Understanding the current state of practice in the construction and demolition waste sector through the lenses of circular economy: The Italian recycled materials market for the road construction sector

Konstantinos Mantalovas [(1)], Francesco Acuto [(1)], Iain Peter Dunn [(1)], Laura Inzerillo [(1)], and Gaetano Di Mino [(1)]

[(1)] Dipartimento di Ingegneria, Università degli Studi di Palermo, Palermo 90128, Italy.
E-mail du premier auteur : ***konstantinos.mantalovas@unipa.it***

Abstract

Construction and demolition waste (C&Dw) is mainly produced during the construction, demolition, or renovation activities of civil engineering structures and it accounts for a remarkable amount of the total C&Dw generated, as it is estimated to be around 30%. This proportion differs between countries belonging to different types of economies and tends to be greater in countries with developing economies reaching 74% of total annual production. There is a plethora of applications that C&Dw can be used for under a circular economic model and in this research a focus is being given in the exploitation of C&Dw within the pavement engineering sector, and more specifically, in the utilization of said waste in road earthworks. Circular Economy can act as a steppingstone towards the uptake of C&Dw recycling and exploitation. To understand the state of practice that exists, a market and an implementation analysis have been conducted in Italy. The current applications of C&Dw recycling into road projects were analyzed along with the existing regulations, and local producers. The results projected the various challenges faced by the involved stakeholders, along with the barriers that hinder the wide recycling of C&Dw in road engineering projects. Finally, the proposed national action plans are analyzed and the future potential exploitation of C&Dw is put into context. The future of the specific research is going to involve a full scale, on-site implementation of C&Dw in a defined road segment.

Keywords
Circular economy, market analysis, construction and demolition waste, circular economic model, recycling.

1. Introduction

Over 35% of waste generated in Europe comes from construction and demolition activities [1] and as such the European Union has set targets to increase the use of recycled aggregates with a view to reducing the amount of this waste that makes its way into landfills. A specific target for reuse, recycling, and other types of material recovery from construction and demolition activities of 70% was set to be achieved by 2020 [1]. Studies show, however. that this target has not been met, a study from 2017 claims that the amount of recycled aggregates actually being used in new construction activities is just 10%. Nevertheless, numbers vary widely, with some studies consistently quoting values over 75% each year since 2016 [2]. The report by the Italian Institute for Environmental Protection and Research (ISPRA) [2] an Italian research centre established by the Ministry of the Environment, does not provide clear data regarding what percentage of inert solids from C&Dw are reused in new construction activities, the independent thinktank Legambiente however, strongly disputes these figures stating in their report "Rapporto Cave 2021" [3] that the data "is not credible", they go on to state that in reality, while it may be true that 74% of C&Dw waste is sent to and processed by recycling plants, the aggregates produced there are not being used and are remaining as stock.

To understand the benefits and the potential impact of recycled aggregates from the Construction and Demolition Waste (C&Dw) in the road industry, first, the total quantities produced by each country

should be considered and processed. In this article, data provided by Eurostat and by Italian Authorities are provided and discussed. Based on the aims of the paper, only waste produced by the "Construction" sector is considered. In Figure 1, the total production of waste (hazardous and inert) in the construction sector for several countries from 2004 to 2016 is provided. From this data a small number of countries (France, Germany, the UK, the Netherlands, Italy, Austria, and Spain) produce the hugest quantities of waste. For more clarity, in 2016, these 7 countries generated almost 88% of the total waste in the construction sector produced by all the selected 29 countries. Although some countries have shown a descendent trend in recent years, others (such as Germany, UK, Netherlands, Austria, etc.) have significantly increased their waste in this sector.

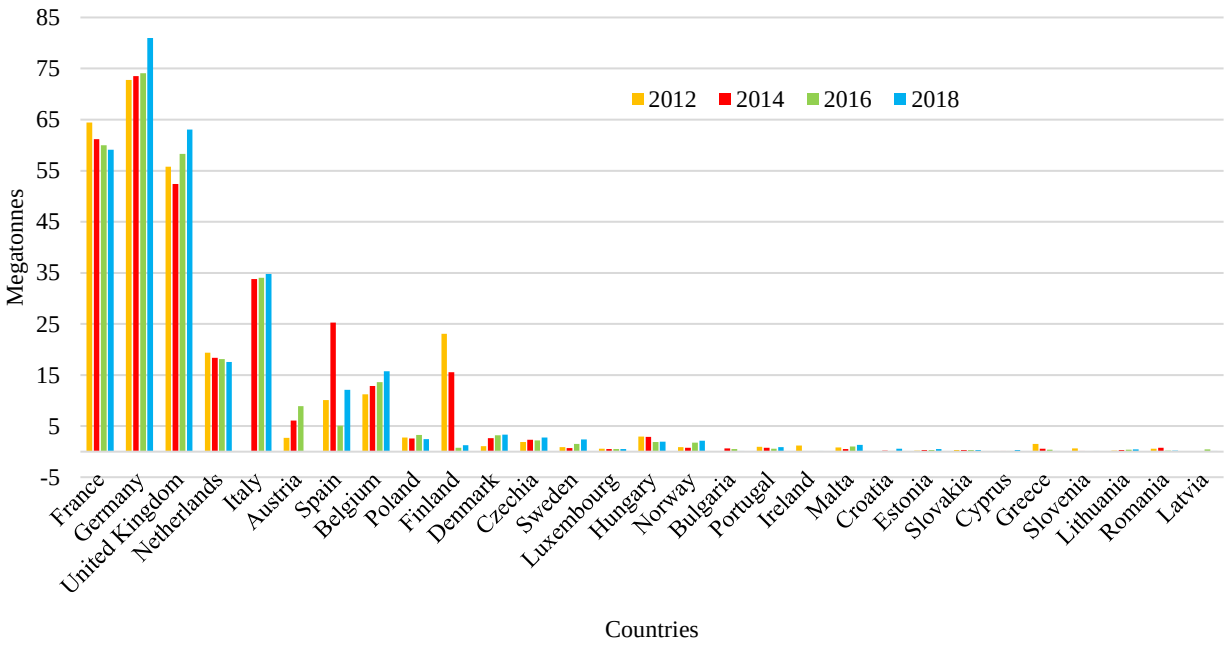

Figure 1: Non-hazardous mineral waste from C&Dw in Megatonnes [Mt] (Eurostat data).

It is clear from the fata that Italy is primed to be at the forefront of the C&Dw recycling industry, if the data is correct and more than 70% of all C&Dw is processed but not used in new construction then there is a market available of low-cost, sustainable materials. In this paper, the current market will be discussed, an overview of the regulatory context in which C&Dw lies will be presented, the challenges facing the implementation of a circular economic model will be described and finally, the national action plan for the increased use of C&Dw will be examined.

2. Analysis of the current Italian market

The current market for C&Dw waste in Italy is still not particularly well developed, at least on a national level [3]. Data does show, however, that a large percentage of recycled aggregates are available in Italy [2] but that they are not being adequately used. There are a number of interconnected theories of why this is the case, these theories will be discussed in this section and then the current state of the market will be presented.

The first, and in the authors' opinion principal barrier to the use of recycled aggregates is the level of distrust present regarding the quality of recycled aggregates when compared to virgin aggregates [4].

Their distrust may be well placed as in the past illegal activities and improper recycling practices resulted in low quality recycled aggregates [15]. Other issues affecting the adoption of recycled aggregates from C&Dw include a lack of reliable data an technical tools from an accredited government body on a national level, a dearth of legislation which actively promotes the use of recycled aggregates such as; taxation on virgin aggregates, or an obligation to recycle inert C&Dw, and finally, the construction and demolition sectors do not adequately perform selective demolition or onsite separation of waste products during construction [15]. According to a report from ANPAR [5] the vast majority (81%) of recycled aggregates which are used in new construction is represented by the infrastructure construction sector (roads, railways, cycle paths, etc.), followed by filling and other uses (12%), while a very small proportion is devoted to related uses, of which a small part for packaging structural concrete. This is due to both, technical legislation which requires recycled aggregates from concrete alone for the packaging of new concrete and, on the other hand, to a poor on-site production of such waste (code EER 170101). While this is heartening it also shows that C&Dw is not realizing its full potential particularly regarding that which is derived from concrete. Concerning sales prices, the market situation is very varied at a national level. Given that, as already mentioned, the failure to sell the finished product represents a "physical" obstacle for many plants (those that are built on areas less than one hectare) to continue to process the incoming waste frequently the sales price of recycled significantly lower than the actual costs of production and CE standards [5]. The goal is stated as being the “End of Waste” with products which are fully circular being given end of waste (EoW) status. It is the goal of many environmental agencies and government agencies that all products achieve this status and that we move from the consumerist model of “waste forever” which is described as “antiquated” to the circular model in which high quality recovery operations are used to allow recycled materials to compete with virgin materials. To achieve this aim, residue and material previously considered waste from industrial processes should be categorised as by-products and operators should be assisted in verifying the conditions qualifying residues as by-products and providing standardized criteria.

3. Presentation of the regulatory context

The regulation in Italy is already rather well developed with multiple ministerial decrees regarding the treatment of construction and demolition waste and defining the scope of its use, much of these regulations however are out of date and industry experts are dedicating a portion of their time to lobbying of updated standards and more extensive regulation. In this section an overview of the regulatory situation in Italy, along with the legal restrictions limiting the use of C&Dw, will be discussed.

3.1.Current Legislation

A full definition of C&Dw is provided in the ministerial decree; **D.Lgs 152/06 – Art. 184** which states that C&Dw is waste derived from construction and demolition activities as well as waste resulting from excavation activities subject to the provisions of **Article 184 bis**. However, a directive of the European Union, **Directive 2018/851/EU**, which is a far more up to date standard states that waste ceases to be such when it has been subjected to a recovery operation and meets all the precise conditions established by art. 6 of the European framework directive. This directive was officially adopted by the Italian Government in the most recent legislation regarding C&Dw; **D.Lgs. n.116/2020**, in this decree, the definition of waste is established and for the first time, construction and demolition waste is defined separately from standard municipal waste. It goes on to provide information on the use of and recycling of C&Dw, waste management, as well as financial

responsibility for such activities. Regarding the use of C&Dw, **D.M. 24/12/2015** describes the "Minimum Environmental Criteria" to be used for new construction, renovation, and maintenance contracts of buildings and for the management of construction sites. Furthermore, a goal for the minimum quantities of recycled aggregate for each material are defined, focusing particularly on construction sites, where at least 70% by weight of the non-hazardous waste generated during the demolition and removal of works and artifacts must be initiated to prepare for reuse, recovery, or recycling. This is expanded upon in **D.M. 11/10/2017** where it is specified that aggregates consisting of recycled material, recovered material, or by-products from construction, is a useful material for manufacturers of building components that must comply with the specific Minimum Environmental Criteria requirements, which do not require the aggregate producer to give evidence of the recycled content.

4. Challenges of implementing a circular economic model for C&Dw

The recycling of mineral waste presents a series of undoubted advantages to limit the appeal of disposal in landfills and the opening of new quarries of natural aggregates. Another goal concerns the construction sector which may deliver the waste to recycling at lower costs than the use of landfill and, at the same time, sourcing materials that have more advantageous prices compared to natural materials, with the same benefits [6]–[10]. However, there are still several obstacles which do not allow the recycling sector to realise its full growth potential and, consequently, make a substantial contribution to achieving the circular economy objectives. Mistrust in the use of derived products from waste, pushes designers and construction managers to favour the use of virgin products, for which risks are moderate, rather than the use of recycled products that require the definition of design features and acceptance checks during ongoing constructions [11]–[13]. The lack of specific instruments, such as special procurement specifications, updated to the harmonized European standards, or the failure to introduce "recycled aggregates" in prices of the building works do not facilitate their use. Thus, the main challenges in Italy Regarding Sustainable Waste Management and the exploitation of C&Dw in the built environment are [14], [15] :

- Distrust in the use of secondary raw materials
- Lack of updated performance assessing tools for secondary raw materials
- Lack of primary and adequate data about inert waste production
- Poor source separation waste and use of selective demolition practices
- Lack of mining taxation
- Lack of prohibition or obligation to contribute to landfilling of inert waste
- Obligation to carry out analysis for waste sent for recovery/recycling

The use of materials coming from C&D activities in Italy is quite reticent due to related illegal practices that happened in the past. The waste material is usually used in road works, where its characteristics are the same as the materials taken from a new source, but if not treated properly before its use, they can create serious problems for the construction company, of both legal and technical nature. It is critical to properly complete the recycling process to obtain high-quality material. Considering this, ISPRA's official numbers on waste output from C&D are simply estimates, and it's possible that illegal practices continue to exist today. An intervention in the public administration would be beneficial in removing all the waste produced by building rehabilitation and demolition. If the required percentage of 70 percent request from the European Union is met, a proper value of re-used C&D waste can be evaluated and estimated with the accurate quantification of data. The absence or lack of appropriate instruments, such as specifications, updated to the harmonised European sector requirements, may be one of the key reasons for the limited large-scale production of recycled aggregates and the uptake of their usage. As a result, the public works sector must guarantee that Special Tender Specifications are revised in accordance with the most recent European technical law, which differentiates aggregates based on their qualities rather than their origin. Italy does not demand a special commitment in the selection operations at the source of the various types of garbage because

of its traditional waste management system but thanks to the European Commission requirements, during C&Dw activities, the different types of waste should be identified through a preventive audit and after a waste management plan should be drawn up [1]. The taxation of virgin resources is another sort of activity that stimulates the use of recycled materials; an increase in the cost of the latter might aid their use only when better performance aggregates are necessary, leaving other uses to recycled aggregates and reused land. A prohibition on the landfilling of inert waste might have a similar impact, promoting the growth of recycling operations as a result [6], [15]–[17].

5. National implementation roadmap and action plan

5.1.Action Plan During Transition Phase

The Italian government has already released a detailed account of the action plan and steps needed for the transition to a more circular economic model. In this file, some of these recommendations will be cited along with a detailed account of steps which must be taken by the Italian Government and industry operating in Italy. The first step defined regards a broad regulatory review and the implementation of many new laws along with the repeal of many existing laws. The report in fact states, in no uncertain terms, that some level of deregulation regarding the process of waste will be required, and it advocates changing the official definition of waste to that which "has no economic value". The belief behind this deregulation is that in a circular economy, waste will have a real economic value and will therefore be unlikely to be illegally discarded, consequently, this deregulation will not lead to any ill effects on the environment as in a circular economic model, illegal dumping of materials which were previously categorised as waste will represent an economic loss. Following this widespread regulatory change, several factors must then be identified:

- Flows of materials, previously categorised as waste, which can now be recirculated back into the economic or production cycle as new raw materials or products.
- Waste flows of materials which can be, but are not currently, re-used or recycled due to obstacles in legislative, authoritative, organizational, economic, or competitive forms.
- Waste flows of materials which are not currently recyclable or reusable

Regarding materials which can be, but which are not currently recycled, the report advocates that groups consisting of legal, logistical, economic, and scientific experts be formed to bypass whatever obstacle stands in the way of the recycling or reuse of these materials or products. Regarding the flow of materials which cannot currently be recycled, the report advocates targeted research and development which will work towards finding methods to make these materials reusable or recyclable and if this is not possible to instead focus on the planning of the "progressive elimination" of these materials from the market, to be replaced by reusable or recyclable materials. The goal is stated as being the "End of Waste" with products which are fully circular being given end of waste (E-o-W) status. It is the goal of many environmental agencies and government agencies that all products achieve this status and that we move from the consumerist model of "waste forever" which is described as "antiquated" to the circular model in which high quality recovery operations are used to allow recycled materials to compete with virgin materials. To achieve this aim, residue and material previously considered waste from industrial processes should be categorised as by-products and operators should be assisted in verifying the conditions qualifying residues as by-products and providing standardized criteria for as many residual flows as possible, to offer certainty to the producers of the residue and to the control authorities.

5.2.The Public Sector - Traceability of Resources and Products

Traceability means the possibility of identifying the phases of production and marketing of a commodity. Generally, the traceability starts from the point of origin of the material, and then extends to the subsequent processes of transport and transformation of the final good. In a context of circular economy, and above all, of safeguarding the employed natural resources, the traceability of an asset (intended both as a material and as a manufactured product) or the traceability of a supply chain, can be an indispensable requisite to guarantee:

- compliance with the rules on management and treatment of resources (e.g., materials, by-products, waste)
- the fight against fraud and unfair competition (compliance with environmental and social requirements)
- the quality of the produced goods
- the content of the type of material present (e.g., if from a renewable source, recycled, permanently recycled, biodegradable or compostable)
- the territorial origin of the materials and the localization of the transformation processes.

Traceability makes it possible to verify, compared to a defined time, how many times the good has been used and to compare the result with the same product with a non-shared function or other form of use. For these reasons, the creation of a "Register of Traced Chains" or RFT is advocated. Furthermore, it would support the realization of an accurate map of material flows allowing a complete measurement of products circularity and it would favour industrial symbiosis while potentially also serving as a reference tool for the legislator to promote and incentivise actions aiming at the whole production chain.

5.3.Indicators - Measuring the CE

Every economic activity should be measurable for the results obtained through a budget (its efficiency or inefficiency) to be precisely quantified. Therefore, all circular economy actions must necessarily be measurable. It is necessary to define precise measurability references for the circular economy, otherwise it would be very difficult (if not impossible) to obtain evidence in terms of results from the actions pursued or to be pursued and consequently difficult to evaluate the benefits in terms of economy and protection of resources. It is necessary to identify a set of parameters allowing us to quantify the "circularity" of products, services, organizations, based on the benefits they generate both in terms of reducing the use of non-renewable resources, and in terms of use of renewable resources. This approach is relatively simple when we consider the quantity of materials used or the energy consumption, while it is more complex when we must assess the circularity of requirements such as the extension of the useful life of a product or the sharing activities. There are examples of methods for measuring circularity at national and international level and the common element of all these methods is the drafting of an input-output budget. There are mainly five key elements of the circular economy, which can be declined through some indicators like in Figure 20.

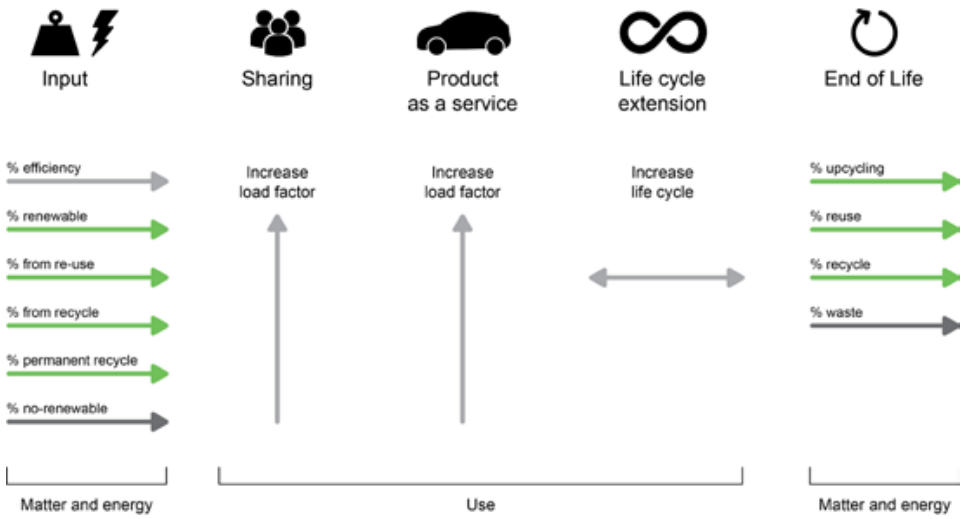

Figure 2: Typical flows of measuring the circularity of a product and/or service

For an easy applicability, especially for small and medium enterprises, it is appropriate that the result is identified with a single circularity index hat in this way can be easily compared to the economic aspects. This index should take in account:

- the circularity of the flow of resources used, which in its turn must consider all the components in terms of materials and energy compared to the budget,
- input (materials and energy if from renewable sources; recycled materials, permanent recycling, reuse, etc.)
- output (materials intended for recycling, reuse, or landfill).
- the circularity of the use of a product or product-service, in a context of extension of its useful life, number of users of the same product, sharing models.
- energy efficiency, water consumption, and environmental impact.

To evaluate their environmental impact, various international reference tools such as the Life Cycle Assessment or the Carbon Footprint are available. To quantify the economic value of the resources it is possible to carry out a Life Cycle Costing (considering therefore also the environmental externalities), or to follow an approach considering the costs/revenues of the resource market. Overall, it is a matter of creating an "input-output" budget considering the entire life cycle of the product. For instance, a methodology that combines both the material circularity and the environmental sustainability of a product and more specifically an asphalt mixture with reclaimed asphalt has been developed by Konstantinos Mantalovas [18]–[21].

6. Conclusions

The current paper addresses the situation regarding C&Dw management in Italy, showing the good results in reaching the levels of waste recycling and re-use established by the European Union reaching a level of 75.1% of C&D waste material prepared for being recycled. Nevertheless, more changes and improvements must be achieved. Another aspect to be addressed is the management of the waste that is not recycled. In 2012 even if 76% of the C&Dw was recycled, 24% went to landfill [22]. Thus, still a significant amount of C&Dw is ending up in landfilling sites but still, the recycling percentage is steadily increasing. The most widely recycled material is mineral waste, in which only 3% reaches landfill waste disposal; other materials still suffer the distrust from the user, poor source separation waste and lack of selective demolition practices [23]. A lot of challenges are faced during the attempt of higher percentages of C&Dw recycling. These can be summarised as:

- Distrust in the use of secondary raw materials
- Lack of updated performance assessing tools for secondary raw materials
- Lack of primary and adequate data about inert waste production
- Poor source separation waste and use of selective demolition practices
- Lack of mining taxation
- Lack of prohibition or obligation to contribute to landfilling of inert waste
- Obligation to carry out analysis for waste sent for recovery/recycling

The Italian government has developed the "Towards a Model of Circular Economy for Italy - Overview and Strategic Framework" to support the circular transition of Italy through specific guidelines, circularity assessment indicators, circular procurement and production schemes, traceability of materials and products, and progress monitoring tools. Once even these aspects are addressed, this can continue the path to better management towards sustainability and good practices.

References

[1] EUROPEAN COMMISSION, "COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL

COMMITTEE AND THE COMMITTEE OF THE REGIONS A new Circular Economy Action Plan For a cleaner and more competitive Europe," Mar. 2020. Accessed: Oct. 28, 2021. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0098

[2] ISPRA - Istituto Superiore per la Protezione e la Ricerca Ambientale, "Rapporti Rifiuti Speciali: Edizione 2021," Rome, Jun. 2021.

[3] Zanchini Edoardo and Nanni Gabriele, "Rapporto Cave 2021:La transizione dell'economia circolare nel settore delle costruzioni," Rome, Jun. 2021.

[4] V. Bilsen *et al.*, "Development and implementation of initiatives fostering investment and innovation in construction and demolition waste recycling infrastructure," Brussels, Feb. 2018.

[5] Canavese Paolo, Mondini Nicola, Zambito Pasquale, Bianco Antonio, Simonelli Angelo, and Pavan Simone, "Gli Aggregati riciclati nelle opere edili pubbliche e private: le opportunità ambientali ed economiche," Valle D'Aosta, 2018. Accessed: Oct. 29, 2021. [Online]. Available: www.anpar.org

[6] EC IES, *Supporting Environmentally Sound Decisions for Construction and Demolition (C & D) Waste Management*, vol. EUR 24918. 2011. doi: 10.2788/54618.

[7] M. R. Munaro, S. F. Tavares, and L. Bragança, "Towards circular and more sustainable buildings: A systematic literature review on the circular economy in the built environment," *Journal of Cleaner Production*, vol. 260, 2020, doi: 10.1016/j.jclepro.2020.121134.

[8] C. Oreto, F. Russo, R. Veropalumbo, N. Viscione, S. A. Biancardo, and G. Dell'acqua, "Life cycle assessment of sustainable asphalt pavement solutions involving recycled aggregates and polymers," *Materials*, vol. 14, no. 14, 2021, doi: 10.3390/ma14143867.

[9] I. T. Mercante, M. D. Bovea, V. Ibáñez-Forés, and A. P. Arena, "Life cycle assessment of construction and demolition waste management systems: A Spanish case study," *International Journal of Life Cycle Assessment*, vol. 17, no. 2, pp. 232–241, 2012, doi: 10.1007/s11367-011-0350-2.

[10] M. Arm, "Self-cementing properties of crushed demolished concrete in unbound layers : results from triaxial tests and field tests," *Waste Management*, vol. 21, no. 3, pp. 235–239, 2001.

[11] I. L. Ciclo and D. E. I. Rifiuti, "Il ciclo dei rifiuti," pp. 1–23, 2010.

[12] D. Lgs. 36/03, "Attuazione della direttiva 1999/31/Ce relativa alle discariche di rifiuti," *Gazzetta Ufficiale della Repubblica Italiana*, vol. 59–12/03/2, p. 48, 2003.

[13] M. Paleari, A. Campioli, D. Di, and E. Residenziali, "I RIFIUTI DA COSTRUZIONE E DEMOLIZIONE: LCA DELLA DEMOLIZIONE DI 51 EDIFICI RESIDENZIALI," pp. 47–62, 2020.

[14] Ministero dell'Ambiente e della Tutela del Territorio e del Mare and Ministero dello Sviluppo Economico, "Towards a Model of Circular Economy for Italy," 2017.

[15] J. Cárcel-Carrasco, E. Peñalvo-Lòpez, M. Pascual-Guillamón, and F. Salas-Vicente, "An overview about the current situation on c&d waste management in italy: Achievements and challenges," *Buildings*, vol. 11, no. 7, 2021, doi: 10.3390/buildings11070284.

[16] I. Del Rey, J. Ayuso, A. P. Galvín, J. R. Jiménez, and A. Barbudo, "Feasibility of using unbound mixed recycled aggregates from CDW over expansive clay subgrade in unpaved rural roads," *Materials*, vol. 9, no. 11, 2016, doi: 10.3390/ma9110931.

[17] S. Iodice, E. Garbarino, M. Cerreta, and D. Tonini, “Sustainability assessment of Construction and Demolition Waste management applied to an Italian case,” *Waste Management*, vol. 128, no. June, pp. 83–98, 2021, doi: 10.1016/j.wasman.2021.04.031.

[18] K. Mantalovas and G. Di Mino, “Integrating circularity in the sustainability assessment of asphalt mixtures,” *Sustainability (Switzerland)*, vol. 12, no. 2, pp. 9–12, 2020, doi: 10.3390/su12020594.

[19] K. Mantalovas and G. Di Mino, “The Sustainability of Reclaimed Asphalt as a Resource for Road Pavement Management through a Circular Economic Model,” *Sustainability*, vol. 11, no. 8, p. 2234, 2019, doi: 10.3390/su11082234.

[20] K. Mantalovas *et al.*, “European national road authorities and circular economy: An insight into their approaches,” *Sustainability (Switzerland)*, vol. 12, no. 17, 2020, doi: 10.3390/su12177160.

[21] K. Mantalovas, “Increasing the Circularity of asphalt mixtures : Integrated Sustainability and Circularity Assessment as a progress monitoring tool towards more Circular and Sustainable asphalt pavements Increasing the Circularity of asphalt mixtures : Integrated Sustain,” University of Palermo, 2021.

[22] Universidade NOVA, “Screening Template for Construction and Demolition Waste Management in Italy,” no. October, 2015.

[23] European Commission, “EU Construction & Demolition Waste Management Protocol,” *Official Journal of the European Union*, no. September 2016.