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Welcome Message by the Conference Chair

Associate Professor Dr. Rasyikah Md. Khalid

Dear delegates of the 29th ISDRS Conference 2023,

The Faculty of Law, Universiti Kebangsaan Malaysia, UKM (or the National University of Malaysia), was proud to be the main organizer of ISDRS 2023. We were very grateful to be supported by our co-organizers: IDEA UKM, Institute of Fuel Cell UKM, Institute of Visual Informatic UKM, Institute of the Malay World and Civilization UKM, UKM-Graduate School of Business, Hadhari Institute UKM and UKM Strategy Center.

We were fortunate to receive 377 abstracts from researchers in 41 countries. This is, by far, the highest number of submissions in ISDRS conferences in the Asia continent, after Hong Kong and Nanjing. ISDSR conference in Europe generally attract around 400 abstracts, and we nearly hit that target.

ISDRS 2023 provided the platform for ISDRS members, mostly from Europe, to learn about the issues and progress in sustainable development in ASEAN. Likewise, ASEAN delegates benefited from the intellectual discourse and found new collaboration networks.

ISDRS2023 also introduced special themes on ASEAN, Religion, and IR4.0, led by UKM scholars.

The Malaysia conference took place in the middle of Agenda 2030, seven years and a half after SDGs were first launched in 2015 and seven years and a half more toward 2030. Papers presented at ISDRS 2023 have assessed the 5P of SDGs: people, planet, prosperity, peace, and partnership.

I hope that international delegates have enjoyed your stay in Malaysia. Beautiful moments of the sustainable field trips to Malacca, a UNESCO world heritage site, and to the Forest Research Institute of Malaysia or FRIM, a UNESCO tentative list as the oldest and largest man-made forest in the world, have been recorded in the conference album on the website.

My heartful gratitude goes to all delegates for making ISDRS 2023 a success, and I hope to see you all in Kathmandu, Nepal, for ISDRS 2024.

Rasyikah Khalid,

Chair, ISDRS 2023.

Keynote Address

Matthew Baird

Matthew Baird has over 32 years' experience in environmental and planning law in the Asia-Pacific Region. He was admitted to the Australian Bar in 1991 and practiced for 25 years in environmental and planning law. Matthew has consulted to the Asian Development Bank, UNEP, UNDP, IFC, WWF, PACT, and Vermont Law School, providing capacity building and training on programs on environmental law and advocacy in Asia and the Pacific since 2010. He has worked on environmental law and governance issues, including EIA, hydropower, water governance issues and public participation in ASEAN since 2010. He was a member of the Technical Working Group for the drafting of the Cambodian Environment and Natural Resources Code 2023. He is an Honorary Research Fellow at the Myanmar Centre for Responsible Business and a Fellow of the Environment Institute of Australia and New Zealand. His doctoral dissertation at the University of Southern Queensland is on EIA in ASEAN. He was appointed a Teaching Fellow of the College of Law (Australia) in 2021 and leads the ESG Law and Practice Group.

Plenary Speakers

Mazlin Bin Mokhtar

Emeritus Professor Dato' ChM. Dr Mazlin Bin Mokhtar is the Deputy Head (Research), & Director, Ecological Systems Program, United Nations Sustainable Development Solutions Network Asia Headquarters (UN SDSN ASIA) at Sunway University. He was the Director of the Institute of Environment and Sustainable Development and the Vice Chancellor (Research and Innovation) in Universiti Kebangsaan Malaysia (UKM).

Karlene Maywald

The Hon. Karlene Maywald is the Deputy Chair of ICEWaRM. Karlene was the representative for the seat of Chaffey in the South Australian House of Assembly from October 1997 until March 2010. During her tenure, from 2004 until 2010, she was South Australia's Minister for Water Security and the River Murray during one of the worst drought periods in living memory. She has a proven, long-standing track record in water management and is passionate about water reform in Australia.

Ahmad Parveez Ghulam Kadir

Datuk Dr. Ahmad Parveez Ghulam Kadir is the Director General of the Malaysian Palm Oil Board (MPOB) since 2019. He has more than 30 years of experience in the oil palm industry with expertise in the field of plant molecular biology, genetic engineering and biosafety. He has developed transgenic oil palm and has gained recognitions both locally and internationally and filed 15 patents. He is also an active member of the International Society for Oil Palm Breeders (ISOPB) president and American Oil Chemists' Society (AOCS) Asian Section chairman.

Weena Gera

Weena Gera is Associate Professor of Political Science and former Vice Chancellor for Administration (2019-2022) at the University of the Philippines Cebu. She has published and consulted on various governance analyses in the Philippines and Southeast Asia. In 2018, she was among the five recipients of the Gro Brundtland Award for Women in Sustainable Development. In 2019, she was conferred the Bernd Rode Award in the Senior Researchers category by the ASEA-UNINET for her research project on ecosystem services toward sustainable mineral development in the ASEAN.

Lance Manuel

Lance Manuel is the Texas Atomic Energy Research Foundation Professor of Engineering at the University of Texas at Austin. He is a Fellow of the American Association for the Advancement of Science (AAAS), the American Society of Civil Engineers (ASCE), and the American Society of Mechanical Engineers (ASME). He serves on the Marine Board of the National Academies of Sciences, Engineering, and Medicine (NASEM). He is the Editor-in-Chief of the ASME Journal of Offshore Mechanics and Arctic Engineering. For over 25 years, he has been active on projects related to renewables, primarily wind energy.

Olena Shevtsova

Olena Shevtsova is a guest researcher at Södertörn University in Stockholm, Sweden. She has been working upon a theory on stakeholder partnership in public administration. She has speaking at global level as EGRISS Steering Committee member (Expert Group on Refugee, IDP and Statelessness Statistics), participated in UN recommendations development BG-4e-EGRISS-IROSS-E.pdf (un.org), speaker at high-level events - UN World Data Forum, expert meetings of UNECE, UN ESCAP.

Stella Emery Santana

Professor Stella Emery Santana is a Professor of environmental law at FAESA Centro Universitario Brazil since 2006, and has been the director of the international program since 2009. She is a private consultant for international and environmental law issues. She has been the chairperson for the Espírito Santo state bar environmental commission for two terms, and was a volunteer in this commission until 2017. In 2016, she worked with the president of the Espírito Santo Environmental Agency as the environmental and administrative law consultant for the Samarco mining dam breakout that occurred in November 2015.

Olawale Olayide

Olawale Olayide is the Secretary of ISDRS. He is a sustainability expert with research experience in the areas of Agricultural Economics, Food Systems, Climate Change, and Circular Economy. He currently works at the Faculty of Multidisciplinary Studies, University of Ibadan, Nigeria. He is the Convener of the annual Circularity Africa Conference, Pioneer President of the Africa Circular Economy Research and Policy Network, and Founder of the Interconnections for Making Africa Great Empowered and Sustainable (IMAGES) Initiative. He has cognate experience in partnerships and policy engagements in continental and global affairs.

Siti Kartom Kamaruddin

Prof. Ir. Dr Siti Kartom Kamarudin is the Professor of Chemical Engineering at Department of Chemcial & Process Engineering, UKM. She is now the Director of Fuel Cell Institute of UKM. She is a world expert in low carbon energy related to Fuel Cell and Hydrogen Technology. Her is the recipient of the WIPO Award for the Best Women Invention and Best Innovation Award from TIPPA. In 2016, she was awarded by `The World Most Influential Minds' as top 100 world scientist in engineering. Since 2016 to 2021, she is recognized as the `Highly Cited Researcher' by Clarivate as top 1% Cited Researchers in the field of Engineering.

İlknur Öner

Professor. Dr. İlknur Öner is a Professor of Sociology, and the Head of Disaster Research Center, Fırat University, Elazig Turkiye. She is a member of the National Sociological Association since 2000, and have been involved with the International Sosiological Association since the 1994 Bielefeld Congress. Cuurently she is a a board member of ISA and a newsletter co-editor which is published in English, Spanish, and Turkish since 2018. She is an active member of ISA group on Sociology of Childhood, Sociology of Disaster, Sociocybernetics, and Women, Gender, and Society.

Tomás B. Ramos

Tomás B. Ramos is a professor of sustainability assessment and planning at NOVA University Lisbon and senior researcher at CENSE, Center for Environmental and Sustainability Research. He is listed in the World's Top 2% Scientists, and currently the Executive Editor of the Journal of Cleaner Production (Elsevier, IF: 11.072), the Editor-in-Chief of the journal Cleaner Production Letters (Elsevier), and member of the Editorial Board of several leading scientific journals. He was the ISDRS Board of Directors (2013-2019), member of the Accreditation Council of the Order of Engineers of Portugal (2004-2010) and President of the Portuguese Environmental Engineering Association (1997-1999).

Rose Liza Eisma-Osorio

Atty. Rose Liza Eisma-Osorio, an environmental lawyer and professor at the University of Cebu School Of Law. She was elected in 2019 as Chairperson of the International Union for Conservation of Nature – Academy of Environmental Law (IUCNAEL) – the first Asian to lead the academy. She is one of the founders of the Philippine Earth Justice Center, Inc. (PEJC), which has filed several environmental cases, including the landmark decision of the Supreme Court in Resident Marine Mammals and Dolphins vs. Reyes, where she acted as the stewards of the dolphins and whales, to stop illegal oil exploration in marine protected area in the Philippines.

Antonio A. Oposa

Antonio A. Oposa Jr., President of The Law of Nature Foundation, is one of Asia's leading voices in the global arena of environmental law. He pioneered the practice of Environmental Law in the Philippines, and his work is known locally and internationally for establishing, in the highest court of law, the principle of inter-generational responsibility – that this present generation has a responsibility to protect the environment for future generations. He is an expert in environmental policy and law, governance and litigation; an effective and respected activist for forest and marine protected areas in his native country; and a true warrior for the environment.

Nini Shazrina A. Shamli

Nini Shazrina is the Director of Corporate Services of Landasan Lumayan Sdn Bhd (LLSB), a wholly owned subsidiary of Menteri Besar Selangor (Pemerbadanan) (MBI). She was involved in various corporate restructuring exercises within MBI to improve efficiency through optimization of resources. In 2022, she was transferred to LLSB, a state-owned entity to spearhead the rejuvenation of Klang River under Selangor Maritime Gateway (SMG) project. The SMG aims at sustainable management of the Klang River Basin, once heavily polluted. Her project unlocks the tourism potentials along the river and ensures citizen to enjoy the best quality of life.

Peter Dobers

Peter Dobers is the President of ISDRS. He is professor of business administration at Södertörn University in Stockholm since 2015. During the years 2016-2022, he was the dean and chairperson of the Faculty Board. From 2022, he is the program director of the 2-year master's program Leadership for Sustainable Development. In the summer of 2022, he was elected to the Knowledge Foundation's board. His current research includes corporate social responsibility, guided tours in the broadest sense, sustainable development of regions, and cities' future investments as sustainable cities.

Definition of design strategies for sustainability for fashion accessories of the Made in Italy footwear sector, through Life Cycle Assessment methodology. The case-study of a brass buckle for footwear by Santoni Srl.

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Abstract. The success of the Italian footwear sector is due to the entrepreneurial ability and typical organization of the industry, which is in the context of a "long production chain", consisting of a system of high-quality sub-suppliers. Today, considered the ever-increasing importance of the issues of environmental sustainability of products and production processes several BtoB companies in the footwear production chain have taken a proactive approach to environmental sustainability. The objective is to seek where their greatest environmental impacts reside and how to make improvements to make footwear components and accessories more sustainable and circular. Among the most critical products are brass accessories and their finishing process that generates pollutants that are difficult to recycle and dispose of. Therefore, the case study of Santoni Srl, represents a significant example of a preventive approach to sustainability, which can contribute to understanding the importance of using LCA-Life Cycle Assessment methodology to define ecodesign strategies to improve sustainability and circularity. The paper presents a case study of a company in the footwear sector that initiated this approach in line with the "Planet" target and SDG 12, moving toward more sustainable production processes and consolidating its green reputation.

1. Introduction

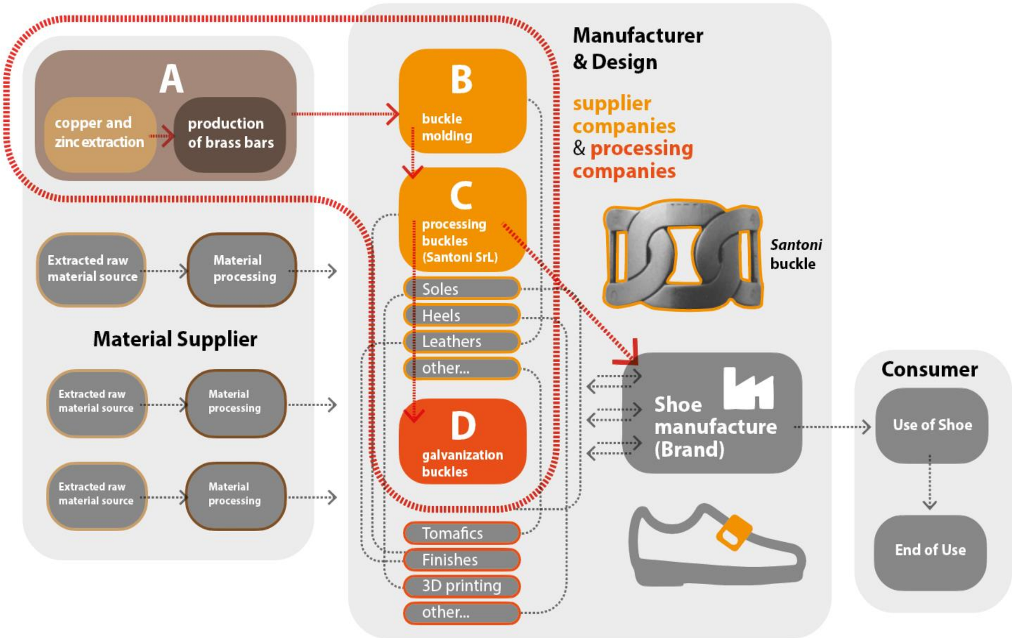
The Italian footwear sector is one of the pillars of the Made in Italy Fashion System and has always been a leader among the producers of high-end and luxury footwear. In 2021, Italy, is the first footwear producer in the European Union, and the eighth exporting country worldwide, in terms of volume, only second to China, in terms of value, (Apiccaps, 2022, pp.4-5). The success of the sector is related to the entrepreneurial capacity and to the typical structure of the sector, embedded in a context of Supply Chain, consisting of a high-quality sub-supply system of raw materials, tanneries, components, accessories, machine manufacturers, pattern makers and stylists. The result is, therefore, a territorial concentration of companies organized in areas and industrial districts, mainly located in seven Italian regions: Marche, Tuscany, Veneto, Campania, Lombardy, Puglia, and Emilia-Romagna.

The "long supply chains" of the footwear sector are characterized by the presence of a few large companies, holders of one or more brands, which deal with the creative and commercial phases, and many highly specialized small and medium-sized companies, which have high technical processing skills in developing footwear components and accessories. It is an economic-productive reality, which questions different sectors and protagonists, and attributes an important role to all the players in the supply chain (suppliers, sub-suppliers, etc.). As shown in figure 1, the supply chain is a heterogeneous system of companies dedicated to the manufacture of different materials (leather, leather, textile, rubber) and components that contribute to the production of the shoe (accessories, die-makers, sole factories, heel factories, insole factories), while others are services suppliers, aimed at commercial activities. This Italian district model has allowed to develop high quality products and to strengthen the competitiveness of Italian companies against their competitors, thus contributing to the global success of the footwear sector. However, today, given the ever-growing importance of the environmental sustainability issues of products, and production processes, the long-chain structure of the footwear sector creates greater complexity in the sustainable management of the entire supply chain: from the procurement of raw materials to the multiple processes and finishing of components, to the creation of accessories, up to the production and marketing of the final product. Furthermore, the final report of the study carried out by Quantis (2022, p.28), highlighted that more than 60% of the emissions from the production of a shoe are generated in the processing phases of the components and accessories, therefore upstream of the assembly and distribution phases. Indeed, it is precisely in the supply chain that it is necessary to intervene with environmental assessments of the components, to improve the environmental performance and the circularity of the final product. Therefore, component and accessory supplier companies, can play an important role in improving the environmental footprint of footwear and its supply chain, in turn becoming a stimulus for sustainable transformation of their suppliers and customers. Recently, several B-to-B companies in the footwear production chain, have adopted a proactive approach to environmental sustainability, seeking where their greatest environmental impacts lie and how to improve, to make the components and accessories of footwear more sustainable and circular (European Commission, 2020). The growth in this approach to sustainability and circularity of the footwear companies in the supply chain, manufacturers of accessories and components, is due to a market that is starting to demand greener products, both in the high-end and in the luxury sector. It is not uncommon the use of secondary raw materials, eco-sustainable, biodegradable, or recycled materials, as well as processing technologies and treatments with a lower environmental impact. In fact, the footwear accessories sector mainly produces items made of brass, zinc, or steel, covered with a thin layer of precious metal such as gold, ruthenium and palladium. This process of depositing the finishing material generates pollutants that are difficult to recycle and dispose of.

Therefore, the case study of Santoni S.r.l, subject of this paper, represents a significant example of a preventive approach to sustainability, which can help understand the importance of using the LCA-Life Cycle Assessment methodology, to define strategies of DfS-Design for Sustainability aimed at improving the environmental performance of the product and the company, with positive impacts on the entire supply chain. The LCA, was carried out according to the ISO 14040 standard on one of the most representative products sold by the company in recent years: a brass buckle, for the Made in Italy footwear sector. The aim of the analysis carried out, was to identify the main environmental criticalities, from cradle to gate, and to identify improving strategies, with a view to sustainability and circularity. Finally, the Design for Sustainability strategies were outlined to improve and optimise the environmental performance of the product, estimating, in their adoption, an overall reduction of CO_2 emissions (Kg CO_2-eq), up to twenty times compared to the current model.

The paper aims to highlight the importance - for Made in Italy SMEs - of activating Design for Sustainability (DfS) strategies, to accelerate the transition process towards the Circular Economy, through the quantification of the environmental impacts of their products, trying to play a conscious and important role within the supply chain in BtoB relationships. Furthermore, the contribution presents the case study of the Santoni company, a player in the footwear sector of the industrial area of the Marche region, which has started this approach in line with the "Planet" target (reducing the ecological footprint, changing the way we produce and consume goods and resources) and SDG 12: "Responsible Consumption and Production", activating, through the evaluation and planning tools of eco-design, more sustainable and circular production models.

Figure 1. Scheme of the production chain in the footwear sector, from the material production phase to the consumption phase: boundaries of the buckle system produced by the Santoni S.r.l company



2. Literature Reviews

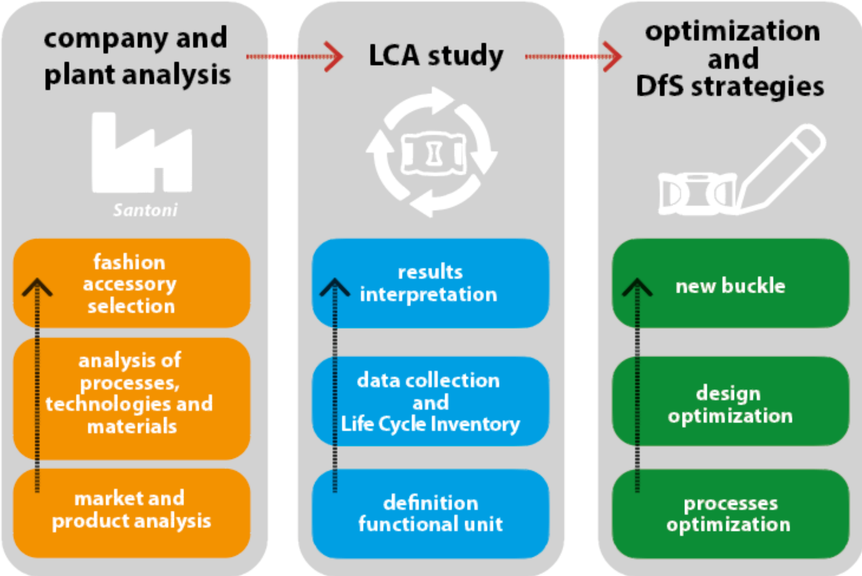
In 2018, billions of pairs of footwear were produced, with an increase of 20.5% compared to 2010. About 87.6% of world footwear production takes place in Asia, 3.2% in Europe, which however consumes 13.6% of the total. Particularly in Italy, the levels of per capita consumption are among the highest: 6.8 pairs of shoes per year (Muthu & Li, 2021, pp. 305-320). Considering the significant growth in shoe production, it has been estimated that, in 2016, the overall contribution of the footwear sector to climate change was approximately 3.29 billion tons of CO_2 (Marques et al., 2017, pp. 303-308). Estimates confirm that the fashion system is one of the most polluting industries in the world, second to the oil industry. The study also highlighted that the main drivers, influencing the impact categories, are attributable to the production of components and the extraction of raw materials. In this scenario, the main brands that govern the entire production chain, increasingly delegate the different phases of the creation of their products to many small/medium-sized enterprises scattered throughout the world (Macchion et al., 2018, pp. 9-28), sometimes, underestimating the social and environmental aspects that affect the life cycle of their products. This BtoB system, in addition to limiting the traceability of flows (materials and technologies) and establishing a transparent interaction between the various players in the supply chain, also has strong repercussions on the environmental performance of shoes. According to Macchion et al. (2020, pp. 2679-2691), considering the problem in the management and control of the inputs and outputs of the supply chain, it may be strategic to develop a sort of "identity card" of the product, as a traceability system between the actors themselves, to monitor the quality of processes and materials that influence the sustainability of products. Progress has been made in the last ten years, thanks to the work of researchers from all over the world, who have defined design guidelines - as a useful tool for companies - suitable for planning and at the same time aimed at improving sustainability criteria and circularity of the shoes. For example, in the “Handbook of Footwear Design and Manufacture”, the following are discussed: engineering design methodologies; technical solutions, aimed at reducing production waste; strategies to optimize production processes for productivity. The European Commission has also moved in this direction, developing a guiding tool for the "Circular Economy: Environmental and Waste Management". It is a questionnaire aimed at collecting data, which differentiate products in the footwear market from an environmental point of view, trying both to influence and support companies in the sector, in the choice of materials, processes and finalization, in order to reduce the emissions to soil, air, and water as much as possible (European Commission, 2013). Obviously, in the footwear sector, most of the environmental impacts depend on the nature of the raw materials and semi-finished products used in the production of the shoe body and, to a certain extent, in the development of accessories. According to Quantis (2018, p.28), the materials most used by the footwear industry are: synthetic materials, leather,

and fabrics, present respectively at 57%, 25% and 18%. Furthermore, although leather materials are present in only a quarter of footwear production, their impacts are significant, ranging between 30% and 80%, depending on the categories of environmental damage taken into consideration. To confirm this data, we report the LCA study, limited to the Swedish footwear market, which found that a pair of leather shoes shows an impact up to three times higher than a shoe made of another material (Gottfridsson & Zhange, 2015, p.41). In the same study, the impact result related to the production of footwear materials stands out, with the highest value of almost 80% of the total life cycle. Particularly for leather shoes, the main causes of impact (around 70 %) are due to the slaughter and tanning processes (Rossi et al., 2021, p.700). In summary, the materials that contribute the most to environmental impacts - per kilogramme - are leather, wool, nylon, aluminium, synthetic rubber, polyethylene terephthalate, polyurethane, and viscose. In the manufacture of accessories (hinges, buckles, eyelets, etc.), on the other hand, it is iron, copper, zinc, brass, and aluminium. Although the weight of metal accessories represents only slightly more than 10% of the final product, a recent study by LCA has shown that, unlike the other impact categories, the main contribution to eutrophication and acidification, estimated at up to 35%, is mainly due to the materials and treatments used for these accessories, especially those made of metal alloys such as brass (Zottin, 2019, p.60). The issue of processing and treatment of footwear components is a critical environmental aspect, even for small items such as eyelets and buckles. A recent study, focused on the economic and environmental comparison of three buckles for shoes and belts - one made of brass sheet and the other two buckles of the same model, made of zamak – highlighted that the greatest impact is related to the nature of the raw materials that make up the accessories (brass and zamak) and the galvanic treatment they undergo (Odorisio & Germani, 2020, p.57). To corroborate the results of this study, we report the work conducted by Bandinelli, Fani and Bindi (2021, p. 4453) on the critical question of the galvanizing process for the ennoblement of metal fashion accessories, generally coated with a thin, precious layer such as gold. The paper discusses the role of Physical Vapor Deposition (PVD), as a technology, alternative and more sustainable, compared to traditional galvanic, trying to highlight the opportunities and criticalities, compared to the numbers and complexity dictated by the fashion system, characterized by short-time delivery cycles, and by a high variance, in terms of shapes and finishes.
In conclusion, it can be stated that in recent years, the LCA methodology applied to the footwear fashion sector, has focused, as a priority, on the study of the impacts associated with the materials of the main components such as soles and uppers, neglecting the use phase of the footwear, as it is difficult to quantify in the inventory phase (LCI). Although some studies have shown that even the accessories supplied with shoes affect the sustainable behavior of the entire supply chain, the analysis of the environmental impacts of these accessories still appears to be little studied and considered marginal. However, it is evident that the production of accessories generates a quantifiable contribution over the entire life cycle of a pair of shoes, highlighting the importance, in the development phase of new models, of a weighted and sensitive choice regarding materials and types of surface treatments to be adopted. In this scenario, also the companies supplying accessories, assume a significant role in the generation of impacts and are therefore motivated to develop, through the tools and strategies of DfS, new solutions aimed both at reducing emissions and at enhancing the aesthetics of their products, an essential parameter for many fashion brands.

3. Methodology

As already mentioned, the paper intends to describe the DfS strategies, proposed to improve the environmental performance of a small-medium company in the footwear sector, a manufacturer of metal accessories for high-end footwear, i.e. Santoni S.r.l. The article describes the process and the results of the life cycle analysis (LCA) of a brass buckle produced by the company and the possible environmental optimization options. The methodology adopted was divided into three macro-phases: (i) productive-economic categorisation of the Santoni company; (ii) development of an LCA study of a brass buckle and evaluation of the environmental impacts, mainly expressed in kg of CO_2-eq; (iii) product optimization through DfS strategies.

Figure 2. Summary scheme of the methodology adopted for the environmental analysis and the redesign of the buckle



The first macro-phase aimed at reconstructing the role of the Santoni S.r.l company within the footwear supply chain, analyzing the main products developed and the manufacturing processes carried out in the production plant. At the end of this activity, a brass buckle was identified as the most significant accessory for analyzing the life cycle of a fashion accessory for the footwear industry. The purpose of the study was to evaluate the "from cradle to gate" environmental performance of the buckle, intended to complete, as an accessory, a model of classic high fashion shoes. The product is single-component, single-material and made of galvanized eco-brass (90% recycled and Pb free).

The total weight of the single buckle is approximately 36 gr. The Economic Order Quantity (EOQ) is of tens of thousands of pieces per year, and the production cycle for the realization of the product includes four important macro-processes described below, ordered by production phase: (i) macro-process "A": in this phase the semi-finished products, i.e. the eco-brass bars, are made by a foundry located in the industrial area of Florence, generated with 10% virgin material and 90% recycled; (ii) macro-process "B": the eco-brass bars are transported to another factory, also located in the industrial area near Florence, where they are reduced to billets and forged to obtain the initial geometry of the buckle, also referred to as a raw buckle. This process involves at least three highly energy-intensive steps: billet annealing, forging and metal blanking; (iii) the macro-process "C": represents the heart of the production cycle and is the main actor, object of the study. This phase takes place inside the Santoni S.r.l production plant, located in the Fermo area, and involves eleven manufacturing processes, from the grinding of the raw piece to the surface treatments of tumbling and polishing, up to the final transport to the company that makes the shoes (from process “C1” to process “C11”, as shown in figure 3). Once all the processes have been completed, the pieces are packed and shipped to the final customer; (iv) the macro-process "D": concerns the galvanizing phase, i.e. the electrolytic process responsible for the surface ennobling of the pieces, capable of improving their resistance to wear. This treatment takes place in a plant outside the Santoni S.r.l company, located in the industrial area of the province of Macerata, central Italy.

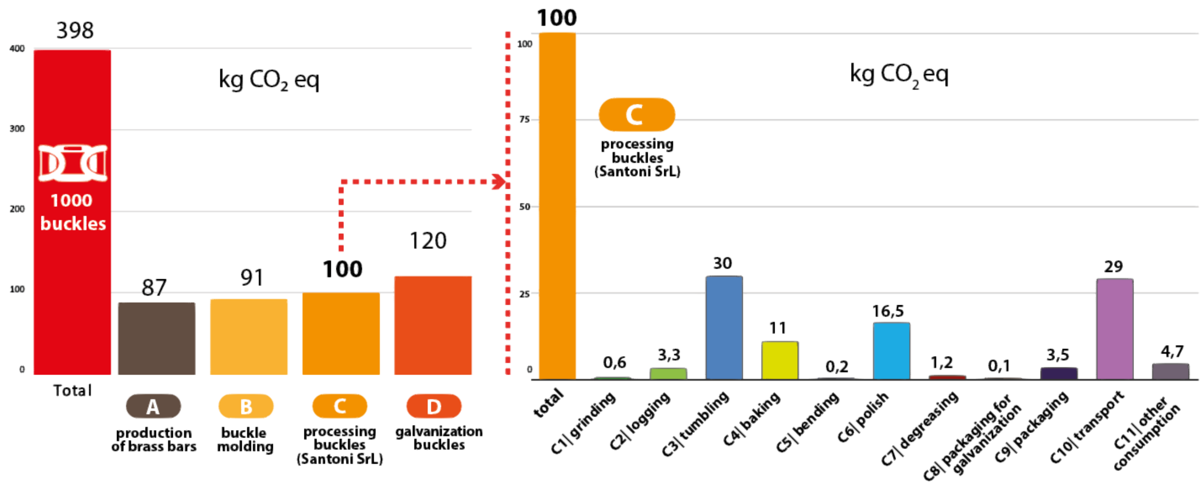
The second macro-phase of the LCA study was conducted according to the indications of the UNI EN ISO 14040/44 standard, thus carrying out: the definition of the objective and purpose of the study; inventory analysis; impact assessment; data interpretation. The activities carried out to achieve the objectives and report the results were as follows: analysis of the company's production processes; definition of the analysis objectives, system boundaries and assumptions for carrying out the inventory; identification of a product representative of the company in terms of units produced and selected as the object of analysis, or a brass buckle produced for a men's shoe of a well-known Italian brand; data collection in the company by means of structured checklists and video and photo reports of the individual production processes and surface treatment; data selection from existing databases (if direct data collection was not possible); set-up of the inventory and collection of primary and secondary data by means of measuring instruments carried out in the production plant; collection and estimation of data in the literature; data processing and evaluation through the use of Simapro software; summary and interpretation of the results of the study; identification of necessary measures for possible improvement of the environmental compatibility of processes and products.

The selected functional unit refers to the production and processing - i.e. all forming and surface treatment processes - of 1000 pieces. The Ecoinvent 3 (2021) database available in SimaPro was used for the inventory phase and the compilation of the data required for the modelling of all phases considered. Therefore, the modules already in the database were linked to the technologies and materials from which the buckles are made, identifying the direct and indirect environmental impacts and ultimately the avoided impacts. Several approximations and estimates were made to fill in the missing primary data. The information collected in the initial measurement and data collection activities was used to model all the macro processes in SimaPro ("A "+"B "+"C "+"D") that make up the production cycle for the manufacture of one thousand pieces. After defining the LCI phase, the assessment of the environmental damage associated with the production of the 1,000 eco-brass buckles was carried out. The factors of the assessment method EF 3.0 were used as impact factors. This is a method taken from the EU Communication COM /2013/0196, which sets out the procedures for the dissemination of the Product Environmental Footprint (PEF) and the Organisation Environmental Footprint (OEF). In particular, the results generated by the PEF method form the basis for communicating information on the environmental footprint of products and are therefore an effective tool for improving the company's green reputation in a transparent and correct manner. Once the phase of evaluating and interpreting the results and the environmental impact associated with the functional unit was completed, the next step was to define strategies for improving and optimising environmental performance. Through on-site research, the first step was to investigate surface treatment technologies and processes that could be an alternative to electroplating and produce the same aesthetic qualities; secondly, environmentally friendly and high-performance materials and semi-finished products were identified as an alternative to brass that could be processed using alternative technologies to forging.
Finally, a "lightweighting" process was initiated through the use of 3D modelling software, aimed at optimising the geometry and estimating a possible reduction in thickness and surface area to be machined.

4. Results and Discussion

Based on the data collection - primary and secondary - for the inventory definition and the mapping of these data in the analysis software LCA, it was possible to identify the main environmental damages related to the production of one thousand buckles - characterisation phase - with the contribution to climate change, expressed by the production of carbon dioxide in kg CO_2-eq.
"Climate change" is an important factor in understanding the evolution of energy consumption throughout the life cycle and was therefore chosen as a particularly meaningful indicator of the impacts associated with the production and distribution of the buckle. The detailed analysis of the macro-process "C" found that the biggest impacts are due to three processes: tumbling, transport paid by Santoni S.r.l. and polishing.

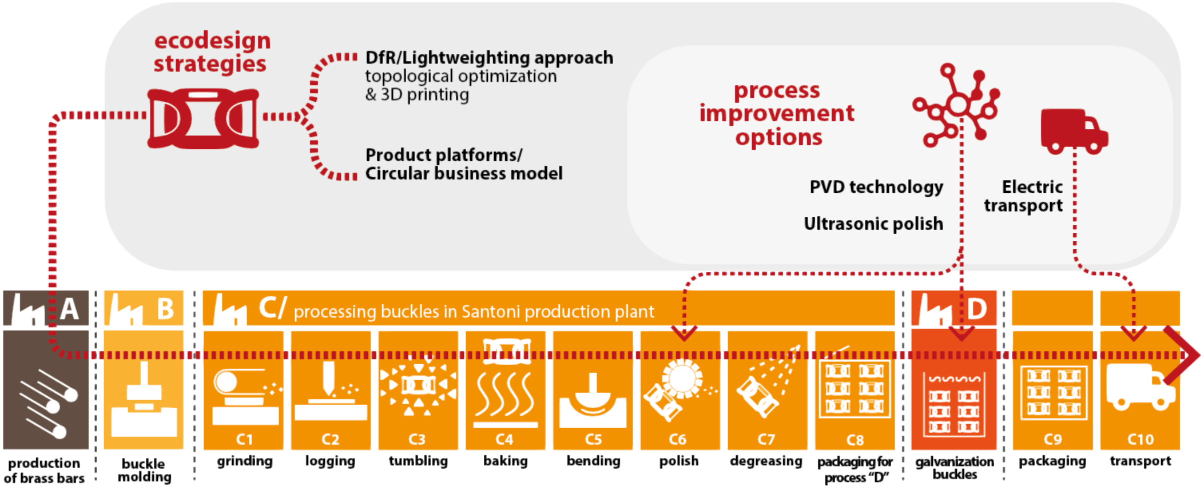
Figure 3. Graph with the results of climate change, expressed in Kg CO2 eq, associated with each main production and processing phase of the 1000 buckles (macro-processes "A"+"B"+"C"+"D") and detail of the individual processing phases within the macro-process "C"



4.1 *Impact Analysis*. An analysis of the impacts generated during the entire production cycle (Figure 3), shows how the macro-processes "A", "B", "D", i.e. those outside the Santoni site, are those that generate most of the impact, both as CO_2 emissions and as a "score", according to the EF.3.0 methodology.The interpretation phase of the study was divided into two parts: the first describes the impacts generated during the entire buckle production cycle, “A”+“B”+“C”+“D”; the second reports the results of the impacts generated within the Santoni production cycle, i.e. the macro-process "C". This approach was necessary as, with a view to identifying improvement actions, it is evident how the company responsible for marketing the product, i.e. Santoni S.r.l, can intervene both directly on the production phases that take place inside of its own plant, and on external ones, trying to stimulate and influence the procurement choices of raw materials and technological processes of its suppliers in terms of environmental improvement. In fact, the activities carried out within the manufacturing process of the Santoni company represent approximately 25% of the total CO_2 emissions: the predominant part of the impacts actually occurs upstream of the macro-process "C", i.e. for the production of the brass bars and the molding of the raw buckles, equal to about 44% of CO_2 emissions; finally, a share equal to approximately 31% of CO_2 emissions to be attributed to the galvanizing process. The results of this study highlight some relevant critical issues attributable above all to the macro-processes "A"+"B"+"D". However, the emission levels are to be considered low for some sustainable choices already undertaken by companies in the supply chain, such as: the choice of a brass rod supplier that uses recycled brass, with a low Pb content; the use of a portion of the electricity produced by the photovoltaic system of the Santoni S.r.l plant; the choice of a galvanizing process that uses gold obtained from the WEEE waste recycling chain (Elomaa et al., 2019, pp. 456-477); the start of recycling, when possible, of the processing waste generated within the Santoni S.r.l company plant (for example, defective buckles re-enter the brass recycling circuit).

4.2 Ecodesign strategies. Following the analytical phase, it was possible to develop a series of interventions, to be implemented in the future, and aimed at further increasing its performance, in terms of sustainability and circularity.
In particular, at least three macro-optimization interventions were explained: the first two aimed at improving the quality of some processes, internal and external to the Santoni company; the last one, strongly aimed at the redesign of the buckle. In summary, the following were proposed to the Santoni company, which makes the buckles: (i) "Interventions for the environmental improvement of internal processes at the Santoni plant": it is hoped that road transport means will be implemented, which are electrically powered (also to exploit the self-production capacity of electricity documented on the production site); it is required to increase the use of electricity from renewable sources; the replacement of the current degreasing process with ultrasound technology is recommended; (ii) "Environmental improvement measures relating to the surface treatment process alternative to galvanizing": it is recommended to replace the galvanizing process with processes with a lower environmental impact, such as the Physical Vapor Deposition PVD technology, for which a reduction of approximately twenty times of CO_2, compared to current values. However, this treatment requires calibration to obtain the same quality standards of the product, especially the colour; (iii) "Product environmental improvement measures": it is advisable to start a buckle redesign process which involves the adoption of appropriate strategies for the reduction and optimization of the material and capable of maintaining at the same time the same qualitative and distinctive of the current product.

Figure 4. Main environmental optimization interventions of the buckle with DfS macro strategies



The first two options for improving the impacts are limited to interventions on specific phases, in particular on the galvanizing phase, on the degreasing process, and finally, on the transport phase, which characterizes the commercial exchanges between the Santoni company plant, and its other suppliers and customers in the supply chain. Although the first two options are already able to give an important result in terms of impact reduction, it is believed that an environmental redesign action would lead to a greater contribution to all manufacturing processes, generating ripple effect benefits, throughout the Supply Chain, from macro-process "A" to macro-process "D" (Figure 4). For example, the adoption of a "Lightweighting" intervention (Tempelman, 2014, pp. 247-258), both as a replacement of material with a lighter and less energy-intensive one, and as a lesser use of brass through appropriate eco-design strategies, would lead to a significant reduction of resources and, consequently, also to a containment of the final costs for the production. In fact, the analyzed product, in addition to being characterized by an expensive material compared to other alloys and metals, appears oversized and heavy for its effective function. Although this aspect of material redundancy is dictated by a need for style, it could be interpreted as a benefit in terms of product durability. However, precisely because of its intended use, i.e. an accessory for high fashion shoes, it is subject to an aesthetic-cultural obsolescence, and therefore destined to a rather short life cycle. Therefore, a Design for Reduction-DfR approach, supported by tools capable of evaluating the effective mechanical resistance of the product, such as finite element analysis-FEM, could be strategic for dimensioning the effective thicknesses so that the buckle resists the traction of the laces without breaking, or, through a topological optimization process (a process that starts from a 3D model, to which forces and constraints are applied, and is resized to obtain the most efficient result), it would be possible to completely redesign the product and make it with the 3D printer. This technology makes it possible to improve the use of the material, optimize the surface to be treated for the final finish, limit the generation of waste and, consequently, also have benefits on transport, reducing volumes and weights. In fact, compared to the development of a traditional buckle made by forging - which produces a waste that can reach up to 48% of its actual weight - the 3D printer would lead to a significant reduction in brass scraps, generating a reduction in the CO_2 emitted during the of pre-production estimated at around 50%. Furthermore, considering that the high fashion sector is characterized by low sales volumes and high aesthetic flexibility, it is expected that the implementation of machines for rapid production would bring the company both an environmental advantage and a reduction in "time to market". As already explained, these accessories are subject to aesthetic obsolescence, therefore another redesign strategy that can be pursued by the company is the development of a platform product system. The new buckle could be designed to be disassembled and customized after the shoes' end of life. For example, in the surface area where the logo is engraved today, one could imagine easily removable and restorable inserts in terms of new logos and finishes. Furthermore, the buckle designed in this way could change its intended use and be part of the development of another fashion accessory by coupling it with other components and materials. Obviously, this type of scenario, certainly more ambitious and long-term, envisages that the company develops an ad hoc service for the recovery of products and launches a strategic marketing activity, aimed at raising the awareness of the players, up to the end user, seeking to enhance and promote a new business and circularity model within the footwear supply chain.

5. Conclusion

Through the LCA analysis conducted on the brass buckle, it was possible both to learn the environmental criticalities associated with a fashion accessory, and to verify the need to manage the complexity of the "long supply chain" of the Made in Italy footwear sector in a sustainable way. In this scenario we note the contribution of the Santoni company, as a virtuous actor, for the promotion of a change of course through the adoption of sustainable practices aimed at evaluating and increasing the environmental performance of its products. This is possible, both by intervening on manufacturing processes - through the choice of suppliers of green oriented materials and technologies - and through the use of new eco-design strategies supported by new product optimization tools such as topological analysis and production technologies energy efficient like 3D printers.

In particular, an environmental redesign approach, primarily oriented towards the reduction of materials and resources, would have a strong impact on the entire supply chain, above all if one considers that, currently, the ratio between the weight of the single buckle and the waste generated for its production, is close to a value of 1 (36g buckle/34g waste). Finally, in a future scenario, the adoption of a new business model oriented towards circularity criteria and characterized by the development of a platform product system could further increase the environmental benefits throughout the supply chain involved, enhancing the final quality of the high-end shoes and also confirming the internationally recognized "value" of Made in Italy products.

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