Lecture Notes in Civil Engineering

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4th International Conference "Coordinating Engineering for Sustainability and Resilience" & Midterm Conference of CircularB "Implementation of Circular Economy in the Built Environment"

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Lecture Notes in Civil Engineering 489

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ISSN 2366-2557 ISSN 2366-2565 (electronic)
Lecture Notes in Civil Engineering
ISBN 978-3-031-57799-4 ISBN 978-3-031-57800-7 (eBook)
https://doi.org/10.1007/978-3-031-57800-7

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The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

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Preface

As Organizers of the CESARE 2024 and CircularB Midterm Conference, we are honoured to present the Proceedings of the 4th International Conference on "Coordinating Engineering for Sustainability and Resilience" and the Midterm Conference of the COST Action CircularB on "Implementation of Circular Economy in the Built Environment", held in Timişoara, Romania, from the May 29th–31st 2024.

This volume, published in Open Access by Springer, a prestigious publishing company, embodies our commitment to disseminating critical research and innovations in Engineering for Circular Economy, Sustainability and Resilience.

Society and governments require a more efficient and sustainable built environment. An emergent trend is the Circular Economy, which aims at decoupling economic growth from resource consumption. Construction has been identified as a field of action by the European Commission's Circular Economy Action Plan.

The 4th International Conference on the *Coordinating Engineering for Sustainability and Resilience* & Midterm Conference of CircularB *Implementation of Circular Economy in the Built Environment* is co-organized by the Steel Structures and Structural Mechanics Department of the Politehnica University Timişoara, in co-operation with the Romanian Academy, the School of Engineering of the University of Birmingham, the Faculty of Engineering of the Jordan University of Science and Technology, the COST Action CA21103 "Implementation of Circular Economy in the Built Environment" and the Technical Sciences Academy of Romania.

The CESARE 2024 and Midterm CircularB Conference is devoted to the presentation of the most recent results and to the discussion of key issues concerning the contribution of Coordinating Engineering to Sustainability, Circular Economy and Resilience in modern and future built environment, constructions, and infrastructure.

One of the main goals is to promote an exchange of ideas that inspires innovative research paths and fosters new collaborative endeavours. We expect to have an impact on the future research and development activity in all topics included in the programme.

169 authors from 31 countries on five continents are contributing with 63 scientific papers and two Keynote Lectures, covering ten topics, i.e.

1. *Sustainable Infrastructures:* This chapter lays the foundation for integrating sustainability into infrastructural development, highlighting innovative practices that minimize environmental impact while enhancing social and economic benefits;
2. *Structural Engineering:* Focusing on the core principles of engineering for resilience and sustainability, this chapter discusses cutting-edge designs and technologies that ensure the longevity and durability of structures in the face of environmental challenges;
3. *Energy Systems and Structures:* Examines the integration of sustainable energy systems within built environments, showcasing solutions that reduce energy consumption and carbon footprint;

4. *Innovation in Materials, Products, and Systems:* Highlights revolutionary materials and systems that are setting new standards for sustainability and efficiency in construction and design;
5. *Circular Value Chains and Stakeholders Engagement:* Discusses the importance of creating circular value chains and engaging stakeholders in collaborative efforts to foster a Circular Economy within the built environment;
6. *Circularity KPIs and Criteria for Material, Flow and Design Assessment:* Details the key performance indicators and criteria essential for assessing and optimizing circularity in materials, design, and workflow processes;
7. *Circular Business Models and Economic Viability of Circularity Solutions:* Analyses various circular business models, emphasizing their economic viability and potential to drive sustainable industry practices;
8. *Environmental Impact of Circularity Strategies and Solutions:* Explores the environmental implications of circularity strategies, focusing on their potential to mitigate environmental degradation and promote sustainability;
9. *Standards and Regulations:* Provides an overview of the current standards and regulations that shape sustainable and circular practices in the built environment, highlighting challenges and opportunities for policy development;
10. *Digitalisation and BIM for Circular Design and Evaluation in Construction:* Concludes with an examination of how digitalisation and Building Information Modelling (BIM) are revolutionizing circular design and construction, offering new pathways for efficiency and sustainability.

The contributions within these pages are a demonstration to the constant pursuit of knowledge and innovation by our global community. They cover a vast array of topics, from Sustainable Structural Engineering to the implementation of Circular Economy principles in the built environment, all aimed at addressing some of the most pressing challenges of our times.

It is our hope that this Open Access publication will serve not only as a repository of high-quality research but also as a catalyst for further study, discussion, and innovation. By making these contributions freely available, we aim to ensure they are consulted, cited, and impactful, driving positive change in our society and beyond.

We extend our deepest gratitude to all contributors, reviewers, and our publishing partners at Springer for their invaluable support in bringing this work to the broader community. May this Book of Proceedings inspire and facilitate ongoing efforts to engineer a sustainable and resilient future for all.

The Organizers of the CESARE 2024 and CircularB Midterm Conference.

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Italian Regulations and Local Initiatives for Circular Economy in the Construction Sector

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Abstract. European Member States are required to promote initiatives and programs to shift their traditional linear economy into circular economy. The paper shows the Italian initiatives towards circular economy in the built environment, across different application level (national and local) and different drivers (top-down and bottom-up). The method of investigation regards an on-field research based on direct dialogue with various stakeholders of construction sector in the national context. The results show the current barriers to circular material flows and the successful initiatives in Italy. Firstly, the top-down strategies are reported, as well as existing standards, national regulations and local policy. Secondly, the bottom-up strategies are shown, stressing the local stakeholders involvement. Based on the discussion, potential improvements are highlighted to align the current Italian initiatives with the broader European Commission circular economy objectives, considering also the best practices developed in other European countries.

Keywords: Circular Economy · Policy Framework · Stakeholder Engagement · Reuse · Recycling · Design for Reversibility

1 Introduction

The construction sector is particularly relevant for achieving a circular transition, since it causes approximately 50% of all material extraction and 37.5% of total waste production, at European level [1]. Furthermore, it is responsible for 40% of primary energy demand in the EU and 36% of greenhouse gas emissions [2].

Circular economy, declared as a priority in the context of European policy [3], aims at a sustainable economic system and a resource efficiency by preserving the added value of products as long as possible. The circular economy objectives, highlight the relevance of waste management, underlining the implementation of the waste hierarchy (prevention, reuse, recycling, energy recovery and, lastly, landfill), already defined by the Waste Framework Directive 2008/98/EC.

Circular economy has been re-proposed by the European action plan [4], underlines the importance of strategies oriented towards the re-design of products and processes, based on sustainable consumption models.

V. Ungureanu et al. (Eds.): CESARE 2024, LNCE 489, pp. 615–624, 2024.
https://doi.org/10.1007/978-3-031-57800-7_57

The transition towards circular economy, recently, is even more important as it is part of the six environmental objectives of the Taxonomy [5], which allows the definition of sustainable activities (avoiding greenwashing), relating to every economic sector including, therefore, construction.

Currently, the topic promoted by European policy most discussed in literature is related to the improvements in circular management of inflow and outflow materials from the building process, improving waste identification and quality processing, flow management and planning during the construction phase and the end of life [6]. Other studies propose the reuse strategy as the best practice of building materials management [7]. Further studies are focused on the quantification and mapping of secondary materials stored in products, buildings and infrastructures, for the geolocation of reusable and recyclable urban material resources [8].

Another important topic is related to the change in design process to circularity. Reversibility, adaptability, flexibility, and design for disassembly are the main strategies to extend products and buildings' useful life [9]. Construction technologies, as well as modular elements, dry technologies, mechanical connections, off-site constructions, are relevant enablers to achieve a circular design process. Several studies agree with the importance of Building Information Modeling (BIM) to monitor the use of resources during the whole life cycle, sharing information between operators and simulating building and components reuse scenarios [10].

Nevertheless, in practice, circular economy strategies are rarely applied at the building level in a systemic manner and in a life cycle perspective. Moreover, there is still different and fragmented circular strategies application in the European countries, highlighting the need for more effective and coordinated actions and policies promoted by European Commission [11].

In this paper the circular economy application in the Italian context is presented in depth, showing the top-down and bottom-up initiatives in the Italian context, both at national and at local level. The scope of paper is to give an in-depth investigation, useful for policymakers, on the Italian level of alignment to the European target on circular economy, highlighting barriers and opportunities for improvement.

2 Method of Investigation

The results come from an on-field research based on direct dialogue and semi-structured interviews with various stakeholders of construction sector at national scale, favoring the medium-large sized companies: policymakers, manufacturers, designers, investors, constructors, facility managers and waste managers. The sampling procedure is based on a "reasoned" selection of stakeholders, which concerns operators with experience within circular strategies. This allowed to proceed with the identification of the expected results, concerning the current barriers for material circularity and the best successful initiatives at national and local Italian context.

3 Current Barriers to Circular Material Flows in Italian Context

Statistics show that in Italy 76% of waste from demolition and construction (excluding excavated earth) is recycled or recovered, therefore the objective established by the Waste Framework Directive (WFD) (Directive 2008/98/EC) is achieved [12]. However, the largest quantity of construction and demolition waste (CDW) in Italy is made up of inert materials, which represent 75–85% of the total CDW [13]. The percentage of the WFD is consequently satisfied only by the treatment of the aggregates, not considering other lighter fractions of construction and demolition waste, such as materials of synthetic origin, which may have a higher potential for reuse and recycling. Furthermore, the WFD only requires sending for recovery, and this does not always lead to effective recycling. In particular, recycled aggregates are used for road foundations and fillings, therefore downcycled.

To overcome this situation towards more effective circularity, the analysis conducted across Italian practitioners shows economic, logistical and cultural barriers currently existing in Italy.

Italy has a large territorial surface and a lot of natural resources available for the production of building materials, such as aggregates for the production of concrete, clay for the production of bricks, etc. which constitute the majority quantity of construction material. Therefore, in Italy, resource extraction is relatively cheap, and on the economic point of view, stakeholders are not incentivized to find a more sustainable resource utilization and management through recycling and reuse.

Moreover, Italy does not have restrictive regulations or tax on extraction of raw materials, hence the use of raw materials is sometimes more economically advantageous than the use of secondary ones.

The lack of market demand for recycled materials caused long periods in storage centers of resources. In fact, sometimes, recycling plants earn more from the collection of inert waste rather than from the sale of secondary raw materials.

On the other side, in Italy there are not restrictive landfill ban, resulting in lower landfill fees. The landfill price can vary by region (law 549/1995 on solid waste landfill costs) and sometimes it can be comparable or more advantageous to the gate fee of recycling plant. Consequently, there is a lack of interest in improving the quality of demolition waste, to prefer reuse or recycling rather than landfill. This is also caused by the lack of pre-demolition monitoring which could stimulate greater waste differentiation.

Logistical barriers represent a further obstacle for recycling practices: transport distances lead to neutralizing the economic and environmental advantages. For a small quantity of waste, generated in medium or small demolition works, a long distance from the treatment plant can lead to prefer landfill, if it is closer.

In terms of design process, through discussion with stakeholders, it also emerged that in cases of building refurbishment or demolition and new construction, the need to reduce process times leads to an overlap of building operation, e.g. demolition practices at the same time of refurbishment executive design. Consequently, the materials emerging from the demolition process (e.g. false ceilings, floors, bathroom fixtures, etc.) do not find a destination within the refurbishment intervention (as they have already been disposed before the drafting of the definitive and executive project), thus resulting in the generation of waste related to products often still in good condition. Moreover, the traditional

Italian constructive techniques (load-bearing structure in reinforced concrete, brick-cement floors and brick walls with plaster finish), do not facilitate the separation of valuable materials potentially reusable.

4 Successful Top-Down Initiatives at National and Local Italian Level

Top-down initiatives include actions and policies activated at the highest level, such as by government or Public Administrators. The national legislation is fundamental for influencing the practices towards circularity, for example encouraging the market of secondary materials, facilitating the waste management and circular building process.

From a circular point of view, it is decisive to consider the materials coming out from construction processes no longer as waste but as resources, introducing regulation related to the 'End of Waste' (EoW). The 'EU Construction and Demolition Waste Management Protocol' [14] highlights the particular commitment within national policies aimed at defining EoW decrees.

In recent years, Italy has worked on the definition of the EoW criteria for inert construction and demolition waste (Decree 152/2022). The EoW decree defines the recovery process of construction and demolition waste and the transformation process to be able to classify it as a new product. In Annex 2, the technical standards for the use of recycled aggregate considers not only the use for construction of civil engineering earthworks, road, railway and airport foundations, but also the use to produce new concrete (harmonized with UNI EN 12620).

However, this Italian EoW decree only concerns inert waste. There are still not reference legislation related to other types of products and materials. Moreover, the need for coordination and harmonization of EoW policies among Member State is still under discussion.

An important initiative to encourage the reduction of raw materials consumption and landfill in Italy is represented by Green Public Procurement (GPP) (Legislative Decree 50/2016), according to which Public Administrations must integrate Minimum Environmental Criteria (CAM) in the field of public tenders. CAM (approved with Ministerial Decree 256/2022) requires several sustainability strategies across the building process (design, construction, maintenance, end of life) and some strategies fully achieve the circular economy objectives.

There are mandatory requirements about minimum percentage of recycling content in building products (e.g. concrete, steel, bricks, each type of insulating material, etc.) and about disassembly of construction parts.

The percentage value of the recycled material content must be demonstrated through a certificate in which this information is clearly reported, for example Type III environmental product declaration (EPD), 'ReMade in Italy' certification and other certified label.

Moreover, a particular CAM requirement is related to the disassembly and end of life: at least 70% (by weight) of the building components, excluding systems, must be disassembled at the end of their life to then be subjected to preparation for reuse, recycling or other recovery operations. The designer must declare the 'plan for disassembly and

selective demolition', based on the ISO 20887 standard 'Sustainability in buildings and civil engineering works – Design for disassembly and adaptability – Principles, requirements and guidance', or UNI/PdR 75 'Selective deconstruction – Methodology for selective deconstruction and waste recovery from a circular economy perspective' or on the basis of any information on the disassembly of one or more components, provided by the EPDs compliant with UNI EN 15804.

In the context of public building, another successful Italian top-down initiative regards the use of BIM during the design phase. BIM enables efficient information sharing throughout the supply chain, reducing the risk of building design errors and waste during the construction phase [15].

In compliance with the Italian Ministerial Decree 560/2017, in public works, the use of BIM digital tools is mandatory, in order to allow the interoperability and usability of building project information by each operator during the design, construction and management process. The mandatory use of BIM concerns projects that exceed a cost limit. This cost limit decreases every year and by 2025 it will affect most of the public projects.

Locally top-down initiatives are less frequent. A local successful initiative is the 'Lombardy Roadmap for Research and Innovation on Circular Economy', developed in 2019, that intends to provide a framework for the development of a circular economy transition in the Lombardy Region, with the aim to stimulate the cooperation between public and private stakeholders and build strategic initiatives on circular economy. The document provides detailed descriptions of the strategic research and innovation priorities to the related phase of circular economy value chain. Hence, the structure is organized across production/design, distribution, use/service maintenance, collection, remanufacturing/repair, recycling and feedstock.

The 'Lombardy Roadmap' introduced circular economy as one of the main drivers to foster the development of emerging industries in the Region. Strategies to boost circular economy in the Region were set starting from the needs and the priorities collaboratively pointed out by diverse regional stakeholders.

5 Successful Bottom-Up Initiatives in Italian Context

Bottom-up initiatives refers to the strategies derived from stakeholders' activities, defined by groups of operators, such as investors, manufacturers, designers, etc.

For example, the voluntary initiatives to obtain building sustainability certification (e.g., a green building rating systems) influence the building process towards circularity and sustainability, with added value in terms of increasing building economic value, lowering maintenance costs, and enhancing wellbeing and visibility for occupants.

In Italy, the use of Green Building Ratings Systems (e.g. LEED, CasaClima) is often encouraged by the fact that in some urban context sustainability certification increases the commercial value of the building. This objective, which is increasingly requested by investors, influences the choices of intervention and practices along the process, determining compliance with the sustainability and circularity criteria to be achieved in order to obtain certification.

The choice to respect criteria of a sustainability protocol (in Italy the most used are LEED and BREEAM), influences the decisions and behaviors of operators. For

example, the management of waste and the traceability to recycling are supervised by the LEED Accredited Professional (LEED AP). The building sustainability certification encourages, also, the use of LCA as a tool to demonstrate the actual environmental impacts avoided by materials and construction solutions.

In general, the building sustainability certification reward mechanisms favor the development of circular practices not yet commonly applied and helps to optimize the material use and to lower costs for all the stakeholders.

Included in the bottom-up initiatives are the voluntary adhesion to organized working groups or focus group among the stakeholders of the building value chain, to set a virtual place useful to share knowledge and experiences on circular economy. The goal is to collect, develop and disseminate circularity procedures in the construction sector and best practices, providing information on current standards and figure out future development advisable to government.

In this context, in 2017, the European Commission and the European Economic and Social Committee (EESC) created the European Circular Economy Stakeholder Platform (ECESP), a European platform that would activate networks between stakeholders at local, regional and national levels, for the exchange of ideas and information.

At Italian national level, ICESP (Italian Circular Economy Stakeholder Platform) has been configured as ECESP 'spin-off' to collect initiatives, experiences and critical issues on the circular economy in Italy, and then communicate them to the ECSP European network. ICESP working groups favor dialogue and synergies between institutions, central and local public administration (which make up 8.7% of the total participants), citizens and third sector (which representing 10.4%), training and educational sector, research and innovation (18.1%) and trade companies and associations, which constitute the predominant reality within the ICESP network (62.8% of the total participants). The working group give useful output (surveys, report, position papers, etc.), aimed at encouraging top-down initiatives by policy makers [16]. In Italy, another active working group on circular economy is related to the bottom-up initiative of Green Building Council Italia. This working group is composed by designers, constructors, manufacturers, investors, universities, building sustainability experts, etc. For example, an output is a position paper that identifies 13 key actions for the transition to the circular economy in construction sector specific for Italy [17].

6 Discussion

Against the obstacles that persist in Italy to improve the circularity of material flows, the previous paragraphs show that there are also several successful initiatives to overcome the barriers.

However, the circular transition is still slowing down, and the reason is probably due to the fact that the incentives do not concern all types of building materials (the EoW concerns only aggregates) and not all types of buildings (the CAM applies only to public buildings). Furthermore, local initiatives are fewer and not equally distributed throughout Italy.

The lack of specific restrictive regulations (e.g. for landfills and resource extraction) causes less awareness among stakeholders who have not understood the actual (economic) benefit of the commitments required by top-down initiatives.

In fact, exploring some European examples, countries which statistically show a higher rate of waste recovery (i.e. avoiding landfill) have waste regulations (even also prior to the WFD). For example, Germany has introduced the 'Kreislaufwirtschaft Bau' (Circular Economy in Construction) initiative since 1995, as a voluntary commitment to reduce the quantities of construction and demolition waste sent to landfill, which has led to high waste recovery rates. Belgium, Netherlands, United Kingdom and Denmark, have legislation establishes specific bans or taxes to increase the fees of landfills. The high cost of landfill tax encourages stakeholders to prefer other types of waste destinations, and practices of reuse and recycling is more frequent.

Belgium and the Netherlands have a different contextual characteristic from Italy, in fact the scarcity of raw materials favor the recycling of existing materials. Instead, United Kingdom presents, as well as Italy, a territory with huge quantity of inert raw materials: hence, to promote secondary materials economically advantageous, United Kingdom imposes an Aggregates Levy.

In Italy, while recycling (mainly downcycling) reaches the statistical recovery rate of 76%, instead the practice of reuse is still poorly applied in practice (as happen in other European countries). Reuse is still poorly applied in practice because there are still several barriers. The analysis of the stakeholders' perspectives highlights the lack of legislation related to the tests, quality, performance and technical process necessary to certify the reused materials (without certification the materials are not used for liability reasons).

Stakeholders also highlighted challenges from technological aspects: current constructive systems are not designed for disassembly; therefore, it is difficult not to damage the elements during disassembly. Disassembly is also more expensive than demolition due to the use of manpower. Moreover, logistic system for reused materials has not yet been developed.

To achieve more efficient end-of-life material flows towards reuse, traceability system is needed to monitor all material/waste fractions and cover the entire process, also considering the possibility of avoiding waste through the extension of the life cycle of the building parts (not only when demolition has already been decided).

It is essential to define, at the Italian level, a system for the traceability of building and demolition waste, also through the introduction of pre-demolition audit tools. It is then essential to improve the traceability of the components of the building in order to map its "history" and its use, and therefore promote its reuse.

The introduction of the material passport [18] could be a solution for increasing knowledge about the materials stored inside the building, raising the chances of reuse and recovery.

In fact, materials passport maintains knowledge of all building materials in the long term, preserving their (economic) value. Material passport systems and databases can interact with BIM software and can be available to all users involved. Through a shared material passport system, it is also possible to know the quantity and the location of materials stocked in the urban mining. Nevertheless, legislation on mandatory use of material passports has not yet been introduced in Italy, and a common definition and harmonized tools/systems are lacking [19].

Moreover, it is necessary to encourage a building process that create relationships among stakeholders (in particular designers, constructors, manufacturers, and demolishers) in order to share knowledge and information to improve the change in design process towards circularity. If in Italy BIM is quite diffuse and incentivized by legislation, and the disassemblability of construction is required by CAM, there is not yet a wide choice among reversible construction solutions.

In fact, most of the time, the reuse of products is hindered by the impossibility of obtaining materials that are still in good condition following demolition activities (due to demolition practices that damage the products).

From a sustainability point of view, circular strategies could only apparently bring environmental benefits in a single life cycle phase. It is possible that circular strategies shift environmental impacts to other life cycle phases. For example, promotion of recycling considers the environmental benefit of avoiding landfill disposal, but without considering the environmental implication of the recycling process activities (transport, reprocessing, etc.). Hence within the promoting initiatives towards circular economy, it is necessary to emphasize improvements towards sustainability (not only circularity) combining the use of tools based on Life Cycle Assessment methodology in order to evaluate the most environmentally sustainable solutions, both for material construction solutions and for building end-of-life management.

It is therefore necessary to promote the use of Life Cycle Assessment (LCA) in upstream, during the decision-making process, to improve a planning process for waste prevention, and in downstream, during the phase of waste management and the end-of-life process. Consequently, it is important to develop supporting tools easily usable by operators or introduce professional support figures prepared for the use of more inclusive tools.

7 Conclusion

The paper shows that Italy still presents various barriers for the activation of circularity and material efficiency processes, also related to the fragmented and discontinuous relationships of the operators in the sector.

Some policy recommendations to promote circular economy in the construction sector, at Italian level, are summarized below:

- the improvement of traceability of materials/waste, through the development of traceability systems, which act on national context, but which are harmonized with initiatives at European level;
- the management of construction waste and demolition waste separately, in relation to their different reuse/recycling potential;
- the establishment of a maximum percentage of construction waste allowed on site, encouraging the collection and reuse chain of construction site scraps and waste;
- the definition of End of Waste criteria for all types of waste materials;
- the establishment of a taxation on raw materials and on the disposal of waste to landfill: this in order to reduce the extraction of raw materials (for example by prohibiting the opening of new quarries) and to encourage the reuse and recycling of products;

– within the GPP, the definition of rewarding criteria relating to ambitious percentages of reuse and reusability rate of the building products;
– within the GPP, the introduction of LCA requirements, supporting the operators by trainings and methodological standards.

To achieve circular economy in the built environment, initiative at national and local level is important as well as the international coordination and harmonization in terms of policies, practices and enabling tools. Moreover, the promotion of cooperation between stakeholders of the building value-chain is priority to allow co-creation of techniques and the diffusion of knowledge and awareness of circular strategies among stakeholders. Future improvements should concern the fields of new circular business models within win-win solutions, based on services, support tool for environmental assessment, and training program towards new skills and competence to enable circular building process.

Acknowledgements. The authors of this paper would like to thank the European Union for funding and COST (European Cooperation in Science and Technology) for supporting the COST Action CircularB CA21103 (www.circularb.eu).

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V. Ungureanu et al. (Eds.): CESARE 2024, LNCE 489, pp. 711–713, 2024.
https://doi.org/10.1007/978-3-031-57800-7