given in Table 5.1.

	Design Principles	Program Development	Schematic Design	35% Design Development	70% Design Development	100% Design Development	Construction Documents	Construction
1	Design for prefabrication, preassembly and modular construction	Medium	High	Medium	Medium	Medium	Medium	
2	Simplify and standardize connection details			High	Medium	Medium	Medium	
3	Simplify and separate building systems	Medium	High	Medium				
4	Consider worker safety during deconstruction & construction			Medium	Medium	Medium	Medium	High
5	Minimize building components and materials	High	High	Medium	Medium	Medium	Medium	
6	Select fittings, fasteners, adhesives and sealants that allow for quicker disassembly and facilitate the removal of reusable materials				Medium	Medium	Medium	Medium
7	Design to accommodate deconstruction logistics	Medium	Medium	Medium	Medium			Medium
8	Reduce building complexity	High	High	Medium				
9	Design to reusable materials	Medium	Medium	High	Medium	Medium	Medium	
10	Design for flexibility and adaptability	High	High	Medium				

High relevance
Medium relevance

Table 5.1 Decisions to prevent/reduce the wastes that will occur during the dismantling/demolition process in the design process [161]

● **Demolition Protocol 2008** is a guide that can be used in dismantling/demolition actions in the United Kingdom. It is emphasized that this guide should be used in the requirements that define the rules for dismantling / demolition actions in England and Scotland. In the Demolition Protocol 2008, it is stated that if the structures are designed to be dismountable, less waste will be encountered when the life of the building ends. It is emphasized that the study titled Design and Detailing for Deconstruction prepared by The Scottish Ecological Design Association/SEDA with the support of the Scottish Government can be used to show the designers the main principles and methods so that the building can be designed in a demountable form [158]. In this study, the possibilities of detachability of construction systems and connection designs between construction products were investigated.

In order to prevent/reduce the C&D waste that will occur in the dismantling/demolition process and which are mentioned in the studies examined, the decisions regarding the design process that will be utilized while constructing a new model are given in Table 5.2 and the studies are criticized.

In the studies examined, the design process was considered as a whole. However, based on the knowledge that the design process is a process that includes sub-processes called preliminary work, preliminary design, final design and detailed design, no evaluation has been made about what should be done in which sub-process. Only the sub-processes of the design process were included in Pulaski's [116] study and the relationship between waste prevention/reduction decisions and these sub-processes was established.

In the studies, it is suggested that the structure be designed to be disassembled, but there is no recommendation to prepare a dismantling plan in order to carry out this disassembly correctly. However, considering that the designer of the building is the one who knows the details of the dismantling best, it is thought that this plan should be prepared during the design process.

The design of the connections between the products is important so that the structure can be dismantled. However, it has been determined that this information is not adequately included in the studies examined. In this context, it is thought that this information should be included while developing an approach to the design process in order to reduce waste in the dismantling/demolition process.

While developing proposals for sub-processes, the following sub-processes were excluded because the dismantling/demolition actions did not start and the designer has no responsibility for the design process for the C&D waste generated in the sub-processes:

◦ Decision of dismantling/demolition of the building,
◦ Determining the dismantling/demolition targets of the building,
◦ Evaluation of the structure
◦ Determination of the dismantling/demolition method,
◦ Obtaining the dismantling/demolition permit of the building,
◦ Preparing the area,
◦ Processing, transport and storage of C&D waste
◦ Cleaning the area.

In the study, the reasons for the formation of C&D waste in the sub-process of dismantling / demolition of the structure will be examined, and solution proposals regarding the design process will be presented.

Studies Reviewed	**Critique of Studies and Aspects That Can Contribute to the Model**
DoW	-The resilience approach is recommended, but resilience is important when the structure is used, not at the end of its life. Since the dismantling/destruction of the building takes place with the completion of its life, it cannot be mentioned that the building, whose life has ended, can adapt to the new situation. Therefore, it is not possible to consider the concept of flexibility in this sub-process.
C2C	-The stated recommendations are acceptable, but it is important to develop a more detailed and holistic approach to the waste prevention/reduction goal.
LEED	**-**There is no proposal for a waste prevention/reduction target, but it has been suggested in various scientific studies that the titles of "Design for Reusability of Construction Products", "Detachable Design", "Design for Adaptive Reuse" can be added to LEED.
BREEAM	The resilience approach is recommended, but resilience is important when the structure is alive, not at the end of its life. Since the dismantling/destruction of the building takes place with the completion of its life, it cannot be mentioned that the building, whose life has ended, can adapt to the new situation. Therefore, it is not possible to consider the concept of flexibility in this sub-process.
Green Star	- The stated recommendations are acceptable, but it is important to develop a more detailed and holistic approach to the waste prevention/reduction goal.
IGBC Green Homes	**-** There is no recommendation for a waste prevention/reduction target.
work by Pulaski	**-** The stated suggestions are acceptable, but the final design sub-process is divided into three sub-processes as 35%, 70% and 100%, but no information is given on how this partitioning will be done. It is debatable how to make such a clear distinction in the final design process.

Table 5.2 Evaluation of the studies examined for the purpose of preventing/reducing the C&D *waste that will occur during the dismantling/demolition process in the design process*

5.2.1. CDW generation in the subprocess of performing the dismantling/demolition of the building and recommendations for preventing/reducing CDW during the design phase

The dismantling/demolition sub-process is the process in which the most C&D waste is produced during the life of the building. If the buildings are not designed in accordance with the principles of disassembly during the design process, since the building is completely destroyed, it is inevitable that all products will turn into waste, and the possibilities for reuse and recycling of products are reduced. The need for large storage areas due to their size and the damage these wastes will cause to the environment increases the importance of the "Design for Deconstruction" approach.

Designing for Deconstruction (DfD): As emphasized in DoW, BREEAM, Green Star, which are studies reviewed in Section 5.2, the DfD approach is important because it reduces C&D waste by increasing the reuse or recycling possibilities of construction products.
Various examples can be given that highlight the ecological and economic benefits of the DfD approach. 97% of the Seattle Kingdom stadium, which was destroyed in 2000, was used in the construction of the new stadium to be built in its place, and 3 million dollars were earned through demolition techniques aimed at the recovery of products. Six existing buildings were demolished for a business center to be built in Manhattan, and the contractor did not pay the waste disposal costs and earned $8,800,000 by selling the products [117]. The method chosen by the computer company IBM when it decided to demolish its own eight-story office building in Winchester (England) in 1993 shows how successful deconstruction applications can be when desired. IBM; asked the company that will carry out the demolition to dismantle the office building floor by floor. Thus, the falling glass, concrete and rubble pieces were kept on the floor of a lower floor, thus providing ease of collection and classification. The glass and steel in the building were then completely recycled, while the carpets, roller blinds and flooring system elements were used directly in the construction of another building without any additional effort [118].
Guy and Shell [119] listed the objectives of the DfD approach as follows:
- Minimizing the waste to be generated by the high reuse and recycling of construction products,
- Extending the life span with the ability of the structure to adapt to change,
- Quickly dismantling and removing the structure from the site,
- Reducing health and safety problems for workers who will carry out the dismantling,
- Reducing the costs of various tools used in dismantling.

Although the DfD approach has an important theoretical place in scientific studies conducted in recent years, it has found a place in few designs. This situation can be attributed to the following reasons:

- The priority in building designs is durability (Design for Robustness),
- No guarantee can be given regarding the robustness and safety level of reusable products,
- Reusable products are not often found in the building market [120].

Although there are difficulties in the implementation of the DfD approach; it is assumed that the problems can be overcome by determining the principles to be followed in the design process and designing in line with these principles. These can be defined as principles regarding:

- The design of the building,
- Product selection,
- The design of the link between components.

DfD principles for the design decisions of the building are followings:

- Designing the structure by stratification: According to Brand's [121] changing speed of layers scheme, the structure is divided into layers for disassembly. Each layer must be used within a certain time interval before it is changed. This provides accessibility to layers without conflict between long-lived and short-lived layers. In this approach, layers with shorter lifetimes are located closer to the surface of the structure and are more easily accessible. These layers can be easily removed from the long-lived layers underneath, without any damage or unnecessary disintegration. The DfD approach is useful when the lifetime of the products used in the building is longer than the calculated lifetime of the building [21].
- Not choosing the masonry construction system: In the masonry construction system, the disassembly of the connections between the products is more difficult than in other systems. It is stated in the provisions of the European Waste Regulation that the masonry structure should not be adopted due to the size and volume of the area they cover after demolition [122].
- Reducing the complexity in the structural system of the building: For example, the use of pre-tensioning and post-tensioning beams and cantilevers in the reinforced concrete skeleton system makes dismantling difficult and increases waste generation [123],
- Designing the floor systems of the building in an accessible way [124]: For this purpose, installing vertically accessible service shafts, horizontally raised floors/removable suspended ceilings,
-Developing dismantling plans that will provide information on how to dismantle building products [125].

For a successful deconstruction plan it is important that the following information on the subject is kept up-to-date:

◦ Creating documents that will provide information on how to dismantle the building products to be used in DfD solutions, preparing the drawings describing the most appropriate dismantling technique for certain building products,

◦ Distribute the deconstruction plan to the relevant groups, revise the plan as needed, and re-notify all relevant groups of changes so that decision makers such as the owner, architect and builder can meet future DfD requirements [126].

DfD principles for product selection are following:

- It is important to choose products that will allow reuse or be recycled after disassembly. For this purpose, dismantling possibilities of building products, which are frequently used in the building production sector, are examined.

◦ Since the chemical adhesives used when putting together block products such as stone and terracotta are stronger than the products, they offer limited possibilities for reuse.

◦ Although concrete provides recycling opportunity, it does not offer reuse for the same purpose after deconstruction.

◦ While the possibility of reuse of wooden construction products (door/window joinery etc.) is high, the reuse of wood used in structural system is more limited [127]. Chipboard or fibrous artificial wood boards, on the other hand, are recyclable, but are less likely to be reused [128].

◦ Metal products are more likely to be recycled than reused [126]. In addition, metal products that do not deteriorate and do not get dirty due to the effect of coatings or adhesives are also very suitable for reuse.

◦ It is theoretically possible to recycle 100% of glass products without loss of substance and quality [128]. It also offers the possibility of re-use in case it is dismantled without breaking/smashing.

◦ Due to the petroleum origin of plastic products (joinery profiles, roof covering, wallpaper, pipes, gutters, etc.), it is impossible to be destroyed in a short time in nature.

Therefore, it is brought into the economy through recycling. In addition, the possibility of reuse of uncontaminated, intact plastic products is also very high.

- Not coating the construction products (steel, etc.) to be reused/recycled with paint or fire protection sprays, allowing the product to remain in its raw condition, thus increasing the possibility of reuse/recycling [129].
- Designing by reducing the amount of building products to be used: For example, reducing the number of interior walls to be used in the building will both prevent/reduce the amount of product to be waste by reducing the amount of product to be used, and increase the ability of the building to adapt to new situations [116].

DfD principles for designing of the link between components:

- Establishing as simple and repetitive connections as possible between building products, using mechanical connections instead of chemical adhesives: In general, three types of connection types can be identified: direct connection, indirect connection and filled connection. In direct connections, the building products form a complete joint with each other without any additional equipment on the joint faces. In indirect connections, the building products are joined to each other by means of an additional component used to ensure the connection at the joint faces. In filled joints, the building products are bonded to each other by gluing with chemicals applied to the joint faces [130]. In DfD solutions, instead of chemical binders, screws etc. should be chosen for mechanical connections. If a chemical binder has to be used, it is important that the binder is not stronger than the bonded components, in order to allow the parts to be separated without damaging the connected parts during disassembly.

-Although block products such as stone and terracotta can be reused, the possibility of reuse increases or decreases depending on the characteristics of the chemicals that bring the products together. For example, the use of cement mortar with high strength in bonding products imposes limitations in terms of dismantling. The use of mortars with lower strength or mechanical connections instead of cement mortar will increase the possibility of dismantling. The facade designed by Renzo Piano for the IRCAM building can be given as an example of the application of the terracotta product (brick) in a detachable form with mechanical connections (Figure 5.1) [131].

Figure 5.1 Application of assembling the brick with mechanical connections [132]

◦ Precast reinforced concrete products offer theoretical reuse possibilities when combined with mechanical connections. Load-bearing components such as pre-built columns, beams and floor slabs present problematic stresses during initial disassembly and repositioning. Another problem in terms of deconstruction is the need to apply a pour-in-place top concrete layer over some prefabricated floor slabs [127].

◦ Cables, pipes, ducts, etc., which are among the most frequently changed building products, are placed in the spaces in wooden wall, floor, and ceiling systems. The placement of flooring system components allows them to be easily removed, when necessary, without causing damage or waste.
◦ The use of accessible and detachable methods in the connection of metal and glass products is necessary for deconstruction. Clips, screws, etc. The mechanical connections made with the product allow easy, fast, and cheap disassembly and assembly of the products for the purpose of maintenance, repair, renewal, and replacement.
◦ Placing the coating products on the surfaces to be coated by mechanical methods (hanging, screwed, clipped, etc.) instead of chemical methods can allow the coating to be easily and undamaged to be removed and thus to be reused. Durmisevic and Brouwer [130] designed a facade layout with different connections from fixed to removable (Figure 5.2). The carrier system component (a) shown in Method 1 also works as the connection part of the facade components (b1, b2, b3), and the combination is provided with the help of chemicals. In Method 2, the second piece was used to connect the carrier and façade components, but again, it was combined with chemicals. In both cases, when dismantling is done on the facade or on the carrier, the products may be damaged. In method 3, the carrier (a) and the facade element (b) are combined with a second connection piece (●).

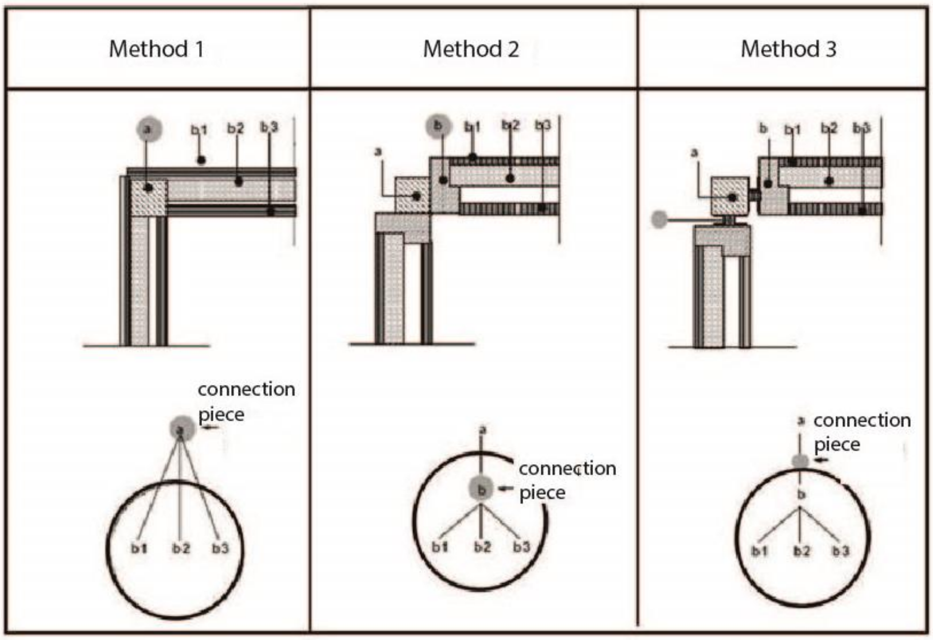

Figure 5.2 Fixed and removable facade cladding layouts [130]

5.3. Examination of recommendations for preventing/reducing CDW occurring in subprocesses of the dismantling/demolition of the building during the design process

In Section 5.2, the sub-process of performing the dismantling/demolition of the building in which the C&D waste is generated during the dismantling/demolition process and the causes of waste generation in this sub-process are discussed. In order to prevent/reduce these wastes in the design process, the DfD approach has been proposed. In this section; the sub-processes of the design process, which are classified as concept design, preliminary design, developed design and detailed design in Section 2.1, and DfD approach proposals are overlapped. In Section 5.2, it is emphasized that the suggestions regarding the DfD approach developed in the design process should be taken into account in which sub-process and at what level, and these suggestions are considered as a design decision for the waste prevention/reduction target.

Figure 5.3 was created by overlaying the decisions developed to prevent/reduce the wastes that will occur in the sub-processes of the design process and the sub-process of dismantling/destroying the building. While creating Figure 5.3, the Sub-Processes of the Design Process are shown as concept design: purple, preliminary design: orange, developed design: blue, detailed design: green. Information on which sub-process of the design process will be handled by the decisions is expressed with the colored box in the decision line.

In Figure 5.3, a code number is also assigned to each decision. While generating the codes, the following are expressed:

- [D1] the way in which the sub-process of performing the dismantling/demolition of the structure coincides with the design decisions regarding waste prevention/reduction in the sub-processes of the design process,
- X given in [D1.X] is the sub-process where waste is generated during the dismantling/demolition process,
- The Z given in [D1.X (Z)] is the improved design decision for waste prevention/reduction.

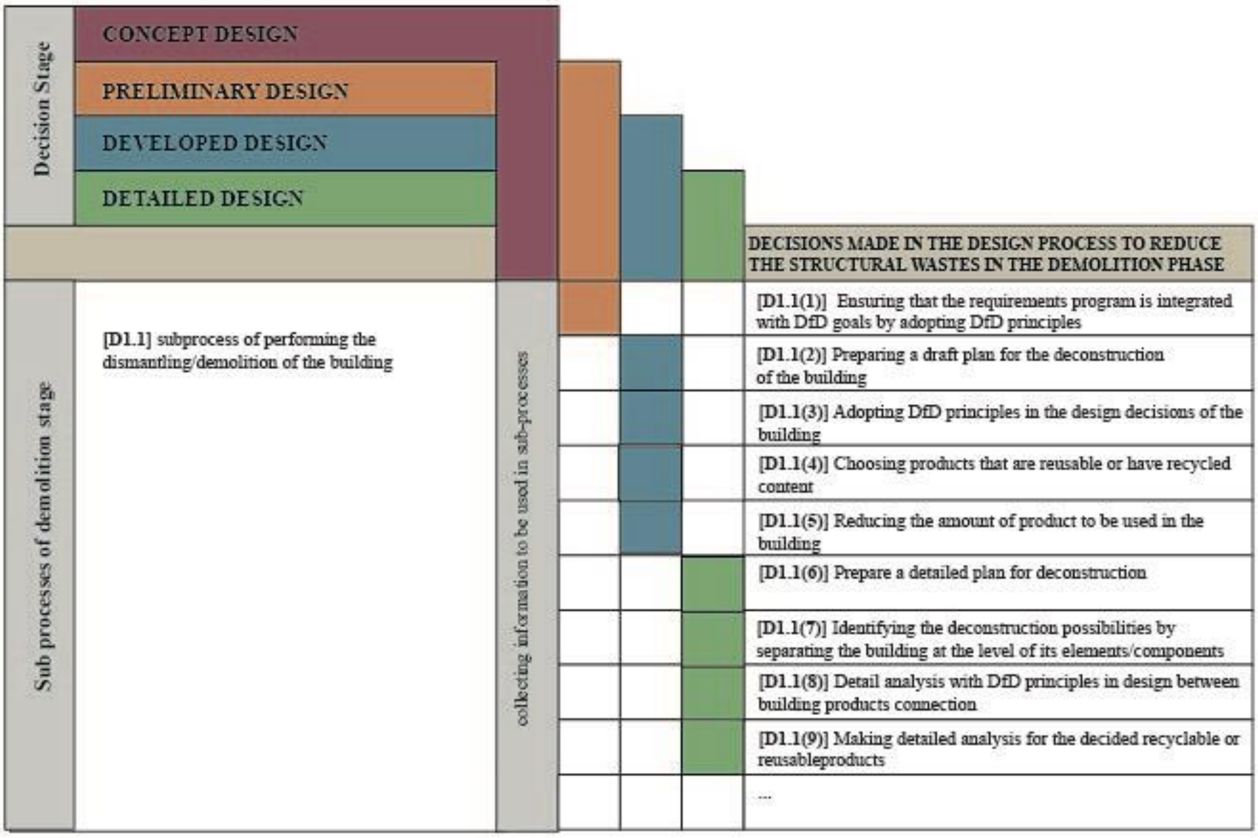

Figure 5.3 Overlaying the waste prevention / reduction recommendations in the demolition process with the design process of the building

PART 6
Case Studies

6.1 Criteria for selecting the best practices of building interventions with eco-effective management strategies for materials and waste

In the study of Altamura [133], in order to represent several types of intervention, in relation to the presence or absence of a pre-existence, the case studies are grouped into three categories. The selected case studies have been classified into those three categories, and identified by the alphanumeric code shown in the analysis sheet of each project:
IDR-Interventions with demolition of pre-existence and reconstruction in the same site
NCR_00 New construction works in previously undeveloped areas
RDC-Restructuring interventions with partial demolitions and reconstructions or extensions
The grouping into three categories allows to compare the possible approaches to the reduction of construction and demolition waste in interventions that start from different conditions: the possibility of reuse of the pre-existence through the conservation of part of its technical elements, in the RDC category, the potential for reuse and recycling of components and demolition materials on site, in the IDR category, the adoption of recycled materials and components from other sites and the reduction of construction waste, in the NCR category.

The fifteen case studies examined in this section derive from a process of collecting and selecting a much larger number of best practices, which took place in part through bibliographic research. From an initial screening of the collected case studies, thirteen significant examples of implementation of sustainable management strategies for materials and waste were identified. Which are chosen to select only the cases in which the different strategies are correlated with each other in a particularly effective way, with remarkable results in terms of reducing the environmental impact of the entire building intervention. A further criterion for the selection is represented by the degree of innovation of the architectural and technological solutions adopted to incorporate the components and materials of reuse, as well as the management methods of the building process.

The best practices identified mainly refer to the British and US geographical context: in these contexts, in fact, a planning-operational practice is beginning to consolidate, in which, through selective demolition, the content of raw materials and incorporated energy present is enhanced in built heritage. Demolitions are more common there. In a study conducted for architecture and design firms in the USA, it was determined that 75% of the participants completed at least one reusable material project, and more than 40% completed projects using recycled materials [134]. And in the US, users have been found to comment that reclaimed building materials are "substandard but environmentally friendly". In these contexts, moreover, real supply chains have been structured, with operators and suppliers specialized in recovery, reuse, and recycling as well as in supporting designers in identifying resources available locally. However, case studies are also examined in the Netherlands, Switzerland, Sweden, Belgium to testify how the theme of conservation and efficient use of resources is becoming important, at least in the context of sustainable projects, in Europe.

Through the analysis of the case studies, 13 design and operational strategies were adopted from study of Altamura [133], through which the cases were compared and filtered. The identified strategies, collected by action area, are the following:

Existing materials management
S.1 Preservation and adaptation of existing buildings
S.2 Partial or total selective demolition of existing building
S.3 Transfer of non-reusable C&D waste to the recycling plant
S.4 Recycling of demolition / construction waste on site
S.5 Recovery of components for reuse on another site (sale or donation)
S.6 Reuse of demolition components on site for a new building

Project material management
S.7 Technological project optimization to reduce construction waste
S.8 Return surpluses and construction waste to the manufacturer
S.9 Design for Deconstruction and technological flexibility
S.10 Reuse of recycled materials and / or components from other construction sites or other
S.11 Use of materials with recycled content
S.12 Use of environmentally friendly materials from controlled / local supply chains

Management of the construction site
S.13 Innovative site management for waste and materials (monitoring, contracts, storage, etc...)

The individual strategies contribute to the achievement of one or more of the following objectives, recurring in the various case studies, which can be considered sub-articulations of the objective of efficiency in the use of resources expressed by the European Union:
O.1 Reduce the environmental impacts of buildings due to materials
O.2 Reduce the energy embedded in buildings
O.3 Reduce the quantity of raw materials used for construction works
O.4 Reduce the amount of C&D waste sent to landfill
O.5 Prevent the production of C&D waste

The individual case studies are examined through a table consisting of 3 sections:
- The credits of the intervention, with an indication of the reuse and recycling targets reached and the sources used,
- Images for understanding the scale of intervention,
- The summary table of objectives, strategies, implementation levels.

In order to compare the case studies, a simple evaluation methodology was developed: the strategies were weighed, through the use of multiplicative factors, to give feedback to their different degree of innovation. This approach makes it possible to understand at first sight the complexity of the intervention in terms of the management strategies of the materials to be construction and waste from C&D adopted.

IDR-1 Douglas School

Figure 6.1 Façade of new building [135]

Figure 6.2 Demolition of old building [136]

Intervention	New construction and renovation of a school building
Location	Douglas, MA, USA
Target achieved on waste	57% (444 tons recycled, 338 tons disposed)
Sources of data and images	https://archive.epa.gov/region1/healthcare/web/pdf/cdrecyclingguide.pdf

objectives					**code**	**Strategies**	**level**
O1	**O2**	**O3**	**O4**	**O5**			
					S.1	Preservation and adaptation of existing buildings	● ○ ○
					S.2	Partial or total selective demolition of existing building	● ● ○
					S.3	Transfer of non-reusable C&D waste to the recycling plant	● ○ ○
					S.4	Recycling waste from demolition / construction on site	● ● ○
					S.5	Recovery of components for reuse in another site (sale or donation)	● ○ ○
					S.6	Reuse of demolition components on site for new building	● ● ●
					S.7	Technological project optimization to reduce construction waste	● ○ ○
					S.8	Return of surplus and construction waste to the manufacturer	○ ○ ○
					S.9	Design for Deconstruction, technological adaptability	● ○ ○
					S.10	Reuse of recycled materials and / or components from other construction sites or other	● ● ○
					S.11	Use of materials with recycled content	● ● ○
					S.12	Use of environmentally friendly materials from controlled / local supply chains	● ● ○
					S.13	Innovative site management for waste and materials	● ● ●

Table 6.1 Adopted strategies of Douglas School construction

Douglas School project was led by Consigli Construction Inc.. The brick structure is in a rural area. While a small portion on the project was renovation and addition, most of the project consisted of construction of a new high school. Contractor used a combination of contract requirements, a worksite management plan and techniques to have its subcontractors to source separate approximately 50 tons of clean new scrap gypsum wallboard from construction debris. Recycling containers are placed throughout the construction site and disposal containers are put further away, in this way source separation increased by making it more convenient for workers to recycle than to discard recyclable materials. Workers collected the materials on a regular basis and kept the wallboard dry and stacked flat in a closed container. Constructor transported the scrap wallboard 100 miles to G-P Gypsum Corporation in Newington, New Hampshire. G-P accepts both interior and exterior clean new scrap gypsum wallboard and makes it into new wallboard.

It is important in this case to oversight of recycling contracting, tie the subcontract language to a waste management plan that requires recycling, specifies recycling techniques, and provides incentives for recycling. Negotiation for disposal fees by type of material to reduce costs based on the market value of the material rather than paying a flat fee for all materials. The aim of reducing the C&D waste is achieved by verifying recyclable materials that are brought to a recycler by requiring that the subcontractor provide “weight slips” from a recycling facility.

It is learnt from the project, developing, and distributing a waste management plan prior to project initiation is important. Discussing waste handling requirements with crew and subcontractors before beginning a project and continue to emphasize their importance as work progresses help to reduce the construction waste. During the construction, monitoring the recycling bins, posting lists of what is and is not recyclable on the containers help preventing cross contamination. It is also helpful to place smaller recycling containers closer to the workers and aggregate materials in a common recycling and disposal storage area. A foreman monitors the recycling and disposal activity for each trade should be considered under the management plan. After the construction, following steps are taken; conducting a cost-benefit analysis of recycling to evaluate savings, and evaluating the impact of recycling on job safety and scheduling milestones.

Material	Tons	Recycling Cost	Avoided Disposal Cost*	Savings
Concrete	285	$8,265	$31,065	$22,800
Metal	69	$1,380	$7,521	$6,141
Wallboard	49	$2,559	$5,450	$2,891
Cardboard	0.67	$67	$70	$3
Wood	40	$4,381	$4,358	($23)
TOTALS	**443.67**	**$16,652**	**$48,464**	**$31,812**

Figure 6.3 cost savings achieved through source separation and recycling [136]

IDR-2 Seattle Kingdome Stadium

Figure 6.4 . Seattle Stadium[136]

Figure 6.5 . Seattle Stadium[136]

Intervention	Demolition of the existing stadium and building new one
Location	Seattle, WA, USA
Target achieved on waste	More than 97% of building materials are used in the new construction
Sources of data and images	https://www.wje.com/projects/detail/seattle-kingdome https://seattle.curbed.com/2018/3/26/17165190/kingdome-seattle-stadium-implosion-demolition https://stadium.org/construction/

objectives					**code**	**Strategies**	**level**
O1	**O2**	**O3**	**O4**	**O5**			
					S.1	Preservation and adaptation of existing buildings	○ ○ ○
					S.2	Partial or total selective demolition of existing building	● ● ●
					S.3	Transfer of non-reusable C&D waste to the recycling plant	● ● ○
					S.4	Recycling waste from demolition / construction on site	● ● ○
					S.5	Recovery of components for reuse in another site (sale or donation)	○ ○ ○
					S.6	Reuse of demolition components on site for new building	● ● ●
					S.7	Technological project optimization to reduce construction waste	● ● ●
					S.8	Return of surplus and construction waste to the manufacturer	● ○ ○
					S.9	Design for Deconstruction, technological adaptability	○ ○ ○
					S.10	Reuse of recycled materials and / or components from other construction sites or other	● ● ○
					S.11	Use of materials with recycled content	● ● ○
					S.12	Use of environmentally friendly materials from controlled / local supply chains	● ● ○
					S.13	Innovative site management for waste and materials	● ● ○

Table 6.2 Adopted strategies of Seattle Kingdome Stadium

The Seattle Kingdome, which completed in 1976, was a 65,000-seat multipurpose sports arena. The stadium's dome was the world's largest thin shell concrete roof, extending 660 feet and rising 250 feet above the playing surface.

The dome was made of cast-in-place concrete with radial concrete ribs running from the crown to the base, with a compression ring at the top and a post-tensioned concrete tension ring at the bottom. Between the concrete ribs were thin concrete shells. The Kingdome was dismantled in 2000, and new football and baseball stadiums were built in its stead.
97% of materials of the Seattle Kingdom stadium, which was destroyed in 2000, was used in the construction of the new stadium to be built in its place, and 3 million dollars were earned through demolition techniques aimed at the recovery of products.

Controlled Demolition Inc. designed the stadium’s implosion, which split the stadium’s ribs into six equal segments, split apart by explosives in two phases targeting the Kingdome’s structural system.

Structural repairs designed for the dome consisting of shotcrete to restore structural integrity, as well as a corrosion protection system to protect steel reinforcement. Additionally, both a new replacement roof and a new acoustical ceiling system are designed [137].
On-site inspections showed extensive issues with the integrity of several of the 40,000 ceiling panels, which were all removed. Further inspection identified regions of poor concrete dome consolidation and voiding, as well as roofing performance problems. Construction company responded by launching a comprehensive, 24-hour examination and restoration plan for the dome.

The ceiling panels were first subjected to rigorous inspections and laboratory testing. The construction company conducted a series of tests and analyses after the dome's concrete shell was exposed to determine the amount and kind of voiding and consolidation defects in the concrete shell. In order to inspect the entire dome from the inside, nondestructive concrete testing such as reflecting ultrasonics and infrared thermography were used. Impact echo, exploratory openings, and core sampling were used to investigate anomalous locations identified by infrared in the 5- to 18-inch-thick shell.
Shotcrete structural repairs were created for the dome to restore structural integrity, as well as a corrosion prevention system for steel reinforcement. A new replacement roof as well as a new acoustical ceiling system were also constructed. So that the stadium could be reopened quickly, a fast-track repair program was devised.

IDR-3 Malden Government Center

Figure 6.6. Render of new offices[138]

Figure 6.7. Old Malden Government Center deconstruction [138]

Intervention	Fully demolition of the former government center and building an office building
Location	Malden, MA, USA
Target achieved on waste	more than 50% of the Consturction and demolition waste is recyled
Sources of data and images	https://www.maldenredevelopment.com/content/transformation-underway-downtown-malden https://www.maldenredevelopment.com/sites/default/files/jag_renderings_184_and_200_pleasant_street_may_2017.pdf

objectives					**code**	**Strategies**	**level**
O1	**O2**	**O3**	**O4**	**O5**			
					S.1	Preservation and adaptation of existing buildings	○ ○ ○
					S.2	Partial or total selective demolition of existing building	● ● ●
					S.3	Transfer of non-reusable C&D waste to the recycling plant	● ● ○
					S.4	Recycling waste from demolition / construction on site	● ● ○
					S.5	Recovery of components for reuse in another site (sale or donation)	○ ○ ○
					S.6	Reuse of demolition components on site for new building	● ○ ○
					S.7	Technological project optimization to reduce construction waste	● ○ ○
					S.8	Return of surplus and construction waste to the manufacturer	● ○ ○
					S.9	Design for Deconstruction, technological adaptability	○ ○ ○
					S.10	Reuse of recycled materials and / or components from other construction sites or other	● ● ○
					S.11	Use of materials with recycled content	● ○ ○
					S.12	Use of environmentally friendly materials from controlled / local supply chains	● ● ○
					S.13	Innovative site management for waste and materials	● ● ○

Table 6.3 Adopted strategies of Malden Government Center

Institutional buildings like schools and hospitals often have highly specific floor plans that relate to their daily operations. This can lead to inflexible layouts that are difficult to adapt as the practices and spatial requirements of these institutions evolve over time**.**
Under-performing architectural or mechanical systems that cannot keep up with current code requirements, or the building's evolving functions. Building elements such as elevators, HVAC systems, asbestos insulation, etc. can be difficult and costly to replace or remove, making it more economical to demolish the entire building.
55% of materials of the Malden Government Center was used in the new construction of the complex building [139].

Figure 6.8 Interior of new building [138]

IDR-4 BRE, The Environmental Building

Figure 7.1 Façade of new building [149]

Figure 7.2 Façade of new building [149]

Intervention	Demolition of an existing building and reconstruction with recycled materials
Location	Garston, UK
Target achieved on waste	95% of the materials (in terms of volume) resulting from the demolition of the pre-existing building recycled or reused
Sources of data and images	https://projects.bre.co.uk/envbuild/index.html

objectives					**code**	**Strategies**	**level**
O1	**O2**	**O3**	**O4**	**O5**			
					S.1	Preservation and adaptation of existing buildings	○ ○ ○
					S.2	Partial or total selective demolition of existing building	● ● ●
					S.3	Transfer of non-reusable C&D waste to the recycling plant	○ ○ ○
					S.4	Recycling waste from demolition / construction on site	● ● ●
					S.5	Recovery of components for reuse in another site (sale or donation)	● ● ○
					S.6	Reuse of demolition components on site for new building	● ● ○
					S.7	Technological project optimization to reduce construction waste	○ ○ ○
					S.8	Return of surplus and construction waste to the manufacturer	○ ○ ○
					S.9	Design for Deconstruction, technological adaptability	● ○ ○
					S.10	Reuse of recycled materials and / or components from other construction sites or other	● ● ○
					S.11	Use of materials with recycled content	● ● ●
					S.12	Use of environmentally friendly materials from controlled / local supply chains	○ ○ ○
					S.13	Innovative site management for waste and materials	● ● ○

Table 6.4 Adopted strategies of BRE Environmental Building construction

Environmental Building by BRE is a 21st-century office model. It shows the way for the future based on a platform of new low-energy targets and is both innovative and environmentally progressive.

It is the first structure to incorporate the Energy Efficient Office of the Future (EOF) Group's Performance Specification into the design brief, which was developed in collaboration with BRE, manufacturers, designers, fuel utilities, and other building experts. The structure received the highest BREEAM rating available [149].

At the planning stage, research and monitoring criteria were created, and performance evaluation has been ongoing since the beginning.

Research and monitoring criteria were defined throughout the planning stage, and performance evaluation has been ongoing since the beginning.

The intervention began with the demolition of the pre-existing building that occupied the site of the new Building 16. First of all, a pre-demolition audit was carried out aimed at identifying the recovery potential of components and materials in the product market. regenerated buildings. The audit identified the following elements to be recovered via soft strip, i.e. manual removal, to be reused in other buildings of the research center or donated to a local organization that supplied them to schools and hospitals:

- furnishings,
- wood waste,
- lamps,
- Venetian blinds,
- components of the fire-fighting system,
- radiators,
- towel appliances,
- switches and lamp holders.

Then the building materials to be recovered were identified, including:

- slate tiles,
- corrugated sheets for roofs,
- downspouts and gutters in cast iron,
- structural elements of the wooden roof.

The latter were sold to a wooden furniture manufacturer.

The existing building was built using 20,000 bricks bonded with cement mortar, instead of lime: this made recovery impossible due to the difficulty of separation. Therefore the bricks were crushed on site and recycled as ballast at the same site.

Due to the non-compliance with the new fire regulations, it was not possible to reuse the doors of the building to be demolished in the new one, despite being in good condition. It was not even possible to sell them because there was not enough time to identify potential buyers, so the doors were sent to landfill. Despite this, 95% of the materials, in terms of volume, resulting from the demolition of the existing building have been reused or recycled.

IDR-5 BRE, Nya Udden Project

Figure 7.3 deconstruction of old building [150]

Figure 7 .4 Concrete elements cut from cast in-place concrete walls delivered to the building site [150]

Intervention	Construction of student residence buildings with recovery of components from house demolitions
Location	Finspång, Sweden
Target achieved on waste	Overall reuse of buildings demolished in another building
Sources of data and images	https://www.irbnet.de/daten/iconda/CIB875.pdf

objectives					**code**	**Strategies**	**level**
O1	**O2**	**O3**	**O4**	**O5**			
					S.1	Preservation and adaptation of existing buildings	○ ○ ○
					S.2	Partial or total selective demolition of existing building	● ● ●
					S.3	Transfer of non-reusable C&D waste to the recycling plant	○ ○ ○
					S.4	Recycling waste from demolition / construction on site	○ ○ ○
					S.5	Recovery of components for reuse in another site (sale or donation)	○ ○ ○
					S.6	Reuse of demolition components on site for new building	○ ○ ○
					S.7	Technological project optimization to reduce construction waste	○ ○ ○
					S.8	Return of surplus and construction waste to the manufacturer	○ ○ ○
					S.9	Design for Deconstruction, technological adaptability	○ ○ ○
					S.10	Reuse of recycled materials and / or components from other construction sites or other	● ● ○
					S.11	Use of materials with recycled content	○ ○ ○
					S.12	Use of environmentally friendly materials from controlled / local supply chains	○ ○ ○
					S.13	Innovative site management for waste and materials	○ ○ ○

Table 6.5 Adopted strategies of NYA Udden Project construction

Udden Project

Gunnar Sundbaum began the Udden project in 1996, when he was looking for methods to cope with empty buildings in Finspng, Sweden**.** The buildings have to be demolished in order to reduce the number of units while also attempting to improve the quality of life in those regions by providing more space between the surviving structures. It was determined to demolish five buildings holding more than 100 units. Gunnar Sundbaum proposed that the "apartments be transported" to Linköping to help with the city's housing problem (especially a housing shortage for students). That is, materials that can be reused should be relocated to a new location and used in the construction of new dwellings. This would necessitate careful deconstruction of the structure so that the materials could be reused. This idea was given to the housing company's controlling directors in Finspng and Linköping's main housing firm [150].
The general contractor carefully disassembled two of the buildings in Finspng to make the most of the materials and products available. The structures were mostly made of concrete with in-place cast beams. These materials were sliced with a diamond saw to be reused. The demolition was based on what the new structure might utilise. Materials and products from around 50 larger apartments in the two destroyed buildings were used to construct a building with 22 smaller units.

NYA Udden Project

In November 2001, the Nya Udden student housing project was finished. However, there are numerous fundamental distinctions between this project and the Udden project. First, the material came from a neighborhood in Norrköping where the structures were constructed with pre-cast concrete elements, eliminating the need for time-consuming element cutting. The deconstruction and construction processes were also organized differently. Different actors were in charge of the deconstruction and construction procedures in this project. The construction procedure was not overseen by a general contractor. Instead, the building process was coordinated by a project management organization that engaged multiple subcontractors.
The new building contained 54 additional tiny apartments, while the original plan was to construct 500 new apartments utilizing Norrköping concrete parts. The agreement between the material supplier and the material user was discontinued because careful deconstruction proved to be more expensive than deconstruction focused at smashing concrete. This led to the conclusion that the majority of the new 500 flats would have to be constructed using traditional techniques using virgin materials and goods.

Reused materials	**Number**	**Tons**
Concrete partition walls	138	524
Concrete outer wall elements	72	208
Concrete beams	224	684
Concrete stair-cases	8	16
Iron banisters	16	
Windows	34	
Window ledges	100	

Figure 7.5 Reused materials and products in the Nya Udden project [150]

NCR-1 Manifesto Eco House

Figure 7.6 Manifesto Eco House [140]

Figure 7.7 Manifesto Eco House [140]

Intervention	New house construction with recyled materials and waste
Location	Chile
Target achieved on waste	More than 85% of building materials are reusable or recyclable
Sources of data and images	https://dergipark.org.tr/en/download/article-file/309730

objectives					**code**	**Strategies**	**level**
O1	**O2**	**O3**	**O4**	**O5**			
					S.1	Preservation and adaptation of existing buildings	○ ○ ○
					S.2	Partial or total selective demolition of existing building	○ ○ ○
					S.3	Transfer of non-reusable C&D waste to the recycling plant	○ ○ ○
					S.4	Recycling waste from demolition / construction on site	○ ○ ○
					S.5	Recovery of components for reuse in another site (sale or donation)	● ○ ○
					S.6	Reuse of demolition components on site for new building	○ ○ ○
					S.7	Technological project optimization to reduce construction waste	● ● ○
					S.8	Return of surplus and construction waste to the manufacturer	○ ○ ○
					S.9	Design for Deconstruction, technological adaptability	● ● ○
					S.10	Reuse of recycled materials and / or components from other construction sites or other	● ● ●
					S.11	Use of materials with recycled content	● ● ●
					S.12	Use of environmentally friendly materials from controlled / local supply chains	● ● ●
					S.13	Innovative site management for waste and materials	● ● ○

Table 6.6 Adopted strategies of Manifesto Eco House

The Infiniski concept and its potential are represented by the Manifesto house: bioclimatic design, recycled and reused materials, non-polluting structural systems, and renewable energy integration. The proposal is based on bioclimatic architecture, which adapts the house's form and location to its energy requirements. The project is prefabricated and modular, allowing for a less expensive and speedier construction process. This modular structure also enables for thinking about the house's coherence with prospective future changes or enlargements, making it easier to respond to the client's changing needs.

The 160m2 house is separated into two storeys and is built from three recycled nautical containers. On the first level, a two-part container serves as the support structure for the containers on the second level. This bridge-like construction creates additional space between the container structure and the thermo glass panels that separate it. As a result, the project generates a total of 160m2 with only 90m2 of container, maximizing and decreasing the need of supplementary building materials greatly. This structure, in the shape of a bridge, responds to the house's bioclimatic needs and provides an effective natural ventilation system. It also aids in maximizing the house's natural surroundings, natural light, and landscape views.

Thanks to vented external solar covers on walls and roof, the house "clothes and undresses" itself, as if it had a second skin, depending on its need for natural solar warmth. The house has two types of "skin": on one side, sustainable forest-sourced timber panels, and on the other, recycled mobile pallets.

In the winter, the pallets can open to enable the sun to warm the metal surface of the container walls, and in the summer, they can close to keep the house cool. This skin also serves as an exterior esthetic finishing helping the house to better integrate in its environment.

Designers took advantage of waste materials in their projects, and recycled wooden pallets and containers were used. More than 85% of construction materials consist of reusable or recyclable materials, such as iron-steel, paper, aluminum. About 70% of the energy need of the house, which was built in just 90 days, was met by utilizing solar panels and wind [140].

Figure 7.8 Manifesto Eco House [140]

NCR-2 RECY house-Belgium

Figure 7.9. Construction of RECY house [141]

Figure 8. RECY house [141]

Intervention	New house construction with recyled materials and waste
Location	Belgium
Target achieved on waste	More than 85% of building materials are reusable or recyclable
Sources of data and images	https://dergipark.org.tr/en/download/article-file/309730

objectives					**code**	**Strategies**	**level**
O1	**O2**	**O3**	**O4**	**O5**			
					S.1	Preservation and adaptation of existing buildings	○ ○ ○
					S.2	Partial or total selective demolition of existing building	○ ○ ○
					S.3	Transfer of non-reusable C&D waste to the recycling plant	○ ○ ○
					S.4	Recycling waste from demolition / construction on site	○ ○ ○
					S.5	Recovery of components for reuse in another site (sale or donation)	○ ○ ○
					S.6	Reuse of demolition components on site for new building	○ ○ ○
					S.7	Technological project optimization to reduce construction waste	● ● ●
					S.8	Return of surplus and construction waste to the manufacturer	○ ○ ○
					S.9	Design for Deconstruction, technological adaptability	● ● ○
					S.10	Reuse of recycled materials and / or components from other construction sites or other	● ● ●
					S.11	Use of materials with recycled content	● ● ●
					S.12	Use of environmentally friendly materials from controlled / local supply chains	● ● ●
					S.13	Innovative site management for waste and materials	● ● ○

Table 6.7 Adopted strategies of RECY House

In a study carried out by the Belgian Building Research Institute (BBRI) in order to increase the preference of recycled materials by the society and decision-makers, a sample building was built using these materials.
The structural system is made of recycled concrete, the floor slab with drainage is made of recycled rubber. “phosphogypsum-sulphogypsum” based panels covered with recycled polyethylene foam, panels containing recycled paper and gypsum, and terracotta blocks produced from expanded polystyrene waste were used on the walls of the partitions. The suspended ceiling is made from recycled rock wool. The roof tiles of the building are made of household plastic, paper and fabric waste, the rain gutters are made of recycled zinc, the windows are made of recycled polyvinyl-based material and cast elements made of artificial resin and ground glass [142]. With this designed application, a database of companies producing recycled materials in Belgium has been created and a wide range of products has been offered to the market.

The “Recyhouse” project has provided important information to all professionals in the sector, including building material manufacturers, with its contribution to the reduction of waste generation and the management of structural waste in the construction sector. It is also important in terms of adding value to the sustainability feature of building materials.

Figure 8.1. Recyhouse-rain gutter, window, wall and floor claddinghouse [141]

NCR-3 Redondo Beach Shipping Container House

Figure 8.2 Redondo Beach Shipping Container House [143]

Figure 8.3 Redondo Beach Shipping Container House [143]

Intervention	New house construction with recyled materials and waste
Location	USA
Target achieved on waste	More than 85% of building materials are reusable or recyclable
Sources of data and images	https://dergipark.org.tr/tr/download/article-file/595528

objectives					**code**	**Strategies**	**level**
O1	**O2**	**O3**	**O4**	**O5**			
					S.1	Preservation and adaptation of existing buildings	○ ○ ○
					S.2	Partial or total selective demolition of existing building	○
					S.3	Transfer of non-reusable C&D waste to the recycling plant	○
					S.4	Recycling waste from demolition / construction on site	○
					S.5	Recovery of components for reuse in another site (sale or donation)	○ ○ ○
					S.6	Reuse of demolition components on site for new building	○
					S.7	Technological project optimization to reduce construction waste	● ● ●
					S.8	Return of surplus and construction waste to the manufacturer	● ● ○
					S.9	Design for Deconstruction, technological adaptability	● ● ●
					S.10	Reuse of recycled materials and / or components from other construction sites or other	● ● ○
					S.11	Use of materials with recycled content	● ● ●
					S.12	Use of environmentally friendly materials from controlled / local supply chains	● ● ●
					S.13	Innovative site management for waste and materials	● ● ○

Table 6.8 Adopted strategies of Redondo Beach Shipping Container House

Built with 8 high cube shipping containers, this two story home was a first for both the homeowners and the architect. “For me as an architect, the challenge has always been how to give my clients the highest level of design while still keeping the projects on budget,” says Peter DeMaria, one of the country’s first architects to incorporate steel cargo containers into residential designs. The Redondo Beach container home is envisioned a modern, loft-style house that was both eco-friendly and budget-minded.

The project is completed in 2007, The Redondo Beach house features a soaring 20 foot high living room outfitted with glass panel airplane hangar doors that fold out to create a seamless indoor-outdoor living space. Most containers come in 20- and 40-foot models and generally cost between $1,650 and $3,000 each, depending on size and wear and tear. One-way containers that have only made one passage are usually in the best shape and demand a premium.

The project has emerged as a result of combining eight containers of different sizes with conventional building methods. While "metal container walls define the boundaries of usage areas", "another container functions as a pool". A house with a strong structure, resistant to mold, fire and termites was created, “at the end of the project site waste was reduced by 70% [144].

Figure 8.4 Redondo Beach Shipping Container House [143]

NCR-4 Villa Welpeloo

Figure 8.5 Villa Welpeloo [151]

Figure 8. 6 Villa Welpeloo [151]

Intervention	New construction of a single-family home
Location	Enschede, Netherlands
Target achieved on waste	70% of recovered components or recycled materials from the local area
Sources of data and images	http://artelnative.altervista.org/villa-welpeloo-superuse-studios/

objectives					**code**	**Strategies**	**level**
O1	**O2**	**O3**	**O4**	**O5**			
					S.1	Preservation and adaptation of existing buildings	○ ○ ○
					S.2	Partial or total selective demolition of existing building	○ ○ ○
					S.3	Transfer of non-reusable C&D waste to the recycling plant	○ ○ ○
					S.4	Recycling waste from demolition / construction on site	○ ○ ○
					S.5	Recovery of components for reuse in another site (sale or donation)	○ ○ ○
					S.6	Reuse of demolition components on site for new building	○ ○ ○
					S.7	Technological project optimization to reduce construction waste	● ● ●
					S.8	Return of surplus and construction waste to the manufacturer	● ● ○
					S.9	Design for Deconstruction, technological adaptability	● ● ●
					S.10	Reuse of recycled materials and / or components from other construction sites or other	● ● ●
					S.11	Use of materials with recycled content	● ● ●
					S.12	Use of environmentally friendly materials from controlled / local supply chains	○ ○ ○
					S.13	Innovative site management for waste and materials	○ ○ ○

Table 6.9 Adopted strategies of Villa Welpeloo

Superuse Studios developed a house in Roombeek, a suburb of Enschede in the Netherlands, made mostly of demolition materials and factory waste. Villa Welpeloo is a home for a couple who want to store and display a collection of paintings and graphics by young modern artists.
The fact that Villa Welpeloo is a permanent structure added to the difficulty. Architects stayed faithful to their ideology when selecting materials. Wherever possible, they used demolition materials and manufacturing waste. They also looked for these elements within a 15-kilometer radius of the construction site. The structure appears to be made up of multiple different-sized boxes that have been stacked and pushed together. Clear lines and the use of only a few materials characterize its appearance.The technological solutions adopted have been conceived according to the characteristics and performance of the components identified as the most suitable, in a process of metabolizing what the territory can offer without further consumption of raw materials and energy, above all thanks to the proximity of the sources. to the project area.The identification of the locally available recycled materials was carried out through a search for possible sources represented in a Harvestmap: this tool, applied by the 2012 Architecten in different projects and therefore on different cities in the Netherlands, consists in the mapping of waste materials existing within a very limited radius of kilometers around the project area. The goal of a Harvestmap is to reveal:
• Available sources of materials
• Buildings in a state of neglect or demolition
• Abandoned areas
• Potential sources of energy for heating, cooling and electricity
• Infrastructure in abandonment
For all materials, components, waste objects, deriving from industrial processes or other building interventions, identified as follows, the map indicates:
• Geographic location
• Quantities
• Dimensions
• Availability
• Potential for reuse
Through this tool, whose realization was the first step of the design process, the architects set up the entire house project based on the availability of waste materials locally [151].
The new materials were used only for concrete foundations, mechanical systems and technical installations, plasterboard coatings for walls and roof, waterproofing membranes, plaster and colors used inside, resin floors. and the window frames. The supporting structure of the building is made up of steel beams, 90% of which come from an old textile plant. Since the type of steel, and therefore the strength, of the beams to be reused was not known, the structural designer was based, for the sizing of the sections, on the worst case, namely the poorest steel quality. Since the beams were not made to measure, as is usually the case, the designer has always adopted the minimum necessary section. The secondary structure is made up of reused wooden beams.The roof and floors were made with reclaimed wood planking, while the crawl space was made with shells. The walls of the bathrooms are made with smile plastic, a recycled plastic obtained from the recycling of coffee cups.
The glass of the window frames derives, in most cases, from production waste from a local glass factory. The thermal insulation of the perimeter walls, on the other hand, consists of recovered polystyrene panels that come largely from a factory building that produces campers, located near the house and destined for demolition.
The building, which has a net area of 312 square meters, has undergone a careful environmental assessment. The reuse of waste materials, in fact, for the 2012 Architecten has not only an aesthetic purpose for its own sake, but also responds to the need for an ecological balance of the materials used.

NCR-5 Hull's Arc building

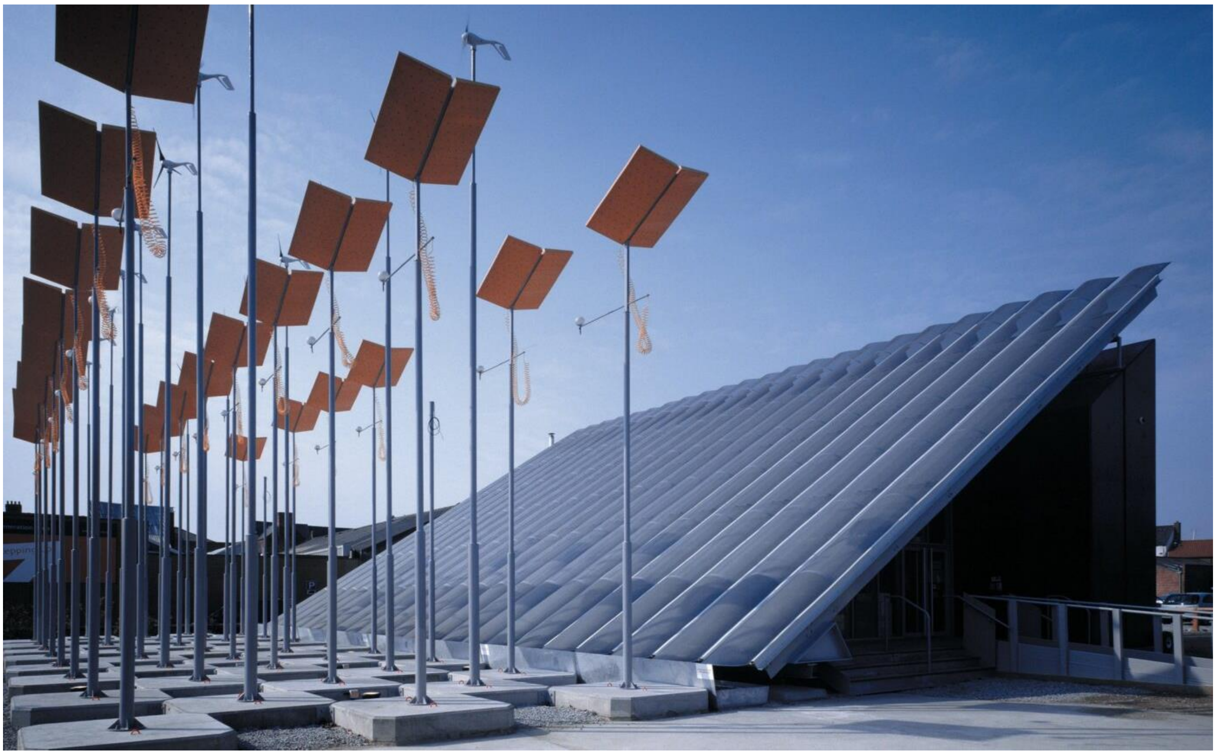

Figure 8.7 Hull's Arc building [152]

Figure 8.8 Hull's Arc building [152]

Intervention	New construction. Modular building completely dry, demountable, reusable / recyclable.
Location	Hull, UK
Target achieved on waste	Edificio decostruibile e riciclabile/riusabile al 99%
Sources of data and images	http://www.arc-online.co.uk/the-arc-building http://news.bbc.co.uk/2/hi/uk_news/magazine/5106934.stm

objectives					**code**	**Strategies**	**level**
O1	**O2**	**O3**	**O4**	**O5**			
					S.1	Preservation and adaptation of existing buildings	○ ○ ○
					S.2	Partial or total selective demolition of existing building	○ ○ ○
					S.3	Transfer of non-reusable C&D waste to the recycling plant	○ ○ ○
					S.4	Recycling waste from demolition / construction on site	○ ○ ○
					S.5	Recovery of components for reuse in another site (sale or donation)	○ ○ ○
					S.6	Reuse of demolition components on site for new building	○ ○ ○
					S.7	Technological project optimization to reduce construction waste	● ● ●
					S.8	Return of surplus and construction waste to the manufacturer	● ● ○
					S.9	Design for Deconstruction, technological adaptability	● ● ●
					S.10	Reuse of recycled materials and / or components from other construction sites or other	● ○
					S.11	Use of materials with recycled content	● ● ○
					S.12	Use of environmentally friendly materials from controlled / local supply chains	● ● ○
					S.13	Innovative site management for waste and materials	○ ○ ○

Table 7.1 Adopted strategies of Hull's Arc building

The Arc Pavilion was conceived as a transportable building, to be moved to a different area of the city of Hull several times over the span of twenty years. This is why it has been designed as a kit consisting of five detachable and reassembly parts, each of which is small enough to be transported on the trailer of a truck. The building is a multifunctional space used as an educational and information center on architecture and the built environment, the first in the United Kingdom [152].

The pavilion, which is configured as a didactic device wants to demonstrate how a low-emission building can be created through an effective deconstructability project. Despite its nature as a deconstructible and removable building, the building is a symbol of the city of Hull, especially for its collaboration with the local caravan manufacturing industry, which provided the five essential elements of the pavilion's structure.

All the elements that make up the pavilion are prefabricated and the assembly systems are entirely demountable. The choice of the supporting structure is linked to the characteristic nature of the terrain, due to the location of the city at the estuary of the River Hull. The pavilion rests on an innovative system of foundations: a mesh of prefabricated reinforced concrete plinths, resting directly on the ground, supports a steel grid filled with pre-assembled boxes, which ballast the structure against the risk of wind lifting. The foundations are thus completely removable and no excavations are required, with a footprint on the ground reduced to zero. Each box that makes up the attic, made of wood and thermally insulated, is filled with recycled brick rubble and is also equipped with an integrated radiant heating system and vinyl flooring on the upper side. For each eventual reconstruction of the building, therefore the boxes that make up the floor can be disassembled and reassembled as single complete and pre-finished units. The foundations of the poles supporting photovoltaic modules and mini wind turbines are also prefabricated.

The elevated structures of the building are made with the use of five caravans with a steel structure and wooden cladding with thermal insulation. The panels are plywood shell structures, whose waterproofing is guaranteed by the fiberglass and epoxy resin coating, used to ensure the watertightness of the boats.

The caravans contain offices, a warehouse, a technical room, kitchen and toilet. The caravans were brought to the site already assembled, placed horizontally on their frame with wheels and then hoisted with a crane. The individual modules remain clearly legible from the outside and are equipped with windows for the recovery of other caravans.

The rest of the structure consists of a sloping roof that rests on the top of the caravans and on the foundation plinths. The roof consists of a lattice of steel beams buffered with translucent polycarbonate panels. Externally, the roof is protected by a curved perforated aluminum sheet cladding which also acts as a sunscreen.

The choice of materials was made on the basis of their resistance and recyclability: for this reason, recycled aluminum supplied by a local producer and steel, recyclable at the end of its life, were used. The caravans are reusable or demountable to recycle their materials, steel and wood from certified forests.

The internal lining is made of birch plywood.

Concrete footings can be reused or recycled as an inert filling material. Both the caravans and the fixtures and epoxy finish were made by local manufacturers.

The raft system adopted for the foundations recalls a centuries-old construction technique of the Hull region and guarantees the protection of the ecological conditions of the site, avoiding any interference with the soil and subsoil.

RDC-1 Boston Scientific Company, Inc

Figure 9.1. New construction of Boston Scientific Company [145]

Figure 9.2. Construction of Boston Scientific Company [145]

Intervention	Demolition and renovation of an office building
Location	Marlborough, MA, USA
Target achieved on waste	92% (702 tons recycled, 62 tons disposed)
Sources of data and images	https://archive.epa.gov/region1/healthcare/web/pdf/cdrecyclingguide.pdf

objectives					**code**	**Strategies**	**level**
O1	**O2**	**O3**	**O4**	**O5**			
					S.1	Preservation and adaptation of existing buildings	● ○ ○
					S.2	Partial or total selective demolition of existing building	● ● ○
					S.3	Transfer of non-reusable C&D waste to the recycling plant	● ● ○
					S.4	Recycling waste from demolition / construction on site	● ● ○
					S.5	Recovery of components for reuse in another site (sale or donation)	○ ○ ○
					S.6	Reuse of demolition components on site for new building	● ● ○
					S.7	Technological project optimization to reduce construction waste	● ● ●
					S.8	Return of surplus and construction waste to the manufacturer	● ● ○
					S.9	Design for Deconstruction, technological adaptability	● ● ○
					S.10	Reuse of recycled materials and / or components from other construction sites or other	● ● ○
					S.11	Use of materials with recycled content	● ● ○
					S.12	Use of environmentally friendly materials from controlled / local supply chains	● ● ○
					S.13	Innovative site management for waste and materials	● ● ○

Table 7.2 Adopted strategies of Boston Scientific Company

BSCI attempted the redesign of a two-story, 30,000 square-foot office building as Stage 1 of a 2-building, 400,000 sq ft venture. The general contractor was Payton Development Corp.; SOS Corp. was demolition subcontractor. The venture included gutting and substitution of interior furnishings and fittings, wall/partition frameworks, HVAC, electrical, plumbing, and roof. The extension was especially complex because renovation started at the same time as demolition, so that employees seem move into parts of the building whereas other zones were still in development. The project was carried out to LEED Silver.
Even though careful and early planning is most of the time a key to successful recycling, Boston Scientific Company project shows that it is not always necessary. The decision to achieve to goal of LEED certification was made when demolition was practically ongoing. Flexibility and cooperation from all parties to pursue this goal were critical to successful recycling.
It is way easier to bring along the participation of contractors, subcontractors, and their employees if the owner makes an active commitment to recycling and maintains interest and involvement all through. Involvement and support from the General Contractors and on-site managers are crucial. If they are committed to recycling, it will permeate down to the rest of the site. Representatives from labor unions can help make recycling a success. They will generally jump on board if they grasp the reasons and aims for recycling, as well as how recycling can make work easier and more fulfilling.
It is important to make sure the recycling coordinator is a visible member of the project management team and is frequently on site. This emphasizes the importance of recycling and ensures that questions and concerns about recycling may be addressed as they arise.
It's critical that everyone who comes to work on the site is properly trained on recycling goals and processes, understands how items should be divided and handled, and knows who to contact if they have issues.
It's difficult to be trapped into pre-existing plans, markets, or shipping arrangements when everybody is working on a short deadline. It is critical to be willing and ready to find new markets for nontraditional materials, swap markets to improve recycling rates or costs, or hire a new hauler that can adapt to changing needs [146].

Material	Tons	Recycling Cost	Avoided Disposal Cost	Savings
Furnishings	470	$0	$37,125	$37,125
Wallboard Partitions	93	$8,000	$12,787	$4,787
Metals	65	$0	$8,125	$8,125
Wire and Cable	10	$0	$1,250	$1,250
Ceiling Tiles	19	$4,980	$5,706	$726
Plate Glass	2	$0	$300	$300
Mixed Debris to Recycling	43	$8,242	$5,912	($2,330)
Recycling Totals	**702**	**$21,222**	**$71,205**	**$49,983**
Mixed Debris to Disposal	62			
Project Recycling Rate	**92%**			

Figure 9.3 cost savings achieved through source separation and recycling [145]

RDC-2 The Green Building / (fer) studio

Figure 9.4 Facade of Green Building [147]

Figure 9.5 Iinterior of Green Building [147]

Intervention	Partial demolition of the former dry good store and building mix used commercial building
Location	Louisville, USA
Target achieved on waste	Most of the materials used are recycled materials, including 100% of the flooring, 70% of the windows, and 80% of the insulation, made from recycled blue jeans.
Sources of data and images	https://www.archdaily.com/118709/the-green-building-fer-studio?ad_source=search&ad_medium=projects_tab

objectives					**code**	**Strategies**	**level**
O1	**O2**	**O3**	**O4**	**O5**			
					S.1	Preservation and adaptation of existing buildings	● ● ○
					S.2	Partial or total selective demolition of existing building	● ○ ○
					S.3	Transfer of non-reusable C&D waste to the recycling plant	○ ○ ○
					S.4	Recycling waste from demolition / construction on site	● ○ ○
					S.5	Recovery of components for reuse in another site (sale or donation)	○ ○ ○
					S.6	Reuse of demolition components on site for new building	● ● ●
					S.7	Technological project optimization to reduce construction waste	● ● ●
					S.8	Return of surplus and construction waste to the manufacturer	○ ○ ○
					S.9	Design for Deconstruction, technological adaptability	● ○ ○
					S.10	Reuse of recycled materials and / or components from other construction sites or other	● ● ○
					S.11	Use of materials with recycled content	● ● ●
					S.12	Use of environmentally friendly materials from controlled / local supply chains	● ● ○
					S.13	Innovative site management for waste and materials	● ● ●

Table 7.3 Adopted strategies of Green Building

The 115 year old former dry goods store transformed into The Green Building, which is a mixed-use commercial building housing a gallery, event space, offices, tenant office spaces, conference room, and a separate tenant restaurant space. It is learnt from the project; its is important to understand the history of the building and the context of the neighborhood.
The studio inventoried the existing building components to determine its weak points.
In this project. Some of the elements of the building were carved away in order to allow a new re-use form to emerge Triple height volumes.
In addition to saving the original mortar shell of the structure, The Green Building team re-used most of the material from the original building. For example, structural wood from the original building was re-milled into finished flooring and furniture. Bricks from the original building were carefully disassembled and re-used in other areas of the remodel.
The Green Building includes a high percentage of recycled materials, including 100% of the flooring, 70% of the windows, and 80% of the insulation, made from recycled blue jeans. The team diverted 551 cubic yards (3cy2) of demo material from the landfill by donating to local salvage yards, construction companies, a nearby farm, and Habitat Restore for Habitat.

Figure 9.6 Facade of Green Building [147]

RDC-3 Office Building at 355 11th Street / Aidlin Darling Design

Figure 9.7. Old office building [148]

Figure 9.8. Old and new office building [148]

Intervention	Partial demolition of the former warehouse and building an office building
Location	San Fransisco, CA, USA
Target achieved on waste	more than 75% of the building's original fabric has been maintained.
Sources of data and images	https://www.archdaily.com/468061/355-11th-street-aidlin-darling-design?ad_source=search&ad_medium=projects_tab

objectives					**code**	**Strategies**	**level**
O1	**O2**	**O3**	**O4**	**O5**			
					S.1	Preservation and adaptation of existing buildings	● ● ○
					S.2	Partial or total selective demolition of existing building	● ○ ○
					S.3	Transfer of non-reusable C&D waste to the recycling plant	○ ○ ○
					S.4	Recycling waste from demolition / construction on site	○ ○ ○
					S.5	Recovery of components for reuse in another site (sale or donation)	○ ○ ○
					S.6	Reuse of demolition components on site for new building	● ● ○
					S.7	Technological project optimization to reduce construction waste	○ ○ ○
					S.8	Return of surplus and construction waste to the manufacturer	○ ○ ○
					S.9	Design for Deconstruction, technological adaptability	● ○ ○
					S.10	Reuse of recycled materials and / or components from other construction sites or other	● ● ○
					S.11	Use of materials with recycled content	● ● ○
					S.12	Use of environmentally friendly materials from controlled / local supply chains	● ○ ○
					S.13	Innovative site management for waste and materials	● ● ○

Table 7.4 Adopted strategies of Office Building at 355 11th Street

355 Eleventh is a LEED Gold adaptive reuse project of a historic and previously derelict industrial building. The three-story building was developed and constructed by the building's primary occupant, a general contractor specializing in green building who wanted to showcase its commitment to cost-effective sustainability. This owner and general contractor occupies the entire second floor, comprised of administration and offices. The third floor is leased to design professionals. A restaurant and bar occupies the first floor and exterior courtyard.

Originally a warehouse, the historic structure's new role as a multi-tenant workspace invoked a new set of constraints for the building envelope. Ample light and air was required for the building's new office use, however San Francisco's Planning Department placed strict limitations on the introduction of new fenestration due to the building's National Register of Historic Places designation. Additionally, the structure's original corrugated siding was required to be replaced in-kind to preserve the building's industrial character. The architectural solution to these conflicting requirements was to perforate the building's new corrugated skin with fields of small holes, allowing light and air to pass through new operable windows hidden behind. The perforated outer skin mitigates solar heat gain while enabling cross-ventilation of the interior. This rudimentary double-skin façade becomes a screen for sunlight and air, allowing the stoic, industrial character of the original building to be maintained without the visual introduction of new fenestration [149].

By carefully designing the new spaces, more than 75% of the building's original fabric has been maintained. Significant structural upgrades were undertaken to ensure proper seismic performance of the existing timber frame – an investment on par with new construction. Clearly registering the rhythm of the historic post-and-beam structure, the original fenestration of the building's north façade was preserved and refurbished. The existing timber and concrete frame was carefully sandblasted to reveal the warmth and texture of the original materials. As day turns to evening, the perforations in the building's new skin gradually reveal the historic character of the timber frame within.

Figure 10.1. Old and new office building [148]

RDC-4 Kindergarten Hirzenbach

Figure 10.2. Kindergarten Hirzenbach [153]

Figure 10.3. Kindergarten Hirzenbach [153]

Intervention	Extension and renovation of a kindergarten
Location	Hirzenbach, Zürich
Target achieved on waste	95% of materials (in terms of volume) deriving from demolition recycled or reused
Sources of data and images	Detail, n.12/2010, pp. 1310-1313 https://www.baunetzwissen.de/boden/objekte/bildung/sanierung-und-erweiterung-der-schulanlage-hirzenbach-in-zuerich-214400

objectives					**code**	**Strategies**	**level**
O1	**O2**	**O3**	**O4**	**O5**			
					S.1	Preservation and adaptation of existing buildings	● ● ●
					S.2	Partial or total selective demolition of existing building	○ ○ ○
					S.3	Transfer of non-reusable C&D waste to the recycling plant	○ ○ ○
					S.4	Recycling waste from demolition / construction on site	○ ○ ○
					S.5	Recovery of components for reuse in another site (sale or donation)	○ ○ ○
					S.6	Reuse of demolition components on site for new building	○ ○ ○
					S.7	Technological project optimization to reduce construction waste	○ ○ ○
					S.8	Return of surplus and construction waste to the manufacturer	○ ○ ○
					S.9	Design for Deconstruction, technological adaptability	○ ○ ○
					S.10	Reuse of recycled materials and / or components from other construction sites or other	○ ○ ○
					S.11	Use of materials with recycled content	● ● ●
					S.12	Use of environmentally friendly materials from controlled / local supply chains	○ ○ ○
					S.13	Innovative site management for waste and materials	○ ○ ○

Table 7.5 Adopted strategies of Kindergarten Hirzenbach

The extension of the school complex included the integration of the nursery school with a new building and a multifunctional gym. The school, dating back to 1959, in fact needed to be renovated and expanded. The new buildings of the school and gymnasium complete the square school building on the south and north sides, adapting in volume and structure to the existing low building. The façade of the pre-existing nursery school was modified with the insertion of large overhanging concrete brise-soleils, which relate to the exposed concrete frame structure. The new buildings were made entirely of recycled concrete, for which Switzerland is at the forefront. The Minergie-Eco standard requires, in fact, that at least 50% of the building elements made of CLS are made of recycled material and that this be recovered within a radius of 25 km. Outside, the new one-story kindergarten building is dominated by the almost white color of the recycled concrete with which it was made, alternating with glass-cement walls. Particular attention was given to the choice of materials for the flooring, in particular polyurethane rubber, natural linoleum and Naturasphalt, particularly resistant materials suitable for the intensive use characteristic of school buildings [153].
The entire school and kindergarten complex is equipped with three different floor coverings. In the wet cells and the gym, the floor is covered with a cast plastic floor made of polyurethane. Such floors create a soft subsoil with high elasticity. They can be produced in different colors and with a matt or glossy surface, but are neither UV-resistant nor open to vapor diffusion and are only suitable for indoor use. The surface in the gym is more special: with a particularly soft top layer over a swinging wooden base.
The rooms in the kindergarten are lined with light-grey, plain-colored linoleum. This natural material is particularly versatile and can withstand heavy loads if it is strong enough. With a factory applied surface finish, it is easy to maintain and clean. Linoleum is permanently antistatic and can be invisibly grouted.

Figure 10.4. Kindergarten Hirzenbach [153]

RDC-5 Long Center for the Performing Arts

Figure 10.5 Long Center for the Performing Arts [154]

Figure 10.6. Long Center for the Performing Arts [154]

Intervention	Refurbishment and expansion with partial selective demolition and partial conservation of an auditorium.
Location	Austin, TX. USA
Target achieved on waste	Reuse or recycling (on site and in other neighboring sites) of 95% of materials and components derived from demolition
Sources of data and images	http://www.publicarchitecture.org/reuse/

objectives					**code**	**Strategies**	**level**
O1	**O2**	**O3**	**O4**	**O5**			
					S.1	Preservation and adaptation of existing buildings	● ● ○
					S.2	Partial or total selective demolition of existing building	● ● ●
					S.3	Transfer of non-reusable C&D waste to the recycling plant	○ ○ ○
					S.4	Recycling waste from demolition / construction on site	● ●○
					S.5	Recovery of components for reuse in another site (sale or donation)	● ● ○
					S.6	Reuse of demolition components on site for new building	● ● ●
					S.7	Technological project optimization to reduce construction waste	○ ○ ○
					S.8	Return of surplus and construction waste to the manufacturer	○ ○ ○
					S.9	Design for Deconstruction, technological adaptability	○ ○ ○
					S.10	Reuse of recycled materials and / or components from other construction sites or other	○ ○ ○
					S.11	Use of materials with recycled content	○ ○ ○
					S.12	Use of environmentally friendly materials from controlled / local supply chains	○ ○ ○
					S.13	Innovative site management for waste and materials	○ ○ ○

Table 7.6 Adopted strategies of Long Center for the Performing Arts

The Long Center for the Performing Arts in Austin, Texas, was born as a public-private partnership intervention to provide a quality cultural structure to the city, with a theater and spaces for ballet, music and opera. The first project, in 2001, involved the demolition of the pre-existing Palmer Auditorium, a domed 1950s building, which was a landmark for Austin. However, given the difficult economic situation, it was impossible to meet the expenditure of 125 million dollars necessary for the total demolition and reconstruction. For this reason, the architect Haas of Nelsen Partners, consultant to the clients, proposed a different approach, based on the reuse of the foundations and the structure around the stage and on the recovery of materials from partial demolition.
The reuse strategy, therefore, was initially introduced as a solution to contain costs, but it has provided many other benefits, including the maintenance of the memory of the place through the partial preservation of the pre-existence and the involvement of the local community, which has responded positively by funding the initiative.

The main contractor, Austin Commercial, joined the team during the development of the project and contributed significantly to the necessary reuse activities to be carried out before construction, and in particular:
• The selective demolition of the pre-existing building
• the drafting of the technical specifications for the new building.
Architect Haas and the contractor thoroughly inspected the pre-existing building prior to deconstruction, identifying many non-structural materials that could be reused with innovative design solutions in the new building. Among these, in particular, the glass of the curtain wall and the aluminum panels of the roof.
The client acted as supervisor during the selective demolition of the original building, of which the foundation and the "stagehouse", ie the stage and its support structure, have been preserved. In fact, it was not possible to reuse the Palmer dome, which proved to be incompatible with the new acoustic requirements of the structure. However, the designers have retained its tax beam, a large concrete ring that now forms the symbolic entrance to the Long Center plaza.
Overall, more than 20,000 tons of materials were removed from the Palmer Auditorium; of these, 95% were recycled or reused in the new building or buildings under construction in the same region. The most important example of reuse is represented by the 5,500 square meters of colored aluminum panels of the roof reused as external and internal cladding of the walls of the new building.
Having anticipated the decision to reuse the structures and materials made recovery and reuse easier and cheaper. Some of the components, then, have proved to be economically advantageous, such as marble slabs and lamps. On the contrary, the purchase of new aluminum panels would have been less expensive than the recovery of those of the roof. However, the detailed technical specifications for their removal, cutting and re-installation made the labor costs acceptable. The overall cost of the intervention, however, was still below average [154].

PART 7
A model proposal for preventing/reducing CDW that will occur in construction, use, and dismantling/demolition process in the design process of the building

In the 3rd, 4th and 5th chapters of the study, the reasons for the formation of C&D waste in the construction, use and dismantling / demolition processes were examined. Considering the amount of C&D waste generated in these processes and their damage to the natural/artificial environment, the need to prevent/reduce these wastes in economic and ecological terms arises. The importance of the design process is emphasized in order to reduce these wastes. In order to form the basis for the design decisions regarding the prevention/reducing of the C&D waste that will occur during the design process, the studies of the institutions at the national/international level have been examined. In the light of the data obtained from these studies, design decisions that will prevent/reduce C&D waste have been determined. In this part of the study, a model is created that defines what needs to be done in the design process in order to prevent/reduce the C&D waste that will occur during the construction, use and dismantling/demolition process, and focused on the expansion of this model.

The model, which is for the prevention/reduction of C&D waste that will occur in the construction, use, dismantling/demolition processes, including the sub-processes of the design process -concept design, preliminary design, developed design, detailed design-, and for each sub-process, related to the construction, use and dismantling / demolition process, is considered as a feed-forward-feedback model in which design decisions are defined and supervised through checklists.

The steps that make up the model are in a relationship with each other. Model consists of following four main steps:

-“Concept design Sub-Process” step,
-“Preliminary Design Sub-Process” step,
-“Developed Design Sub-Process” step,
-“Detailed Design Sub-Process” step.

In the concept design sub-process step, environmental factors and requirements are determined depending on environmental factors, and decision levels are formed for the decisions to be taken in the preliminary design, developed design and detailed design sub-processes.

There is a flow chart within the preliminary design, developed design and detailed design sub-process steps.

Each step contains the following sub steps:

- Determining design decisions,
- Choosing the ones suitable for the conditions of the building among the design decisions,
- Realizing the preliminary design/developed design/detailed design,
- Auditing the preliminary design /developed design /detailed design with a checklist,
- Deciding whether the design is adequate or insufficient for the C&D waste prevention/reduction objective.

For the design that is deemed satisfactory, the next step is taken, and for the design that is deemed insufficient, feedback is given to the step itself, to the previous step or to the pre-work sub-process step. With the completion of the detailed design sub-process step, which is the last step, the design in which the formation of C&D waste is prevented/reduced in the construction, use and dismantling/demolition processes is obtained.

In addition to the successive steps of the model, the important point to be addressed in the preliminary design, developed design, and detailed design sub-process steps is to make the necessary last-minute changes when user requirements and environmental factors change. In cases where user requirements and environmental factors change during the design process according to the model, it is important to provide feedback to the pre-work step to make the necessary last-minute changes. When the main sources in the literature on preventing/reducing C&D waste are examined, last minute changes are defined as a phenomenon that the customer wants at the last moment during the design process, causing the formation of C&D waste and therefore to be avoided. However, the way in which the last-minute changes are handled within the scope of the thesis is different from that in the literature.

In the design process, it is assumed that there will be no need for changes at the last moment if the environmental factors and requirements depending on the user, natural and artificial environment, if production resources and necessities [66] are fully determined. In cases where environmental factors and requirements do not change, additions/removals made at the request of the customer without any justification should not be accepted, and last-minute changes should be avoided. However, during the design process, the user of the building, the user's requirements or necessities may change. In these cases, last-minute changes are not the ones to be avoided, but the ones that need to be made. Because in this case, if the last-minute changes are not made under the supervision of the designer and in accordance with the whole building, changes can be made during the construction process and C&D waste may occur. In summary, avoiding last minute changes when the conditions of the building do not change, and making changes compatible with the whole design when the conditions change, are considered important for the purpose of preventing/reducing waste.

7.1. The “Concept design stage” step of the model

The concept design sub-process step, which is the beginning of the design process, also constitutes the first step of the model. In the concept design sub-process, environmental factors related to the natural/made environment, user and necessities and requirements are determined depending on these factors. When the decisions made as a result of environmental factors and requirements are evaluated in terms of preventing/reducing the formation of C&D waste, they are grouped under decision levels (Figure 11.1). Accordingly, environmental factors related to the natural/built environment are related to the following:

- Settlement,
- Construction process,
- Usage process,
- Dismantling/demolition process

These factors also create their own needs. With the determination of the requirements, the decision levels regarding the prevention/reduction of C&D waste were determined during the design process.

- Settlement-related environmental factors have revealed the settlement-related requirements. When this information is evaluated in terms of C&D waste generation; if there is a building in the building area, it will affect the decisions regarding that building.
- The environmental factors related to the construction process have revealed the requirements related to the construction process. When this information is evaluated in terms of C&D waste generation, it will affect the product selection and the choice of application method for the product.
- Environmental factors related to the usage process have revealed the requirements related to the usage process. When this information is evaluated in terms of C&D waste generation, it will affect the product selection.

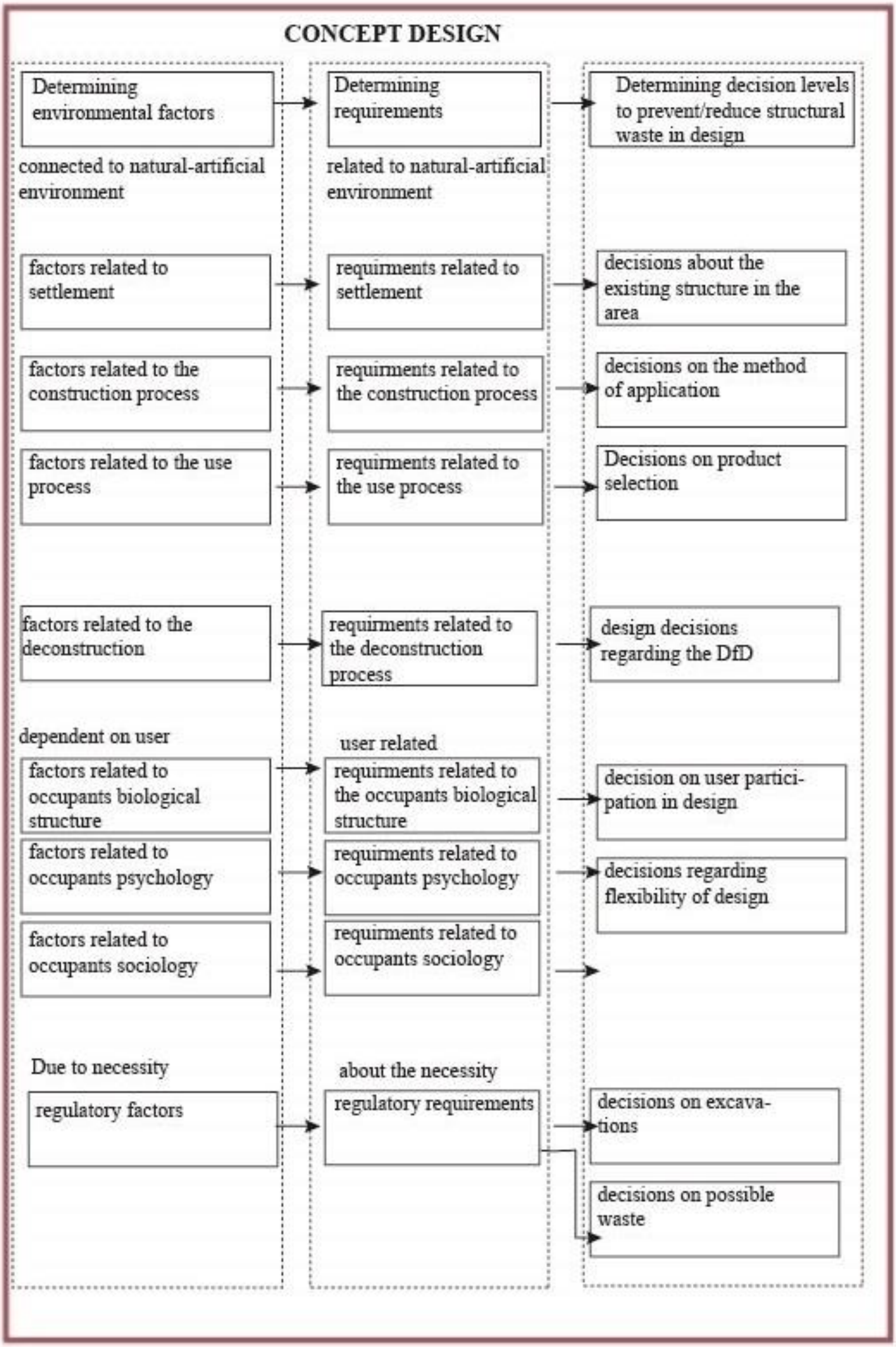

Figure 11.1 The concept design sub-process step of the model related to preventing the C&D waste that will occur during the construction, use and disposal processes in the design process of the building

-Environmental factors related to the dismantling/demolition process have revealed the requirements for the dismantling/demolition process. When this information is evaluated in terms of C&D waste generation, it will affect the decisions regarding "Design for Deconstruction".

Environmental factors related to the user are related to the biological, psychological, and sociological structure of the user. These factors consists of the user's; biological, psychological, and sociological needs.

With the determination of these requirements, the decision levels regarding the prevention/reduction of C&D waste were determined during the design process. It will affect the decisions regarding the user's participation in the design so that the needs of the user can be determined at a full/near-total level. In case the need/user/function/requirements/likes change, the flexibility decision is important.

The relations between the environmental factors determined during the concept design sub-process step, the requirements that depend on them, and the decision levels created to prevent/reduce the C&D wastes in the design process as a result of these requirements are shown in Figure 11.1. After the determination of the decision levels at the correct/sufficient level depending on the requirements, the concept design sub-process step can be started.

7.2. The "Preliminary design stage" step of the model

The preliminary design sub-process step of the model is fed with the information from the concept design sub-process step (Figure 11.2). In order to prevent/reduce the wastes that will occur in the construction, use and dismantling/demolition processes, the design decisions to be taken into account in this sub-process were created in sections 3, 4 and 5, and are shown in Figure 3.3, Figure 4.7 and Figure 5.4. Accordingly, the design decisions to be considered in order to prevent/reduce the C&D wastes that will occur during the construction process in the preliminary design sub-process are determined as follows:

- Reusing the existing structure in the area by preserving it at certain rates,
- Designing with prefabricated products.

The design decisions to be considered in order to prevent/reduce the C&D waste that will occur during the usage process in the preliminary design sub-process are discussed under the following headings:

- Designing with user participation,
- Making flexible design.

The design decision that should be taken into account in order to prevent and reduce the C&D waste that will occur during the dismantling / demolition process in the preliminary design sub-process; has been determined as ensuring that the requirement program overlaps with DfD objectives by adopting DfD principles.

According to the model, the designer should choose the ones suitable for the conditions of the building to be designed among these decisions (Figure 11.5) and perform the design. The design obtained by completing the preliminary design should be audited through the checklists If the design is sufficient for the waste prevention/reduction objective. If the design is insufficient, feedback will be given to the design decisions in line with the suggestions given so that design-related problems that may cause waste can be resolved before the preliminary design sub-process is completed.

It is not possible (in some designs) to take advantage of all the design decisions developed for this sub-process. Because the following may differ:

- type of structure,
- Features of the area where it will be built,

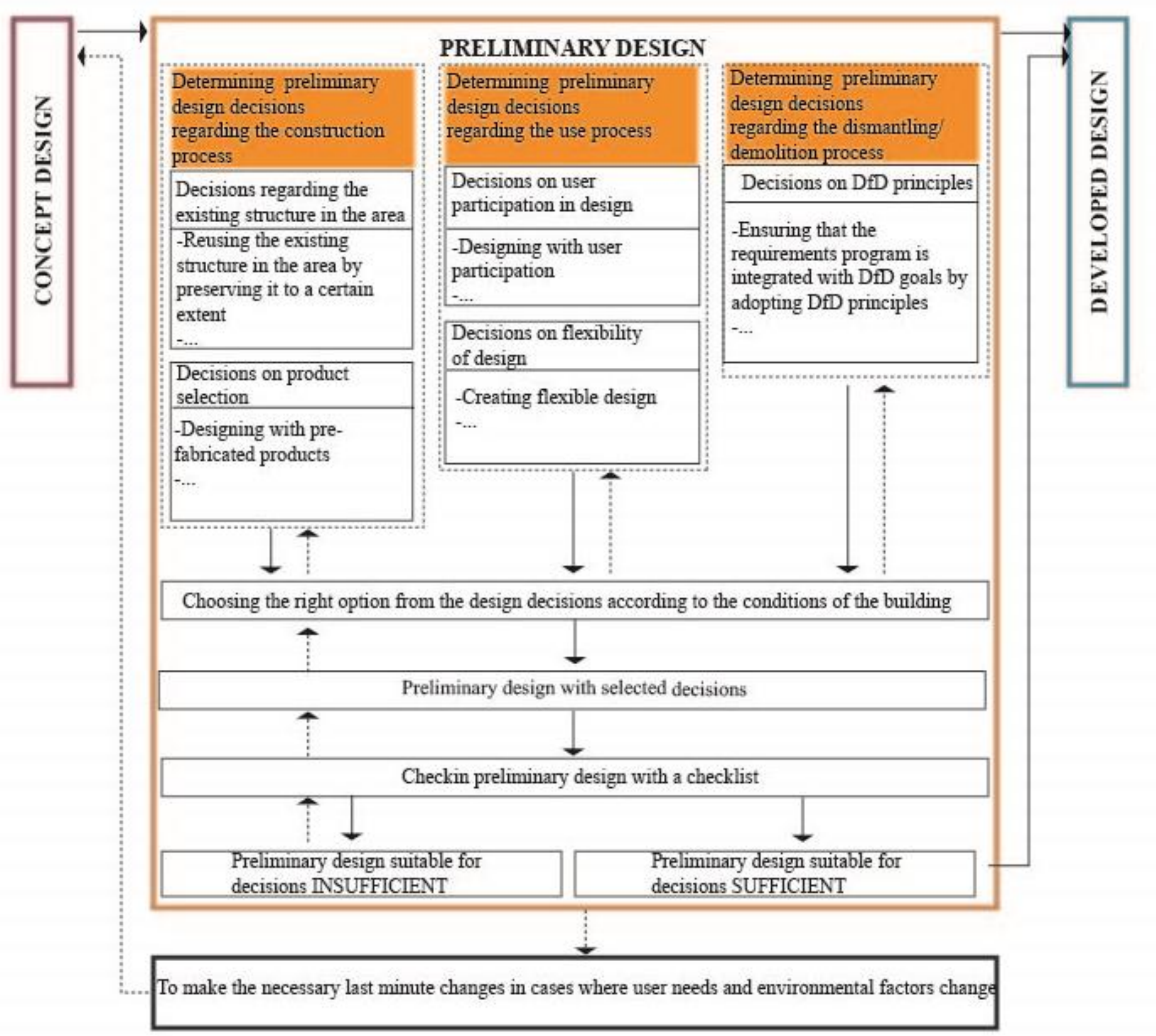

Figure 11.2 The preliminary design sub-process step of the model related to preventing the C&D waste that will occur during the construction, use and disposal processes in the design process of the building

- Requirements of the construction.

For example, the decision to "reuse the existing structure in the area by preserving it at certain rates" may not be used in every design because there may not be an existing structure in the area. Similarly, "User participation for each structure type/function" or "flexibility approach" may not be used. For this reason, when using this model, the designer should choose the design decisions he will benefit from, taking into account the characteristics of the building to be designed, and add new decisions for the target of waste prevention/reduction if necessary. A design that fits all the decisions made by the designer may be considered sufficient, and a design that does not fit may be considered insufficient.

In cases where user requirements and environmental factors change while the preliminary design sub-process is in progress, necessary last-minute changes should be made, and for this purpose, feedback should be given to the “concept design sub-process” step. For the design that is deemed adequate, the "developed design sub-process" step is passed, and for the inadequate design, feedback is given to the step itself or to the "preliminary design sub-process" step. The relationships within this sub-process step are shown in Figure 11.2. In case the design is qualified by the designer, it will be possible to proceed to the developed design sub-process step.

7.3. The “Developed design stage” step of the model

The developed design sub-process step of the developed model is fed not only with the information from the preliminary design sub-process step, but also with the information coming from the concept design sub-process step (Figure 11.3). The design decisions to be taken into account in this sub-process in order to prevent/reduce the wastes that will occur during the construction, use and dismantling/demolition processes are given in detail in Figure 3.3, Figure 4.7 and Figure 5.4 in sections 3, 4 and 5. Accordingly, the design decisions to be considered in order to prevent/reduce the C&D waste that will occur during the construction process in the developed design sub-process are determined as follows:

- Deciding which elements of the existing building will be reused and integrating it with the design,
- Designing with pre-made products,
- Coordinate design with product dimensions,
- Selecting the products in the size and shape suitable for the design,
- Selecting products that are reusable or have recycled content,
- Selecting local/regional products,
- Choosing the application method suitable for the product,
- Establishing the balance of the excavated-filled area by calculating the excavation soil to be excavated,
- To take the decision to use the vegetable soil to be extracted in landscaping works,
- To make reuse decisions in the building area regarding possible wastes.

The design decisions to be considered in order to prevent/reduce the C&D waste that will occur during the usage process in the developed design sub-process are discussed under the following headings:

- Choosing durable products
- Designing with user participation in product selection,
- Designing the building envelope together with the structural system,
- Developing different solutions for the interior,
- Designing that can offer maintenance-repair or replacement.

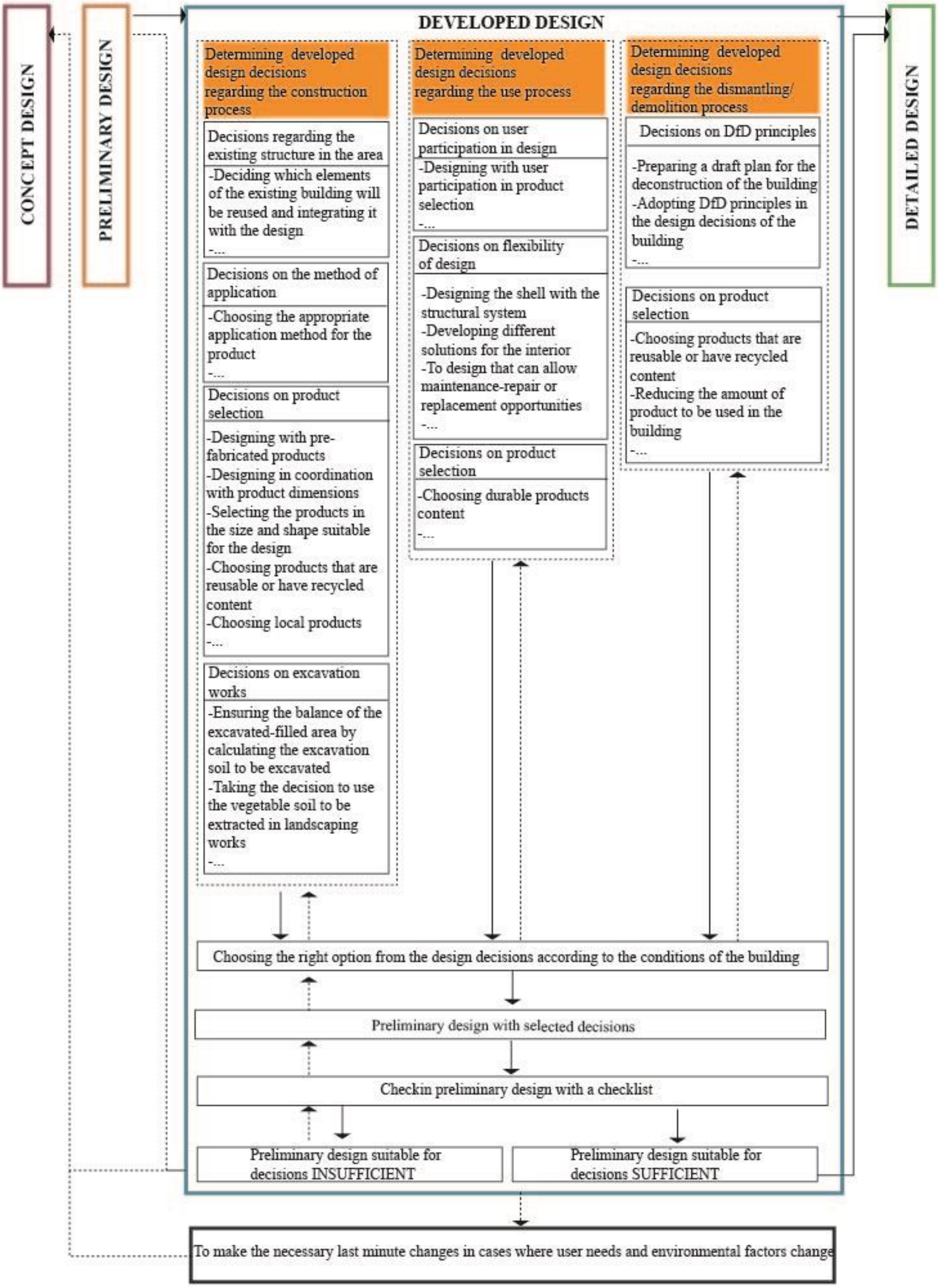

Figure 11.3 The developed design sub-process step of the model related to preventing the C&D waste that will occur during the construction, use and disposal processes in the design process of the building

The design decisions that need to be taken into account in order to prevent and reduce the C&D waste that will occur during the dismantling/demolition process in the final design sub-process are as follows:

- Selecting products that are reusable or have recycled content,
- Reducing the amount of product to be used in the building,
- Preparing a draft plan for the dismantling of the building,
- Adopting DfD principles in the design decisions of the building (space layout, structure, and flooring system setup).

According to the model, the designer should choose the ones suitable for the conditions of the building to be designed among these decisions and perform the design. The design obtained by the completion of the developed design; should be audited through the checklists. If the "Yes" option is selected for compliance with all decisions selected in the checklist, the design is sufficient for the waste prevention/reduction objective. If the "No" option is selected, feedback will be given to the design decisions in line with the suggestions given in the checklist, so that design-related problems that may cause waste can be resolved before the developed design sub-process is completed.

It is not possible (in some designs) to take advantage of all the design decisions developed for this sub-process. Because the following may differ:

- Type of structure,
- Features of the area where it will be built,
- Requirements of the construction.

For example, the decision "to balance the excavated and filled area by calculating the excavation soil to be excavated" may not be used in every design. Because if a basement is to be designed for a building, it may not be possible to provide the balance of the excavated and filled area in this design. For this reason, when using this model, the designer should choose the design decisions he will benefit from, taking into account the characteristics of the building to be designed, and add new decisions for the target of waste prevention/reduction if necessary. A design that fits all the decisions made by the designer may be considered sufficient, and a design that does not fit may be considered insufficient.

In cases where user requirements and environmental factors change while the developed design sub-process is in progress, necessary last-minute changes should be made, and feedback should be given to the "preliminary design sub-process" step for this purpose. For the design deemed adequate, the "detailed design sub-process" step is passed, and for the inadequate design, feedback is given to the step itself, to the "preliminary design sub-process" step or to the "concept design sub-process" step. The relationships within this sub-process step are shown in Figure 11.3. In case the design is qualified by the designer, the detailed design sub-process step can be passed.

7.4. The "Detailed design stage" step of the model

The detailed design sub-process step of the developed model is the result of all the steps that came before it and is in relation with all the steps (Figure 11.4). The design decisions to be taken into account in this sub-process in order to prevent/reduce the wastes that will occur during the construction, use and dismantling/demolition processes are given in detail in Figure 3.3, Figure 4.7 and Figure 5.4 in sections 3, 4 and 5. Accordingly, in order to prevent/reduce the C&D waste that will occur during the construction process in the detailed design sub-process, the design decisions to be considered in the detailed design sub-process are discussed with the following items:

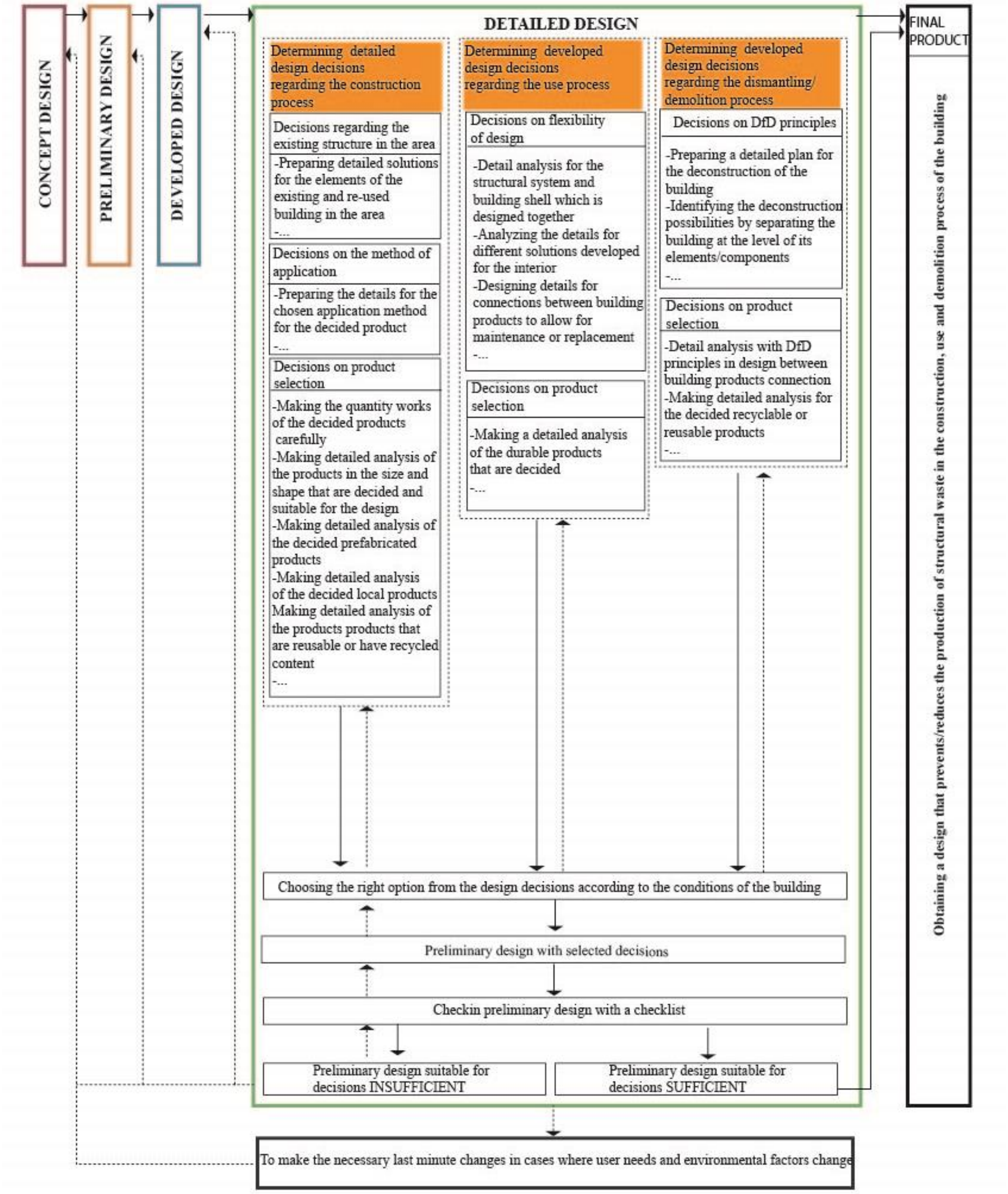

Figure 11.4 The detailed design sub-process step of the model related to preventing the C&D waste that will occur during the construction, use and disposal processes in the design process of the building

- To prepare detailed solutions for the elements of the existing and reused building in the area,
- To prepare the details regarding the application method chosen for the decided product,
- To make the quantity works of the decided products without any mistakes,
- To analyze the details of the products in the size and shape suitable for the design,
- To analyze the details of the pre-made products,
- To analyze the details for the products that can be recycled/reused,
- To analyze the local/regional products in detail.

The design decisions determined to prevent/reduce the C&D waste that will occur during the usage process in the detailed design sub-process are as follows:

- To make detailed solutions of the durable products that are decided,
- Analyzing the details for the structural system and building envelope designed together,
- Analyzing the details for different solutions developed for the interior,
- Designing details for connections between building products to allow for maintenance or replacement.

The design decisions that need to be taken into account in order to prevent and reduce the C&D waste that will occur during the dismantling/demolition process in the detailed design sub-process are as follows:

- To analyze the details in connection designs between building products with the principles of DfD,
- To analyze the details for the products that can be recycled/reused,
- To prepare a detailed plan for deconstruction,
- Separating the building at the level of its elements/components and determining the dismantling possibilities.

According to the model, the designer should choose the ones suitable for the conditions of the building to be designed among these decisions (Figure 11.5) and perform the design. The design obtained with the completion of the detailed design; it should be audited through the checklists. If the “Yes” option is selected for compliance with all decisions selected in the checklist, the design is sufficient for the waste prevention/reduction objective. If the “No” option is selected, feedback will be given to the design decisions in line with the suggestions given in the checklist, so that design-related problems that may cause waste can be resolved before the detailed design sub-process is completed.

It is not possible (for some designs) to take advantage of all the design decisions developed for this sub-process. Because the following may differ:

- Type of structure,
- Features of the area where it will be built,
- Requirements of the construction.

While using this model, the designer should choose the design decisions that he will benefit from, taking into account the characteristics of the building to be designed, and add new decisions for the target of waste prevention/reduction if necessary. A design that fits all the decisions made by the designer may be considered sufficient, and a design that does not fit may be considered insufficient.

In cases where user requirements and environmental factors change while the detailed design sub-process is in progress, necessary last-minute changes should be made, and for this purpose, feedback should be given to the "preliminary design sub-process" step. For the inadequate design, feedback should be given to the step itself, to the "developed design subprocess", "preliminary design subprocess" or "concept design subprocess" steps. The relationships within this sub-process step are shown in Figure 11.4. In case the design is qualified by the designer, a design will be obtained in which waste generation is prevented/reduced throughout the construction, use and dismantling/demolition processes.

7.5. Construction of a model for preventing/reducing CDW that will occur in construction, use, and dismantling/demolition process

In Sections 11.1, 11.2, 11.3 and 11.4, the steps in the expansion of the model to be created to prevent/reduce the C&D waste that will occur during the construction, use and dismantling/demolition processes during the design process of the building are defined.
In Figure 11.5, these steps and their relations are determined; the model is intended to prevent/reduce the C&D waste that will occur during the construction, use and dismantling/demolition processes in the design process of the building.

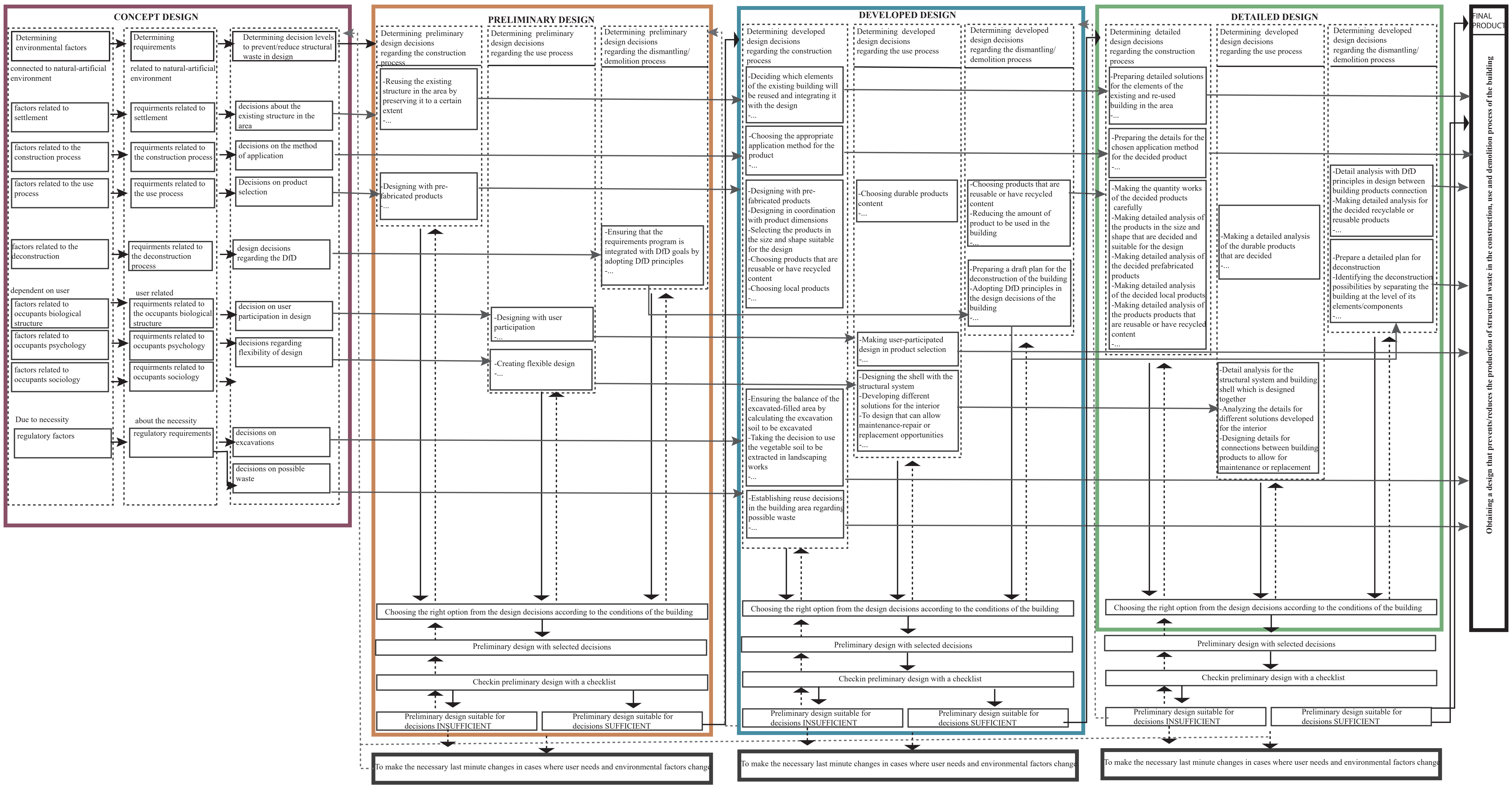

Figure 11.5 A model for preventing/reducing CDW that will occur in construction, use, and dismantling/demolition process

PART 8
Conclusion and recommendations

Any work to be done on the activities of the building sector, which has significant effects on living/non-living environments and the economy, is important. For this purpose, it has been seen that many studies have been carried out on building products, which have an important place in the sector. However, in the literature review, there was no detailed model to be used by the designers in the design process of the building, which was created to prevent the building products from becoming a structural waste by using them in a sustainable way. It is important to carry out a study to prevent/reduce the structural wastes generated during construction, use and dismantling/demolition processes due to the risks and negative effects they pose on living/non-living environments and the economy. The most important role in preventing/reducing these wastes falls to the designers during the design process of the building. Because a large part of the structural wastes generated during the construction, use and dismantling/demolition processes are related to the decisions in the design process of the building. In this context, in this study, a model has been tried to be created to prevent/reduce the structural wastes that occur during the construction, use and dismantling/demolition processes in the design process.

In the study; First of all, the design process was handled, and the sub-processes -preliminary study, preliminary design, final design, application design- were examined. In the following sections, the construction, use and dismantling/demolition processes are examined. The relationship between construction, use and dismantling/demolition processes and the generation of structural waste has been mentioned. According to this:

● Sub-processes that generate waste due to design errors during the construction process:
  - Excavation works,
  - Transport of products to the building area,
  - Application of products to the structure,

● Sub-processes that generate waste due to design errors in the usage process:
  - Transition to use,
  - The user lives in the structure,

● Sub-processes that generate waste due to design errors in the dismantling/demolition process:
  - Performing the dismantling/demolition of the structure

While developing suggestions to prevent/reduce the wastes generated in these sub-processes during the design process, studies were examined. DoW and C2C aimed to prevent/reduce structural waste directly, LEED and BREEAM certification systems are widely used in the world, Green Star, and IGBC Green Homes certification systems are discussed because they are studies at the local level. Decisions that are thought to contribute to the model were selected from these studies (Table 3.2, Table 4.1, Table 5.2), and new decisions that should be included in this model were developed. With the finding that these decisions should be overlapped with the sub-processes of the design process, it was emphasized in which sub-process of the design process the decisions should be handled.

Design decisions to prevent/reduce the formation of structural waste in the sub-processes of construction, use, dismantling/demolition and the sub-processes of the design process were overlapped.

While the model was being built, the following sub-processes of the design process formed the main steps of the model:

● Concept design,
● Preliminary design,
● Developed design,
● Detailed design.

In the concept design sub-process step, environmental factors and requirements depending on environmental factors were determined, and decision levels regarding the decisions to be made in the preliminary design, developed design and detailed design sub-processes were determined. A flow chart has been constructed in itself for the preliminary design, developed design and detailed design sub-processes. These include the following sub-steps;

- Determining design decisions,
- Choosing the ones suitable for the conditions of the building among the design decisions,
- Realizing the preliminary design/final design/implementation design,
- Auditing the preliminary draft/final draft/implementation draft with a checklist,
- Deciding that the design is adequate or insufficient for the structural waste prevention/reduction objective.

At each step, among the determined design decisions, the ones that fit the conditions of the building are selected, and the design is carried out in line with these decisions. The designer checks the compliance of the design with the structural waste prevention/reduction target with checklists and can improve the points he deems insufficient in line with the suggestions given in the checklists. As a result of the inspections, the next step is taken for the design that is found to be "adequate", and feedback is given to the step itself, to the previous step or to the concept design sub-process step for the design that is deemed "inadequate". Considering the design as “Adequate” or “Insufficient” for the structural waste prevention/reduction objective taking into account the conditions of the building depends on whether the design decisions chosen by the designer are fully adhered to. If the determined design decisions are fully complied with, the design is considered to be at the "Adequate" level for the waste prevention/reduction target.

With the completion of the detailed design sub-process step, which is the last step, the design in which the formation of structural waste is prevented/reduced in the construction, use and dismantling/demolition processes is obtained.

In addition to the successive steps of the model, the important point to be addressed in the preliminary design, developed design and detailed design sub-process steps is to make the necessary last-minute changes when user requirements and environmental factors change. In cases where user requirements and environmental factors change during the design process according to the model, it is important to provide feedback to the concept design step to make the necessary last-minute changes.

The effectiveness of the created model depends on the use of the model from the beginning of the design process and the development of design decisions suitable for the characteristics of the building to be designed/added new ones. For this reason, the designer/design team should choose design decisions according to the characteristics of the building at the beginning of the design process and add new decisions if necessary. By using the model systematically throughout the design process, the structural wastes that will occur during the construction, use and dismantling/demolition processes can be prevented/reduced.

In this thesis; unlike the design approaches for waste prevention/reduction in the literature; a new and integrated model has been proposed, which deals with life processes of the building in its entirety. Since the model can be developed in itself and offers a flexible approach; can be used for different types of structures to be designed. The following are suggested for the functionality of the developed model and to be a source for future studies:

• In the design process of the building; Addressing the structural wastes that will occur during the construction, use and dismantling / demolition processes as an agenda item,
• Establishing a working team in the design process in order to implement the developed model, including an expert on structural waste management in the team,
• Making the designers involved in the process aware of the importance of their role in preventing/reducing the formation of structural wastes,
• Considering the steps of the proposed model holistically for the correct implementation,
• Supporting the model with incentives, sanctions, and obligations to ensure that the developed model can be used in the design process of the structures,
• Encouraging the use of recycled/reusable products in new building production in legal regulations; For this purpose, establishment and functioning of the system for providing second-hand products.

Future prospects for research, firstly, it should be noted that, for the purposes of a concrete advancement in the methods of managing construction and demolition waste, it is essential to identify ways of obtaining effective capillary data that make basic information clearer and more reliable (quantities and types of waste produced, percentage of materials sent to landfill, etc.). In this sense, if it were possible to make the use of construction site waste management plans binding a significant amount of data would become available, which could provide material for developing a national database to be subjected to statistical surveys. An interesting research perspective opens up for the architectural technology sector, which aims at defining a "demountable" construction model that integrates positively with the characteristics and technological solutions of the built heritage. In addition, it is essential to develop solutions that allow the designer to transmit to the client information on the disassembly methods envisaged in the design phase, so that he can then transfer them to the company that will demolish or maintain the building in the future. In this area, research can offer an important contribution.

Secondly, as highlighted in the model, there are many possibilities for the transfer or completion of tools. In particular, it should be noted the need, which could be filled with a future development of this research, to carry out:

- A national mapping of authorized facilities for the recycling of aggregates and for the collection of recycled components and materials, possibly computerized to facilitate the identification of qualified operators;
- National platforms that allow the exchange or sale of materials and components deriving from construction and demolition activities;
- A guide for the selection of materials for the purpose of defining the specifications in the specifications based on the LCA of products.

The research can be used by following actors in future:

-The model can act as a teaching aid for young professionals such as architects and engineers coming into the industry by giving them a basic information and understanding of C&D waste generation, and how to reduce it before starting to design a new project.

-Demolition contractors can use the model as a marketing aid to impress potential clients to win a project because of its ability to give rational and structured decisions.

-Policy makers can also use the research to have new regulations to improve the process.

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