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Article

Sustainability as source of competitive advantages in mature sectors: the case of ceramic district of Sassuolo (Italy)

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Abstract: Talking about sustainable development refers mainly to the environmental sphere, but the concept is much broader and also takes into account the social and economic conditions. The concept of sustainability, in this sense, is linked to the compatibility between the development of economic activities, the related social phenomena, and the protection of the environment. Therefore, the ability to balance social, economic and environmental sustainability is the very meaning of the concept of sustainable development. Firms that choose to develop policies and strategies to enhance and pursue sustainable development in the medium to long term have the burden of having to quantitatively document the improvements in production processes with the aim of sustainable development. As a result, one of the biggest challenges for European industry is to introduce sustainability principles into business models leading to competitive advantage. This is particularly important in raw material and energy intensive manufacturing sectors such as the ceramic industry. The present state of knowledge lacks a comprehensive operational tool for industry to support decision-making processes geared towards sustainability. In the ceramic sector, the economic and social dimensions of the product and processes have not yet been given sufficient importance. Moreover, the traditional research on industrial districts lacks an analysis of the relations between firms and the territory with a view to sustainability. Finally, the attention of scholars in the field of economic and social sustainability, has not yet turned to the analysis of the Sassuolo district. Therefore, in this paper we introduce the Life Cycle Sustainability Assessment (LCSA), as a method that can be a suitable tool to fill this gap, because through a mathematical model it is possible to obtain the information useful for decision makers to integrate the principles of sustainability both at the microeconomic level in enterprises, and at the meso-economic level for the definition of economic policies and territorial governance. Environmental and socio-economic analysis was performed from the extraction of raw materials to the packaging of the product on different product categories manufactured by the Italian ceramic industries of the Sassuolo district (northern Italy). For the first time the LCSA model, usually applied to unitary processes, is extended to the economic and industrial activities of the entire district, extending the prospect of investigation from the enterprise and its value chain to the integrated network of district enterprises.

Keywords: Sustainability; Competitive Advantage, Sassuolo Tile Ceramic District, Life Cycle Sustainability Assessment (LCSA); Italian Ceramic Industry; Meso-economic level; Interpretative Method.

1. Introduction

The challenge of sustainable development embraces all three pillars of sustainability: environment, economy and society. Sustainable development is economic development that is compatible with social equity, environmental protection and the rights of future generations [1]. The concept of sustainable development therefore refers to economic growth that meets the welfare needs of societies in the short, medium and, above all, long term. The introduction of rules for safeguarding the environment and tools for monitoring company activities is important not only for protecting consumers by defending principles of civilization but also for companies that are striving to produce high-quality products. Accordingly, this capacity can be considered a strategic factor with great impact on competitive advantage building in the medium/long run, with special emphasis in mature sectors where sources of differentiation are less likely [1]. Above and beyond short-term economic expediencies, companies are historic players whose actions influence the social life of the surrounding community. In addition, such community will evaluate firms' actions and behaviors according to the impacts they may provoke. Following the Institutional Theory [2] the consequences of entrepreneurial decisions are not limited to the company itself but extend to the various spheres of social life and affect the various economic and social parties and territories which are no longer neutral places. Therefore, as long as firms' impacts do not fit norms, values or game rules of the society, companies will be more poorly evaluated. This paper aims first of all to conceptually develop the theme of relations and interdependencies between ceramic producers organized in industrial districts (ID) and the territories in which they operate. After that, it will empirically determine the environmental, economic and social impact of the main products of the Sassuolo ceramic district, using the Life Cycle Sustainability Assessment (LCSA) structure with a territorial extension that presupposes an innovative contribution to current literature.

2. Background and research aims

2.1 Environment and economic activity

Economic activity, like all human activity, takes place within the natural environment. The economic system and the natural environment are therefore interdependent, which determines both the way in which the economic system affects the environment and the limits that the environment places on the evolution and expansion of the economic system [3]. The environmental limits that the economic system must consider are established by the laws of thermodynamics. The first law of thermodynamics is presented first in the form of the law of the conservation of matter: matter can neither be increased nor destroyed but only transformed [4]. The material flows from the environment to the economic system are the same as the flows that return from the economic system to the environment; the economic process can only transform the material extracted from the environment to eventually return the same material to the environment in the form of waste [5].

The processes of transformation of matter that take place in the economic system imply the use of energy, defined as the "capacity to do work". The first law of thermodynamics states that energy, like matter, can neither be created nor destroyed; energy can only be transformed, converted from one form to another [6]. This energy conversion has an important effect, highlighted by the second law of thermodynamics. This law states that in every energetic transformation a part of the energy is dispersed in a form that can no longer be used to perform further work [7]. The environment is an essential resource base for the functioning of the economic system. The scarcity of resources that is the fact that they are useful and at the same time available in limited quantities compared to the request, is the condition for the talk about of economic resources [8].

If environmental resource activity is over-exploited beyond regeneration or assimilation capacity, environmental resources tend to run out and the ability of the environment to provide its services to the economy in the future is compromised. This creates a conflict between exploitation and conservation of the environment which is economically relevant as the environment performs important economic functions not only because the flows of services it offers are exploited, but also because there is an interest in the conservation of the stocks of goods it contains [9]. When environmental exploitation goes beyond the natural capacities of regeneration and assimilation, it is an alternative use of non-environmental economic resources (such as capital and labor) that goes against the objective of conservation. In this case, the exploitation and preservation of the environment become alternative purposes of resource allocation [10].

The essence of the concept of sustainable development is that the exploitation of environmental resources should be contained within the limits of regeneration capacity so that the stock of these resources is not depleted. If the stock of environmental resources is to remain constant in the long term, the exploitation flow of these resources must also be kept constant within the limits of their natural regeneration capacity [11]. But the only way in which the flow of use of environmental resources can remain constant in the presence of a continuous growth of the domestic gross product of an economy is that the flow of use of the environment per unit of gross domestic product is continuously reduced over time [12]. This also requires a profound structural modification of production processes. For this reason, economic growth to be sustainable must be based more and more on the material recycling [13], on a non-dissipative form of energy use and on an increasing weight of the intangible production component in the gross domestic product [14].

The most recent strategic documents of the European Union and the relative EU policies aim at combining competitiveness of member countries' enterprises and economies, social cohesion and sustainable development [15]. Further intergovernmental programmes promote the same strategic objectives of economic, social and environmental sustainability [16]. These documents identify local authorities, businesses and civil society as the actors responsible for implementing the strategic objectives set, although the key role of local authorities as relevant players in the promotion and implementation of policies and governance tools for sustainable environmental, economic and social development is highlighted. About the role of companies in contributing to greater socio-economic and environmental sustainability, the European Union has recently promoted the approach and concept of Corporate Social Responsibility (CSR). This is a way of voluntary integration, beyond the legal obligations, by companies of the social and environmental implications in their commercial operations and in their relations with the various stakeholders [17]. In order to address environmental issues, adequate information and knowledge is needed to underpin the choice of the most effective actions. Moreover, knowledge must be effectively usable and meaningful. The purpose of this information should be to provide an overview of sustainability, to overcome a sectoral view of the issues and to focus as much as possible on key elements. Finally, the issues addressed should not be limited to strictly environmental issues but should also include social and economic concerns [18]. An appropriate indicator system based on the laws of thermodynamics can be used to assess the pressures that economic and social activities exert on the environment, the resulting changes in the state of the environment, the resulting impacts (e.g. on ecosystems, human health, resource availability) and the political and social responses to these impacts through improvement actions. Sustainability indicators should reflect the mutual links between the environmental, economic and social aspects of development [19]. The sustainability assessment may cover:

- territorial systems (cities, regions, states) [20], environmental components (the atmosphere, soil, water) [21] and, lastly, socio-economic components (economic sectors, population) [22];
- actions relating to development policies (in the fields of energy [23], transport [24], urban areas [25], the protection and valorization of ecosystems [26] and Cultural Heritage [27], actions aimed at social integration and cohesion).

2.2 Environment and territory

In Italy, the geographical concentration of supply chains (based on an integrated system of production, where the entire process is controlled and managed in close collaboration with the best local producers), has allowed many companies to share in the industrial risk linked to development in harmony with the local situation. The system of districts, in fact, has had the ability to create development by reducing the distortions of capitalist systems and enhancing the integration of the industrial reality with the social and environmental fabric [28]. Economic theory has long recognized that agglomeration economies are able to improve the productivity of enterprises and encourage processes of territorial concentration of productive activity in districts [29]. In the decade of the 1990s these ideas represented the starting point for numerous theoretical studies, which forcefully brought out the link between territory and economic development [30-34]. However, research has focused almost exclusively on the benefits of economic development without considering the social costs involved. Today, in economic analysis, space ceases to be considered only a source of cost for businesses, and increasingly assumes the role of a favorable (or unfavorable) milieu, creating externalities (economic or non-economic) [35]. Space thus becomes the place where economic agents meet to organize forms of collaboration [36].

Industrial districts (ID) are the structures where the interaction between territories and firms in the supply chain is best observed [37]. The organizational structure of the industrial district explains the variables that are at the base of the localization and investment choices of the entrepreneurs and that therefore affect the local development [38]. The development process acquires definitively its character of "social process" and no longer only a technical process. Within an industrial district, the territory represents a determining factor in the processes of economic and social growth because the anthropological, historical, cultural and environmental factors that contradict it, affect the specificity of the models of productive organization of the district [39]. However, in the analysis of industrial districts, the relationship between companies and their local context has long lacked a fundamental dimension in the logic of sustainability: that of environmental protection, that is, the link that exists between productive activities and pollution phenomena related to them. This is inconsistent with the growing importance of sustainable development principles in business strategies and public decision makers' agendas. Only recently has there been a growing interest (both theoretically and empirically) in sustainability as a driver of growth in industrial districts [40-42]. Given the importance of the socio-territorial context to district businesses, it is inevitable that the issue of environmental sustainability will also become crucial from the point of view of competitive development [43]. A local district system can be seen as a network of locally concentrated enterprises whose stability derives from a dynamic yet balanced relationship with the community and the networks of interaction that characterize individual enterprises [44]. This balance is dynamic because even in local systems it is possible to highlight the presence of a life cycle whose trend follows that of the product, the greater production specialization of a local system. This is the case of the Sassuolo ceramic district located in the provinces of Modena and Reggio Emilia in Italy, analyzed in this paper [45]. The dynamism of this balance can favour, both from a theoretical and managerial point of view, the adoption of a life-cycle methodological approach, to explain the dynamics of some of the most famous district systems and to describe the prevailing modes of interaction among economic operators [46-50]. However, the adoption of a life-cycle perspective requires that the main social actors do not limit their responsibility to the stages of the supply chain that they directly control but would constitute the prerequisite for a solid sustainability assessment, in order to identify opportunities for reducing environmental impact, industrial costs and, as a consequence, greater efficiency in the use of resources [51,52].

2.3 Life-cycle paradigm from a territorial approach

The implementation of sustainability policies requires the development of increasingly refined quantitative and qualitative tools for analyzing the environmental, economic and social impacts, the Triple Bottom Line (TBL) associated with collective and individual choices, both with more limited effects and with more complex medium and long-term implications [53]. Environmental Life Cycle Assessment (LCA) is the main operational tool for determining environmental impact. It is an objective method for the identification and quantification of the consumption of materials, energy and emissions into the environment and for the evaluation of the potential impacts in physical terms that they generate during the entire life cycle of the product [54]. This procedure is standardized by the ISO 14040-44:2006 standards. Life Cycle Costing (LCC) is an economic evaluation methodology that allows the identification of all future costs and benefits associated with the life cycle of a product/service to determine its cost over its entire life cycle. It is often used in the planning phase to make choices of multiple investment options and to consider the impact of all expected costs that characterize the life cycle of the investment and not only of the initial one [55]. The normative reference for the LCC is ISO 15686-5:2017. S-LCA is the methodology for assessing the positive and negative social impacts generated by a product/service over its entire life cycle on the various stakeholders involved. Its main purpose is to promote the improvement of the socio-economic performance of the product throughout its life cycle. This methodology still needs methodological development and the current reference framework is represented by the publication UNEP/SETAC Life Cycle Initiative [56].

Since the three pillars of sustainability concern all three of these aspects (environment, economy and society), it is possible to have a complete and global view of the life cycle through the tool of the Life Cycle Sustainability Assessment (LCSA) tool. It describes the set of business solutions that integrate into the decision-making processes supporting the development of a product (from its conception to its withdrawal from the market), both from the view of the life cycle and the economic, environmental and social assessments necessary for the management of processes, with a total sharing of data related to it between the various company functions [57]. This quantitative analysis tool allows one to implement the principles of sustainability in business strategies and practices through the integration of three different impact assessment tools: LCA, LCC and S-LCA. The integration of the three impact assessment methods is expressed in Klöpffer's conceptual formula [58]:

(1) LCSA = LCA + LCC + S-LCA

Sustainability assessment is not the sum of the results provided by the three analysis systems, as might appear from the formula, but it is necessary to read the results of each methodology in combination with those of the others. The LCA and LCC procedural schemes are the same, both defined by ISO standards: goal and scope definition; inventory analysis, impact assessment and interpretation of results. Therefore, environmental and economic impact assessments can follow the same path, integrating the indicators of each analysis. To integrate the social dimension, in this paper we have maintained the same goal and scope definition already adopted for LCA and LCC, while for the interpretation part we have identified three different interpretative scenarios that have been then combined with each other to arrive at a new construction of reality.

The life-cycle paradigm based on the three pillars of sustainability offers a systemic perspective for decision making [59]. The strategic choice between alternative options should be made by looking at the "*pluses*" and "*minuses*" that characterize a product, process or activity "from the cradle to the grave", reconciling, as far as possible, the environmental, economic and social concerns of economic operators within the supply chain and the territory [60]. Sustainability Analysis, as a tool to monitor a production process, or an integrated supply chain and to develop and valorize a territory, is a topic that is having growing interest in the literature [61]. To this end, the LCA guidelines have recently been adapted to carry out an environmental assessment of a territory. The expectations of this framework, called "*Territorial LCA*", are in line with the European Directive (2001/42/EC) on Strategic Environmental Assessment applied to spatial planning programmes, i.e. to provide an environmental reference basis and compare spatial planning scenarios [62]. However, there is still no empirical evidence in the literature of the integration of the territorial factor into the assessment of economic and social impact, since studies are limited to the environmental dimension. Integrating the territorial dimension in the impact assessment means moving the field of observation from the microeconomic level (the company and its processes and products) to the meso-economic level, then to the entire supply chain with its flows of materials, energy resources, semi-finished and finished products [63]. Mesoeconomic systems are dynamic, complex and open systems with dynamic elements that reflect the complexity of the ways in which macro-targets are achieved [64]. The purpose of their operation is to achieve maximum efficiency from the use of their resources and know-how. Their efficient network structure of interdependent microeconomic agents connected through a division of task, promotes the rational use of the available economic potential of the macro-system, balancing development and minimizing operational risks [65]. According to this definition, the concept of industrial district (ID) can be described as localized meso-economic systems, consisting of interconnected heterogeneous, but complementary, microeconomic agents and specific local institutions that determine the role of these agents and stimulate the innovative development of these systems [66].

2.4 Aim and scope

This work presents an empirical study conducted with the Life Cycle Sustainability Assessment (LCSA) approach for the analysis at mesoeconomic level of the environmental, economic and social performance of the Sassuolo ceramic district in Italy. The research integrates the elements of an evolutionary industrial approach, the life cycle one, with economic-environmental theories, which are interested in the process of forming organizations, their growth and evolution. Based on the literature analysis, for the first time an evaluation of the economic and social impact of the Italian ceramic industry is carried out, as well as for the first time the integrated approach of LCSA is applied. In fact, there are no published studies by LCC and/or S-LCA concerning the Sassuolo ceramic district. The only known study is the sectorial Environmental Product Declaration (EPD) based on an analysis of the environmental data of Italian ceramic tile manufacturers, promoted by the Italian ceramic industry association (Confindustria Ceramica) [67]. To fill this gap, we propose the following main objectives:

- To assess the environmental and socio-economic impacts associated with the entire production life cycle for different types of ceramic tiles located in the Sassuolo industrial district.
- To verify of the usefulness of LCSA as a tool to support decision-making processes leading to competitive advantages

3. Materials and Assumptions

The Sassuolo industrial district is made up of a network of 79 companies that manufacture ceramic tiles, located in ten municipalities straddling the provinces of Modena and Reggio Emilia. During 2016, ceramic companies produced about 341 million square meters, equal to 82% of Italian production, with a turnover of 5.4 billion euros [68]. Of the ceramic companies that make up the district, six have a turnover of more than 200 million euro, nine have a turnover of between 200 and 100 million euro, and the rest are below 100 million euro. These data have been elaborated by consulting the financial statements of the firms of the district, filed with the local Chambers of Commerce.

Four main types of product are manufactured in the Sassuolo district:

- **Porous double-fired wall tiles**: the tiles are obtained by a process divided into two distinct phases: a first phase of firing of the support which is then glazed and then fired again to obtain the fsion of the glaze. Two different kilns are used. The product, mainly intended for wall coverings, is characterized by high porosity (greater than 10 wt% water absorption), brilliance of the glazes and definition of colours. This typology corresponds to 6% of the total production.

- **Porous single-fired wall tiles (or "monoporosa")**: The tiles are obtained through a technique that involves single firing of the product: both bisque and glaze are fired in a single process, only one kiln is used. The product is porous (greater than 7 wt% water absorption) with aesthetic effects of smoothness and brightness on the surface and it is suitable for indoor wall covering. This typology corresponds to 3% of the total production.
- **Glazed porcelain stoneware**: the tiles are obtained by a single high-temperature firing cycle (1220°C) to obtain complete sintering of the ceramic body, which therefore has frost-hardy properties (water absorption less than 0.5% by weight). The glazing and surface decoration give the product valuable aesthetic effects, as well as resistance to staining agents and chemical reagents, facilitating cleaning operations. For these properties glazed porcelain stoneware tiles are particularly suitable for indoor use. This typology corresponds to 60% of the total production.
- **Unglazed porcelain stoneware**: the tiles are obtained by a single firing process at a very high temperature (1220-1230°C) capable of reaching the complete greification of the product. For this reason, porcelain stoneware is the most performing type of ceramic from a technological point of view and is above all used in solutions for use where high mechanical resistance, absolute frost and chemical inertia are required. Porcelain stoneware is available in various surface finishes. This typology corresponds to 31% of the total production.

The production of ceramic tiles requires large quantities of raw materials that can be schematically divided into at least four fundamental components:

- **Clay raw materials**: clays and kaolin which give sufficient plasticity to ensure good formability.
- **Melting raw materials**: such as feldspars, which produce the glass phases necessary to promote solid-solid sintering reactions.
- **Inert raw materials**: feldspar sand and sand which have the function of balancing the composition of ceramic bodies, also containing the cost, as these are the cheapest raw materials.
- **Additives raw materials**: calcite and/or dolomite used mainly in the production of porous types of, or in smaller quantities as promoters of eutectic to facilitate the melting of feldspars into porcelain stoneware.

Using this classification, it is essential to refer to the composition of the ceramic bodies from which the different types of tiles are obtained. To this end, 15 industrially spray-dried powders [69] of ceramic body, corresponding to the four main product categories of the Sassuolo district, were collected from the main ceramic companies of the district. Chemical analyses were carried out on these powders to determine their composition and establish a compositional range that defines each type of ceramic in a representative way (Table 1a). From the average chemical compositions, through a reverse engineering (RE) process [70], it was possible to reconstruct the formulation of a "medium" body, typical for each product category, using the main raw materials available on the market (Table 1b).

	POROUS DOUBLE-FIRED	POROUS SINGLE-FIRED	GLAZED PORCELAIN	UNGLAZED PORCELAIN
SiO_2	53÷57	60÷65	69÷72	65÷68
Al_2O_3	13÷16	15÷18	17÷19	18÷20
Fe_2O_3	0,5÷0,7	0,5÷0,7	0,6÷0,8	0,4÷0,6
TiO_2	0,5÷0,7	0,5÷0,7	0,5÷0,7	0,3÷0,6
MgO	0÷4	0÷4	0,2÷0,4	0,2÷0,7
CaO	5÷12	4÷6	0,2÷0,4	0,3÷1,2
Na_2O	1÷1,5	1,5÷2,5	2,5÷4,0	3,5÷4,5
K_2O	2÷3	2,5÷3,5	2,5÷3,5	2÷3,5
LOI	11÷14	7÷10	3,3÷3,9	3÷5

(a)

	POROUS DOUBLE FIRED	POROUS SINGLE-FIRED	GLAZED PORCELAIN	UNGLAZED PORCELAIN
Ukrainian ball clay	24	26	24	25
German ball Clay	17	17	18	19
Turkish Na-Feldspar	12	20	24	30
Italian Na,K-Feldspar			7	13
Italian K-Feldspar	11	12	7	
Italian Feldspar Sand	16	15	20	11,5
Italian Calcite		10		
Italian Dolomite	20			1,5
Kg/m^2	16÷18	16÷18	18÷22	21÷24

(b)

Table 1: (a) compositional intervals of the ceramic bodies analyzed (wt%); (b) ceramic body compositions for each category expressed as wt% of raw material and quantity of dough to produce 1 m² of tiles [71-74].

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The compositions of the ceramic bodies shown in Table 1b show that in all product categories, the import raw materials represent more than 50% of the total. This data is an indication of how vulnerable the district and its member companies are in their production processes, due to the criticality of the supply markets.

3.1 Definition of industrial processes

In order to configure a "standard" production plant that could be taken as a reference for the various product categories, it was based on the concept that the plants for the production of ceramic products all have the same plant characteristics, the main differences consist of the particularity of the machinery.

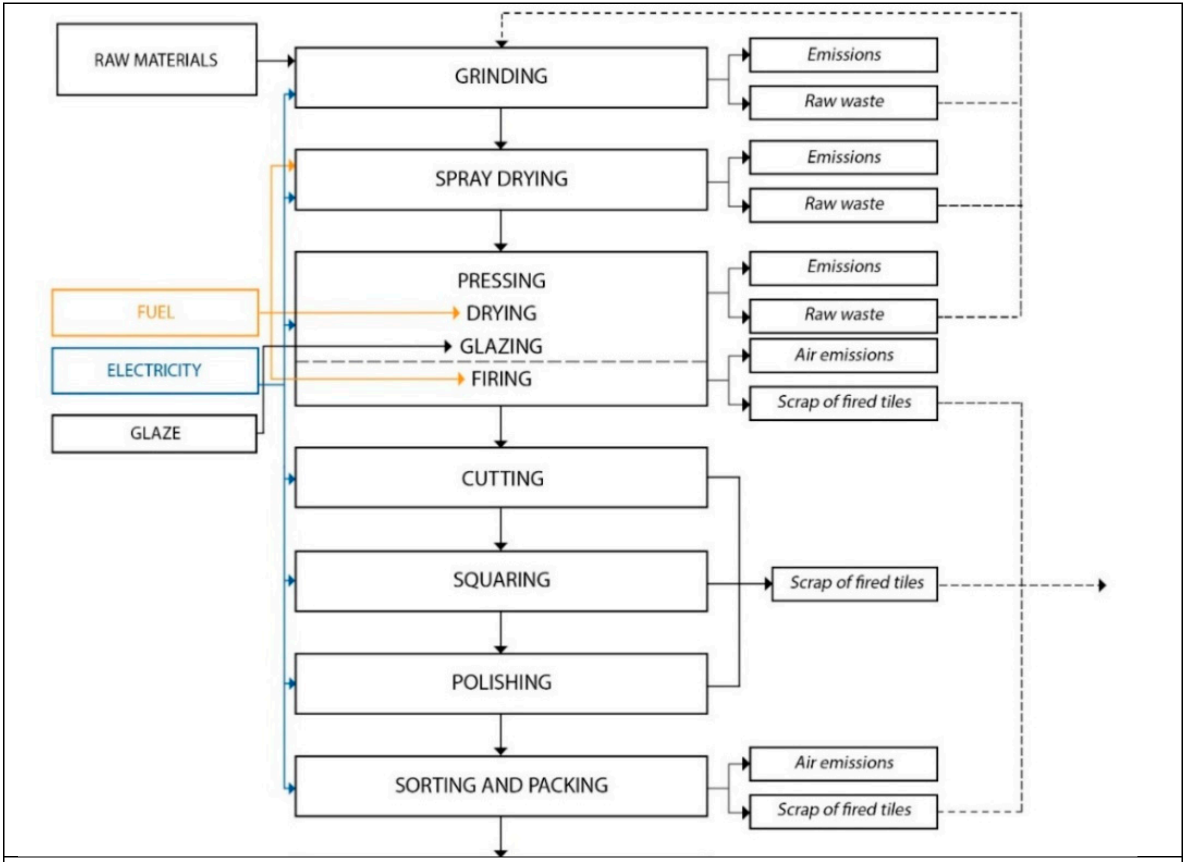

Figure 1: Manufacturing process phases for ceramic tiles.

The production process of ceramic tiles (Figure 1) begins with the selection of raw materials that are used with the particle size obtained in the mine. For this reason, the mixture of raw materials undergoes a wet grinding process (in water) in an alsing mill with grinding media in sintered alumina and/or silica. For subsequent compaction and drying processes, the water content of the slurry obtained must be reduced by spray drying. From the process a spray dried powder is obtained, formed by spherical and uniform granules, which has the characteristic of being very fluid. This makes it easier to fill the moulds and press them. After pressing, the pieces contain between 6 and 7% humidity, so they are subjected to a drying process, with the aim of reducing water by between 0.2 and 0.5%, so that the glazing and firing processes are carried out without defects. Excess water will cause the tiles to break. Tiles leaving the kiln can be cutting and squaring to obtain uniform nominal dimensions (facilitating installation), and/or polishing to obtain a surface as shiny as natural stone. The last stage is the process of verifying the final characteristics according to a series of parameters set by international standards, so that irregular pieces or pieces with decoration defects are separated. The packing stage completes the manufacturing process of the ceramic tile. All input (raw materials) and output (emissions and wastes) flows represented in Figure 1 for each process step, are included in the LCA analysis.

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The possible differences between the machines can be considered irrelevant for the analysis of aggregate average quantities as in this study. In this respect, it should be noted that the great differences between the various product categories do not lie in the machinery used, but in the different grinding and firing cycles and pressing loads, which have a clear impact on energy consumption per m^2 of finished product. Table 2a shows the data relating to the average weight of the various product categories and the relative loss on ignition (L.O.I) from which it was possible to derive the firing efficiency and then determine the value of the surplus of raw material, expressed in kg per m^2, to be added to the theoretical value. During the input phase of the dough creation data on the impact assessment software, the values in the fourth column were considered to determine the amount of raw material to be input.

	Theoretical weight. (Kg/m²)	Loss on ignition (%)	Firing efficiency index	Real weight (Kg/m²)
POROUS DOUBLE-FIRED	16	12,15	0,878	18,21
POROUS SINGLE-FIRED	16	7,88	0,921	17,37
GLAZED PORCELAIN	21	3,52	0,964	21,77
UNGLAZED PORCELAIN	23	4,01	0,959	23,96

(a)

	Cost of electricity (€/m²)	Consumption of electrical energy (kWh/m²)	Thermal energy cost (€/m²)	Thermal energy consumption (kcal/m²)
POROUS DOUBLE-FIRED	0,29	2,64	0,40	14.642
POROUS SINGLE-FIRED	0,17	1,55	0,38	13.910
GLAZED PORCELAIN	0,30	2,73	0,58	21.232
UNGLAZED PORCELAIN	0,44	4,00	0,72	26.357

(b)

Table 2: (a) firing efficiency of the compositions studied and quantity of ceramic body per m^2 needed for production; (b) Consumption of electricity and methane gas (expressed as thermal energy) per m^2 of product.

3.2 Energy consumption

For the quantification of average energy consumption, the data for 2016 was used. The source of the data is the processing of the data collected in the Integrated Environmental Authorizations collected by ceramic companies. Table 2b shows the cost of electricity (expressed in euro/m^2) and heat for each product category. When entering the data in the calculation software, it was decided to enter the average electricity consumption for each m^2 of product; it was therefore considered appropriate to convert the unit of measurement in kWh/m^2. The average electricity consumption, expressed in kWh/m^2, has been calculated using a conversion factor that considers 0.11 €/kWh as the cost of electricity for users of the order of at least 20 GWh/year. The same procedure was adopted for quantifying the average thermal energy consumption (methane gas) per m2 of product. The total cost therefore amounts to 0.224 euro/Nm^3 of methane gas and dividing the cost per square meter by this value, the energy consumption expressed in Nm^3/m^2 was obtained.

3.3 Air pollutant emissions

For the calculation of emission factors of the main pollutants present in gaseous emissions deriving from production processes, reference was made to the data calculated based on the measurements made by ARPAE (Regional Agency for the Environment and Energy of Emilia-Romagna) [75]. For the bodies in which carbonates were introduced (Porous single-fired: 10% of calcite; Porous double-fired: 20% of calcite; Unglazed porcelain stoneware: 1.5% of dolomite and Glazed porcelain stoneware: 0.5% of calcite), CO_2 emissions deriving from the decarbonization process had to be calculated. The reasoning followed to reach the CO_2 emission value per m^2 of product is based on molar ratios and on the approximation that all the Carbon released is fully bound to oxygen. Having calculated the Kg of calcite, $CaCO_3$, and dolomite, $CaMg(CO_3)_2$, present in one m^2 of product, and having their weights and molar ratios, CO_2 emissions were calculated.

3.4 Water consumption

The ceramic tile industry has a relatively high-water requirement, associated with the various functions that water must perform (grinding of raw materials and glazes, cooling, washing of lines, etc.). A large proportion of the incoming water is, however, destined to be re-entered into the environment through gaseous emissions (evaporated water). While the use of water as a washing fluid generally corresponds to the production of waste water. Based on the data collected, it was established that the average water consumption was 11 kg/m^2.

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3.5 Cost of raw materials

Table 3a shows the average market prices of the main raw materials used in the manufacture of tiles, including the costs incurred for transport from the suppliers' mines to the Sassuolo district area. Based on the compositions shown in Table 1b, the cost of each ceramic body was obtained for all the product categories considered (Table 3b).

RAW MATERIAL	MARKET PRICE
Ukrainian ball clay	70÷75
German ball Clay	45÷50
Turkish Na-Feldspar	40÷45
Italian Na,K-Feldspar	35÷40
Italian K-Feldspar	30÷35
Italian Feldspar Sand	30÷35
Italian Calcite	27÷29
Italian Dolomite	58÷63

(a)

	QUANTITY (Kg/m^2)	COST (€/Kg)	COST (€/m^2)
Porous double-fired	18,21	0,0445	0,81
Porous single-fired	17,37	0,0456	0,79
Glazed porcelain	21,77	0,0464	1,01
Unglazed porcelain	23,96	0,0484	1,16

(b)

Table 3: (a) cost of raw materials in the Sassuolo area (€/Ton.); (b) cost per kg and per m^2 of ceramic bodies for each product category.

3.6 Production costs

The cost analysis was based on the "value chain" developed by Porter, which disaggregates a company according to its strategically relevant activities [76].

COSTS	POROUS DOUBLE-FIRED WALL TILES		POROUS SINGLE-FIRED WALL TILES		GLAZED PORCELAIN STONEWARE		UNGLAZED PORCELAIN STONEWARE	
Raw Materials	0,96	*15,6%*	1,24	*16,1%*	1,35	*19,7%*	1,89	*23,4%*
Inks & Glazes	0,85	*13,8%*	0,98	*12,7%*	0,65	*9,5%*	0,41	*5,1%*
Electrical Energy	0,17	*2,8%*	0,29	*3,8%*	0,3	*4,4%*	0,44	*5,5%*
Thermal Energy	0,38	*6,2%*	0,4	*5,2%*	0,58	*8,5%*	0,72	*8,9%*
Consumables	0,5	*8,1%*	0,7	*9,1%*	0,7	*10,2%*	0,84	*10,4%*
Packages	0,21	*3,4%*	0,23	*3,0%*	0,28	*4,1%*	0,34	*4,2%*
Production Staff	1,61	*26,2%*	2,02	*26,2%*	1,64	*23,9%*	1,69	*21,0%*
Accessories	1,13	*18,4%*	1,38	*17,9%*	0,87	*12,7%*	1,02	*12,7%*
Amortizations	0,34	*5,5%*	0,48	*6,2%*	0,48	*7,0%*	0,71	*8,8%*
TOTAL	**6,15**	*100,0%*	**7,72**	*100,0%*	**6,85**	*100,0%*	**8,06**	*100,0%*

Table 4: average production costs by product type in euro/m^2 and percentage on total incidence.

Two areas have been identified: one closely linked to the transformation of raw materials into finished products, value based on costs. The other one called "staff costs" is subdivided into average commercial costs and average general, administrative and financial costs. Charged according to the functional logic of "cost centers" [77]. A survey carried out recently by Confindustria Ceramica (Association of Italian Ceramic Producers) on the dynamics of costs has involved 60 production units concentrated for 89% in the district of Sassuolo and divided into the four types of this study. Employment in the sample companies accounts for 46% of the total number of employees in the sector, and accounts for just under 45%, the weight of production. It is therefore a representative sample and the results are shown in Table 4.

3.7 Social issues

The collection of social data was carried out through the adoption of the Participatory Process [78] of social agents operating in the district. From the methodological point of view, the same procedure has been followed as that already used by the authors themselves for a study concerning the restoration of an architectural work of historical and artistic value [79]. As socioeconomic indicators relevant to ceramic production in the Sassuolo District, the expectations of the main Stakeholder have been adopted.

STAKEHOLDER CATEGORIES	STAKEHOLDER SUBCATEGORIES	STAKEHOLDER DETAILS
1.Human Resources	1.1 Staff Personnel	1.1.1 Blue-collar Workers
		1.1.2 Employees
		1.1.3 Managers
		1.1.4 Top Management
	1.2 Trade Unions	1.2.1 Confederal Trade Unions
		1.2.2 Independent Trade Unions
2.Local Community	2.1 Local Public Institutions	2.1.1 Regional Governments
		2.1.2 Provincial Governments
		2.1.3 Municipalities
3.Society	3.1 Private Business	3.1.1 Company's Shareholders
		3.1.2 Association of Manufacturing and Service Companies
		3.1.3 Chambers of Commerce
	3.2 Public and Private Organization	3.2.1 Regulatory Authorities
		3.2.2 Research Community
		3.2.3 National and International Public Institutions
		3.2.4 Civil Society Organizations
	3.3 Environment	3.3.1 Natural Environment
		3.3.2 Future Generations
	3.4 Media	3.4.1 Newspapers
		3.4.2 Professional Magazines
		3.4.3 TV and Radio
		3.4.4 Internet
4.Consumers	4.1 Trade Channel Operators	4.1.1 Resellers
		4.1.2 Trading Partners
		4.1.3 Business Customers
	4.2 Final Consumer	4.2.1 Private Customers
		4.2.2 Consumers Associations
5.Value Chain Actors	5.1 Suppliers	5.1.1 Large-Scale Suppliers
		5.1.2 Small-Scale- Suppliers
	5.2 Partners	5.2.1 Practitioners and Professionals
	5.3 Competitors	5.3.1 Direct Competitors
		5.3.2 Indirect Competitors

Table 5: stakeholder mapping involved in the ceramic production of Sassuolo District (Source: our elaboration based on the SETAC/UNEP guidelines and the AA1000 standard).

The first step of the Participatory Approach consists of selecting stakeholders. For the operational identification of the Stakeholder we have used an adaptation of the tools contained in the guidelines of the AA1000 "Stakeholder Engagement Standard" (AA1000SES). These guidelines were published in 2015 and provide a framework for organizations to identify, respond and prioritize their sustainability challenges [80]. The AA1000 standard is a liability standard focused on ensuring the quality of social and ethical accounting, auditing and reporting [81]. In this way and in accordance with the SETAC/UNEP guidelines, we have identified the stakeholder involved in the ceramic production adopting the principles of Responsibility, Influence, Proximity, Dependency and Representation described in AA1000 standard. Table 5 shows the correspondences between the categories defined by the SETAC/UNEP guidelines and sub categories of stakeholders in the Sassuolo District.

4. Method and data processing

The procedure we propose for the Life Cycle Sustainability Assessment (LCSA), provides for the integration between the three tools of impact assessment (LCA, LCC, S-LCA), so in accordance with ISO 14040, ISO 14044 and ISO 15686 standards we will adopt the same main phases for each dimension (environment, economy and society): goal and scope, inventory analysis, impact assessment and interpretation. We will also upscale the traditional LCSA to the ceramic district, considering the territorial component by processing data relating to the management of the entire supply chain.

4.1 Goal and scope definition

The objective of the of the experimental analysis is to assess the environmental and socio-economic impact of ceramic production in the Sassuolo district.

4.1.1 System Studied

Ceramic tiles, produced by the companies belonging to the District of Sassuolo, which extends territorially between in the provinces of Modena and Reggio Emilia in Italy and includes the municipalities of Sassuolo, Fiorano Modenese, Formigine, Maranello, Castelvetro, Castellarano, Scandiano, Casalgrande, Viano and Rubiera.

4.1.2 Function of the system

For this study four types of medium ceramic products were identified and adopted, representing the entire district production: porous double-fired wall tiles, porous single-fired wall tiles, glazed porcelain stoneware and unglazed porcelain stoneware. The ceramic tiles under study are intended and applied for both floor and wall coverings, installed both in internal and external environments.

4.1.3 Functional unit

For the purpose of this study, the functional unit chosen, is 1m^2 of each of the selected product categories, in accordance with the method used to create the Sector EPD of Italian ceramic tiles [67]. However, for the analysis of the sector, we have made a change of functional unit using as a reference the production volume of the district for each product category and the total district production.

4.1.4 System boundary

The system boundaries include the whole life cycle of the product consistent with the LCA (cradle-to-grave) procedure: extraction, transport and grinding of raw materials; pressing, glazing, decoration, firing and packaging of tiles; in addition to the use, maintenance and disposal of equipment, emissions in to the air and water during manufacture and management of scrap and processing waste [82]. In this study, we have also adopted the spatialization of each phase of the LCA [61], considering also the flows of raw materials and their impacts that come from other territories both in Italy (Tuscany, Piedmont, Sardinia) and abroad (Germany, Turkey and Ukraine).

4.1.5 Data quality and impact assessment methodology

Primary data on raw material extraction processes have been provided directly by mining companies, as well as data on inks, glazes and pigments production processes have been provided by the chemical companies producing these materials. Instead, the Ecoinvent database [83] was used as a secondary data source. For the study, the SimaPro 8.0.2 software and the IMPACT 2002 evaluation method were adopted to calculate the environmental impacts.

4.2 Inventory analysis

Life cycle inventory background data, costs including inputs and outputs in processes to produce ceramic tiles as well as the emissions and social issues, have already been described in detail in paragraph 3.

5. Results and Assessment Discussion

5.1 LCA: Impact Assessment

Table 6 shows the impact assessments, using as functional unit 1 m^2 of tiles (micro level), for the four types of ceramic products, and the total corresponding weight factor (Pt), these values are represented in the graphic in Figure 1. The processes produce an impact due to 19,7% to the porous double firing wall tiles, 22,2% to porous single firing wall tiles, 25,7% to glazed porcelain stoneware and 32,3% to unglazed porcelain stoneware. In order to estimate the environmental damage that ceramic production has on the district, a further calculation was made by weighting the impacts with the square meters produced for each type of product considered. In this way we have passed from the level of microeconomic analysis (which refers only to the functional unit of 1 m^2 of ceramic tiles) to the level of meso-economic analysis which refers to the production of entire district as functional unit. The results are shown in Figure 2a.

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LCA						
DAMAGE CATEGORIES	IMPACT CATEGORIES	POROUS DOUBLE FIRING WALL TILES	POROUS SINGLE FIRING WALL TILES	GLAZED PORCELAIN STONEWARE	UNGLAZED PORCELAIN STONEWARE	TOTAL
HUMAN HEALTH	Carcinogenic agents	1,45E-05	1,60E-05	2,60E-05	3,50E-05	3,22E-03
	Non-carcinogenic agents	3,80E-05	4,10E-05	4,90E-05	5,70E-05	
	Respiratory inorganic	6,10E-04	7,10E-04	7,10E-04	9,10E-04	
	Respiratory organic	1,00E-06	1,20E-06	1,40E-06	1,70E-06	
ECOSYSTEM QUALITY	Ozone depletion	2,40E-07	3,00E-07	3,60E-07	4,70E-07	4,07E-04
	Aquatic ecotoxicity	6,50E-06	1,00E-05	8,30E-06	1,10E-05	
	Terrestrial ecotoxicity	6,50E-05	8,20E-05	7,70E-05	8,00E-05	
	Aquatic acidification	0,00E+00	0,00E+00	0,00E+00	0,00E+00	
	Soil acidification	9,80E-06	1,20E-05	1,20E-05	1,40E-05	
	Land occupation	3,60E-06	4,90E-06	4,20E-06	5,30E-06	
CLIMATE CHANGE	Global warming	8,90E-04	9,50E-04	1,10E-03	1,40E-03	4,34E-03
RESOURCES	Nonrenewable energy	8,10E-04	9,20E-04	1,20E-03	1,50E-03	4,44E-03
	Mineral extraction	3,20E-06	4,80E-06	2,70E-06	3,60E-06	
	TOTAL	2,45E-03	2,75E-03	3,19E-03	4,02E-03	1,24E-02
		19,7%	22,2%	25,7%	32,3%	

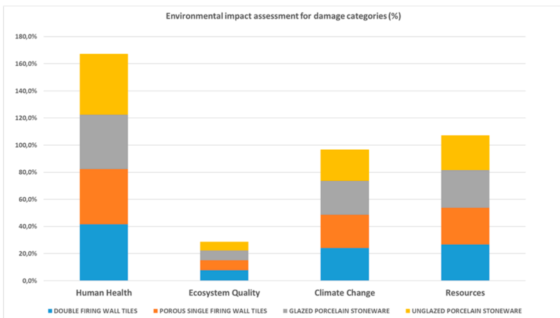
Table 6: results of environmental damage for the four product categories expressed in Pt and obtained with the Impact 2002 model.

The greatest impact for all products corresponds to the category of damage to human health. The detrimental effect on human health is mainly related to the NOx (nitrogen oxide) emissions associated with transportation of raw materials from the extraction sites to the factory sites (41,9% overall). Clearly the same NOx emissions affect climate changes (24,2% in total). Figure 2b shows, in a comparative diagram, the results of the environmental impact of the production categories for the entire district in aggregate form.

LCA MICRO LEVEL	POROUS DOUBLE-FIRED WALL TILES		POROUS SINGLE-FIRED WALL TILES		GLAZED PORCELAIN STONEWARE		UNGLAZED PORCELAIN STONEWARE	
Human Health	2,34E-04	41,5%	2,31E-04	40,8%	2,92E-04	40,1%	3,94E-04	44,9%
Ecosystem Quality	4,35E-05	7,7%	4,19E-05	7,4%	5,24E-05	7,2%	5,69E-05	6,5%
Climate Change	1,36E-04	24,1%	1,39E-04	24,6%	1,82E-04	25,0%	2,02E-04	23,0%
Resources	1,50E-04	26,6%	1,54E-04	27,2%	2,02E-04	27,7%	2,25E-04	25,6%
TOTAL	5,64E-04	100,0%	5,66E-04	100,0%	7,28E-04	100,0%	8,78E-04	100,0%
	21%		21%		27%		32%	

LCA MESO LEVEL	POROUS DOUBLE-FIRED WALL TILES		POROUS SINGLE-FIRED WALL TILES		GLAZED PORCELAIN STONEWARE		UNGLAZED PORCELAIN STONEWARE	
Human Health	5,38E+03	41,5%	3,13E+03	40,8%	6,91E+04	40,1%	4,81E+04	44,9%
Ecosystem Quality	1,00E+03	7,7%	5,68E+02	7,4%	1,24E+04	7,2%	6,94E+03	6,5%
Climate Change	3,13E+03	24,1%	1,88E+03	24,6%	4,31E+04	25,0%	2,46E+04	23,0%
Resources	3,45E+03	26,6%	2,09E+03	27,2%	4,78E+04	27,7%	2,74E+04	25,6%
TOTAL	1,29E+04	100,0%	7,67E+03	100,0%	1,72E+05	100,0%	1,07E+05	100,0%
	4%		3%		57%		36%	

(a)



(b)

Figure 2: (a) impact of production in absolute value and expressed in % for each category of damage at micro and meso level; (b) histograms representing environmental damage (in %) on the ceramic district, subdivided by damage category and type of product.

5.2 LCA: Results Interpretation

The environmental impact analysis carried out at micro level, having as a reference 1 m² of ceramic tiles for each product category, showed that the types with the most moderate impact are unglazed porcelain stoneware and glazed porcelain stoneware, while no significant variations were observed in the category of damage between the various typologies. Changing the perspective of observation and moving on to meso level, then to the district level considering production volumes, takes the effect of weighting volumes downwind and, of course, the most impacting product category is glazed porcelain stoneware.

5.3 LCC: Inventory Costs

Consistent with the LCA analysis discussed before, the same functional unit was adopted for the assessment of costs, for the four product categories already described above: porous double-fired wall tiles, porous single-fired wall tiles, glazed porcelain stoneware and unglazed porcelain stoneware (Paragraphs 3.5 and 3.6).

5.4 LCC: Costs Assessment

In an integrated process for the manufacturing of a product, the life cycle of costs is the sum of the costs attributable to the individual life cycle stages [84]:

$$LCC_{TOT} = \text{Development Costs} + \text{Utilization Costs} + \text{Disposal Costs} \quad (2)$$

To adapt the above conceptual formula (2) to the specific case under study, we propose this new empirical formula:

$$LCC_{TOT} = \text{Production Costs} + \text{Utilization Costs} + \text{Externalities} \quad (3)$$

LIFE CYCLE COSTING	POROUS DOUBLE-FIRED WALL TILES	POROUS SINGLE-FIRED WALL TILES	GLAZED PORCELAIN STONEWARE	UNGLAZED PORCELAIN STONEWARE
PRODUCTION COST				
Production (m²)	22.978.356	13.545.628	236.734.900	121.954.343
Production Costs (€/m2)	6,15	7,72	6,85	8,06
TOTAL PRODUCTION COSTS	141.316.889	104.572.248	1.621.634.065	982.952.005
	2.850.475.207			
UTILIZATION COST				
Utilization Costs (€/m2)	6,56	6,85	8,99	10,01
TOTAL UTILIZATION COSTS	150.738.015	92.787.552	2.128.010.016	1.220.762.973
	3.592.298.557			
EXTERNALITIES				
Human Health	0,11	0,13	0,15	0,17
Ecosystem Production Capacity	0,11	0,14	0,14	0,19
Abiotic Stock Resource	0,54	0,83	0,41	0,50
Biodiversity	0,0014	0,0015	0,0018	0,0023
TOTAL	0,76	1,10	0,71	0,86
TOTAL EXTERNALITIES	17.443.293	14.896.295	168.293.988	104.824.295
	305.457.871			
TOTAL PRODUCT COST €/m²	13,47	15,67	16,55	18,93
TOTAL COSTS BY CATEGORY	309.498.197,60	212.256.095,04	3.917.938.069,26	2.308.539.272,52
TOTAL	6.748.231.634			

Table 7: LCC calculation scheme based on inventory data and applying the empirical formula (2). Externalities are expressed in euro/m².

The calculation of production and utilization (distribution, installation and use phases) costs of the end product, were determined per m² and then projected on a "meso" scale on the basis of production volumes by category and total for the entire district (Table 7). The economic impact assessment (LCC), which is carried out in parallel with the environmental impact assessment (LCA), makes it possible to quantify environmental damage economically. The production of ceramic tiles, as well as other economic activities, uses resources that come from the environment without, however, considering the economic value of the environmental damage caused by the use of these factors of production. Costs incurred by some parts of society because of activities that affect the environmental balance of a territory are referred to as negative environmental externalities or external costs [85]. The EPS 2000 model has been used to estimate externalities. It estimates the economic cost of pollutant emissions based on the willingness to pay (WTP) of the entity responsible, in order to avoid a worsening of the situation created or to remedy a damage caused, attributing an economic value to the damage. Each impact category in the EPS 2000 model attributes a specific weight to the severity of the impact in environmental and social terms. This weight is defined as the

ELU (Environmental Load Unit), whose value is 1 ELU = 1€. Table 7 shows the costs of environmental externalities relating to the damage category for each type of ceramic product considered.

5.5 LCC: Results Interpretation

The adoption of the external costs approach allowed us to monetize the environmental impact of different ceramic tiles production. The LCC analysis assimilates the directional accounting because it introduces into it not only the industrial costs and those of use, but also those that the environment and the company must pay in order to maintain the manufacturing conditions of the ceramic product. The transformation of environmental externalities into internal costs makes it possible to go beyond the individual production units and to consider the territory, switching from micro to the meso level.

5.6 S-LCA: Social Assessment

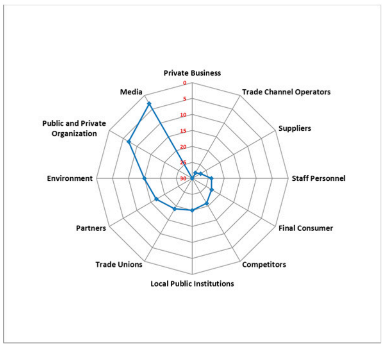
The three impact assessment systems S-LCA, LCA and LCC all refer to the guidelines set out in ISO 14040 which provides for four phases Therefore, for the determination of the social impact, implementing the same Objective and Scope of LCA and LCC, using the so-called Participatory Approach [78] already used for the engagement of stakeholders involved in the management of Cultural Heritage [79]. In the case under consideration in this study, the expectations of the Stakeholders involved in the value chain of the Sassuolo district were adopted as an indicator of social impact. To determine the expectations of the main stakeholders, the qualitative analysis has required the use of various data collection techniques, such as: structured online interviews and focus groups. Subsequently, in order to define the degree of influence that the expectations of the stakeholders have on the producers of ceramic tiles, it was necessary to assign to each stakeholder a prioritization index, constructed with the criteria of power, urgency and proximity already described in the AA1000 standard [80].

STAKEHOLDERS	Power Criterion	Urgency Criteria	Proximity Criteria	Total Prioritization Index	Deviation %
Staff Personnel	7	7	10	24	20
Trade Unions	6	6	7	19	37
Local Public Institutions	10	5	5	20	33
Private Business	10	10	10	30	0
Public and Private Organization	2	2	3	7	77
Environment	5	6	4	15	50
Media	1	1	1	3	90
Trade Channel Operators	9	10	9	28	7
Final Consumer	8	8	7	23	23
Suppliers	9	8	10	27	10
Partners	6	4	7	17	43
Competitors	9	5	7	21	30
MAXIMUM PRIORITIZATION	10	10	10	30	0

(a)

Priority	STAKEHOLDERS	Total Prioritization Index	Weighting Factor	Priority Group
1	Private Business	30	1,0	Priority Group 1 WF ≥ 0,9
2	Trade Channel Operators	28	0,9	
3	Suppliers	27	0,9	
4	Staff Personnel	24	0,8	Priority Group 2 WF ≥ 0,7
5	Final Consumer	23	0,8	
6	Competitors	21	0,7	
7	Local Public Institutions	20	0,7	
8	Trade Unions	19	0,6	Priority Group 3 WF ≥ 0,5
9	Partners	17	0,6	
10	Environment	15	0,5	
11	Public and Private Organization	7	0,2	Priority Group 4 WF ≤ 0,2
12	Media	3	0,1	

(b)



(c)

Figure 3: Scenario 1. Entrepreneurial perspective: (a) mapping, (b) prioritization and (c) graphic representation of the significance of stakeholders.

The social research applied to this case study, raised relevant methodological questions. It has been verified that the analyst's position is not neutral, when he observes social events to infer conclusions, he "interprets" social phenomena based on his background (experience, knowledge and conscience) [86]. Therefore, the research team was confronted with the intrinsic partiality of each member when collecting, processing and analyzing social data [87]. The construction of knowledge is therefore done through a continuous exchange of points of view, including those of the research team, but not only. The interpretative process and the construction of reality is also influenced by the context in which the social event occurs. Converging multiple points of view, such as stakeholder expectations, is a way to build and describe reality. Through the interpretation of these different points of view, the background of the researcher/analysts merges with those of other social agents, creating a new and more complete understanding of the reality under examination [88].

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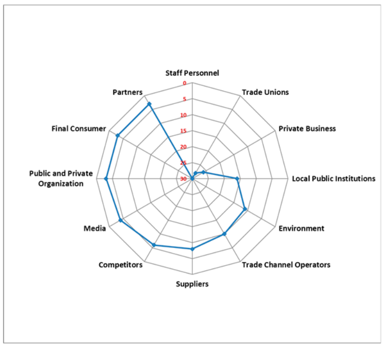
STAKEHOLDERS	Power Criterion	Urgency Criteria	Proximity Criteria	Total Prioritization Index	Deviation %
Staff Personnel	10	10	10	30	0
Trade Unions	9	9	10	28	7
Local Public Institutions	8	4	4	16	47
Private Business	9	8	9	26	13
Public and Private Organization	1	1	1	3	90
Environment	4	5	2	11	63
Media	1	1	2	4	87
Trade Channel Operators	1	4	5	10	67
Final Consumer	1	1	1	3	90
Suppliers	2	1	5	8	73
Partners	1	1	1	3	90
Competitors	4	1	1	6	80
MAXIMUM PRIORITIZATION	10	10	10	30	0

(a)

Priority	STAKEHOLDERS	Total Prioritization Index	Weighting Factor	Priority Group
1	Staff Personnel	30	1,0	Priority Group 1 WF ≥ 0,9
2	Trade Unions	28	0,9	
3	Private Business	26	0,9	
4	Local Public Institutions	16	0,5	Priority Group 2 WF ≥ 0,3
5	Environment	11	0,4	
6	Trade Channel Operators	10	0,3	Priority Group 3 WF ≤ 0,2
7	Suppliers	8	0,3	
8	Competitors	6	0,2	
9	Media	4	0,1	Priority Group 4 WF ≤ 0,1
10	Public and Private Organization	3	0,1	
11	Final Consumer	3	0,1	
12	Partners	3	0,1	

(b)



(c)

Figure 4: Scenario 2. worker's perspective: (a) mapping, (b) prioritization and (c) graphic representation of the significance of stakeholders.

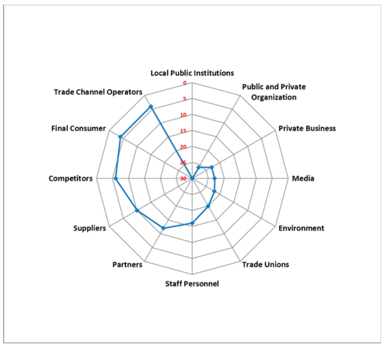
For this reason, the importance of Stakeholders was declined into three sets characterized by three different perspectives of observation of reality. Scenario 1, entrepreneurial perspective (Figure 3); Scenario 2, worker's perspective (Figure 4) and Scenario 3 public institutions' perspective (Figure 5).

STAKEHOLDERS	Power Criterion	Urgency Criteria	Proximity Criteria	Total Prioritization Index	Deviation %
Staff Personnel	2	6	8	16	47
Trade Unions	6	8	6	20	33
Local Public Institutions	10	10	10	30	0
Private Business	7	8	8	23	23
Public and Private Organization	9	8	9	26	13
Environment	7	9	6	22	27
Media	9	6	8	23	23
Trade Channel Operators	1	1	2	4	87
Final Consumer	1	2	1	4	87
Suppliers	4	2	4	10	67
Partners	4	5	3	12	60
Competitors	3	2	1	6	80
MAXIMUM PRIORITIZATION	10	10	10	30	0

(a)

Priority	STAKEHOLDERS	Total Prioritization Index	Weighting Factor	Priority Group
1	Local Public Institutions	30	1,0	Priority Group 1 WF ≥ 0,9
2	Public and Private Organization	26	0,9	
3	Private Business	23	0,8	Priority Group 2 WF ≥ 0,7
4	Media	23	0,8	
5	Environment	22	0,7	
6	Trade Unions	20	0,7	
7	Staff Personnel	16	0,5	Priority Group 3 WF ≥ 0,3
8	Partners	12	0,4	
9	Suppliers	10	0,3	
10	Competitors	6	0,2	Priority Group 4 WF ≤ 0,2
11	Final Consumer	4	0,1	
12	Trade Channel Operators	4	0,1	

(b)



(c)

Figure 5: Scenario 3. public institutions' perspective: (a) mapping, (b) prioritization and (c) graphic representation of the significance of stakeholders.

Table "a" of each scenario considered (Figures: 3, 4 and 5), indicates that for each main stakeholder category and each criterion, a priority index has been assigned (from 1 to 10). The total index is obtained from their sum. Assuming the value 30 (10 + 10 + 10) as the maximum prioritization index, the percentage deviation for each stakeholder indicates the "distance" of this value from the maximum possible index. In the following Table "b" (Figures: 2,3 and 4) stakeholder groups are ordered by total index of decreasing prioritization and by weighting factor obtained by dividing this index with the maximum index of prioritization (30). In this way, it was possible to aggravate the stakeholders in four priority groups. Finally, radial diagram "c" (Figures: 3, 4 and 5) graphically traces the relative relevance of the stakeholders with respect to the index of maximum prioritization.

5.7 S-LCA: Assessment Interpretation

By merging the different perspectives and expectations of the stakeholders of the Sassuolo ceramic district, it was possible to arrive at a new construction of the reality that has overcome the subjectivity of each individual economic agent or stakeholder group, as well as to reduce the problem of partiality of the members of the research team in the data collection and analysis phases. Figure 5 shows the interpretative process for the three scenarios considered: entrepreneurs, workers and public institutions.

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Priority Group	SCENARIO 1 Entrepreneurial Perspective		SCENARIO 2 Worker's Perspective		SCENARIO 3 Public Institutions' Perspective	
	STAKEHOLDER	INDEX	STAKEHOLDER	INDEX	STAKEHOLDER	INDEX
1	Private Business	1,0	Staff Personnel	1,0	Local Public Institutions	1,0
	Trade Channel Operators	0,9	Trade Unions	0,9	Public and Private Organization	0,9
	Suppliers	0,9	Private Business	0,9		
2	Staff Personnel	0,8	Local Public Institutions	0,5	Private Business	0,8
	Final Consumer	0,8	Environment	0,4	Media	0,8
	Competitors	0,7			Environment	0,7
	Local Public Institutions	0,7			Trade Unions	0,7
3	Trade Unions	0,6	Trade Channel Operators	0,3	Staff Personnel	0,5
	Partners	0,6	Suppliers	0,3	Partners	0,4
	Environment	0,5	Competitors	0,2	Suppliers	0,3
4	Public and Private Organization	0,2	Media	0,1	Competitors	0,2
	Media	0,1	Public and Private Organization	0,1	Final Consumer	0,1
			Final Consumer	0,1	Trade Channel Operators	0,1
			Partners	0,1		

INTERPRETATION PROCESS FOR A NEW UNDERSTANDING

1	Private Business	1,0
2	Staff Personnel	1,0
3	Local Public Institutions	1,0
4	Trade Channel Operators	0,9
5	Suppliers	0,9
6	Trade Unions	0,9
7	Public and Private Organization	0,9
8	Final Consumer	0,8
9	Media	0,8
10	Competitors	0,7
11	Environment	0,7
12	Partners	0,6

Figure 6: Interpretative process of fusion of the different perspectives of entrepreneurs, workers and public institutions and construction of a new prioritization of the stakeholders of Sassuolo district.

The table above in Figure 6 represents the logic of stakeholder prioritization for each scenario. Entrepreneurs, workers and public institutions have a different construction of reality depending on the specificity of their expectations. After collecting these different visions, the research team, through a hermeneutical process [89], carried out the fusion of the three different interpretative horizons to arrive at a new construction of reality that is represented in the table below in Figure 5 [90]. It represents a new prioritization of the stakeholders of the Sassuolo district on the basis of the perspectives of the three scenarios that have been considered. The new stakeholder list was built by combining scenarios (in columns) with priority groups (in line) across them and listing them in descending order of priority, switching from micro to meso level. The new list of stakeholders can be the basis for defining the most appropriate strategies for engagement.

6. Final discussion and conclusions

In this paper it was shown that the LCSA approach helps to incorporate the full social cost of an economic transaction with environmental effects into the price of products, avoiding attributing the external costs to the community and responding to market failures. The research bridges the gap between scholars and practitioners in the field of integrating sustainability principles into business models and economic and industrial policies for the governance of territories.

In a theoretical perspective, the change of the analysis unit, from the enterprise (at micro level) to the district (at meso level), allows one to take into account those externalities that would otherwise remain outside the "gates" of the economic actors and allows one to transform them into sector internalities. The LCSA model also highlighted that the transport of raw materials is one of the most impacting factors, but above all it showed that it is not only a physical operation cost (the transport from the mine to the factories), but also an environmental cost not exclusively attributable to the individual company, but to the entire sector. The determination of the monetary value of externalities has questioned the hypothesis of the "isotropicity" of space considered in terms of "pure distance", that is, that spatial element that must be filled in order to transport people with raw materials and finished products. Distance is not only an operations cost, but also an environmental cost.

Externalities have the consequence of creating situations of interdependence between subjects who are not among themselves in contractual relations. This vision raises the question of managing interactions between economic agents and internalizing externalities that cannot be left exclusively to market coordination. This is a problem of governance of the system and the implementation of appropriate economic policies aimed at attributing the cost of externalities to those who have been able to use public assets for the exercise of their economic activity. The economic quantification of external costs in aggregate terms, broadens the knowledge of the factors of pressure offering private decision makers and public administrators, useful information to prepare responses and targeted interventions of economic policies. We could therefore move from the coercive logic of "forbidding" to the positive logic of "doing better", in which the environment is no longer perceived as externality, a threat and obstacle to the development of businesses, but as an opportunity to stimulate product and process innovation.

From a managerial perspective, this experimental research has shown how the correct use of an appropriate scientific tool (the LCSA model) allows one to quantify the economic, environmental and social impact, using process data normally available to economic agents and otherwise not always used profitably. Empirically, the study, adopting the holistic perspective of the life cycle, showed that the transport of raw materials constitutes about 20-25 % of the environmental damage produced by the entire life cycle, for all the production categories of the Sassuolo ceramic district. However, there are no great differences between the different processes of the product categories considered, in terms of environmental impact, demonstrating the standardization of the production phases. The process of technological standardization has also made less relevant the reduction costs related to the territorial proximity and the outsourcing of production phases and the efficiency of learning processes that are at the basis of innovation. The effects of the industrial activities of the Sassuolo district extend beyond the traditional concept of local territory to reach beyond national borders, to the countries from which the raw materials necessary to produce ceramic tiles are sourced. The social dimension of industrial activity in the district and the related costs has led us to ask ourselves about the ways in which economic actors interact and about the model of "government" of the territory. The interpretative study of the expectations of the various stakeholders, divided into three different scenarios, would evoke the creation of a district governance that guides the efforts and investments of all companies towards cost efficiency, value innovation, market presence with an adequate policy of brand, the ability to develop and integrate into international markets. In mature markets technologies and operations are notably standardized. Therefore, traditional sources of competitive advantages will not take place in theses contexts, like the case of the European tiles ceramic industry. Coherently, sustainability can be considered an alternative way to differentiate products, companies or even countries, giving it a significant role in value creation. LCSA let firms or the whole industry identify new opportunities for competitive advantages along the value chain directly related to sustainability. In this paper we have developed a first step into the integration of the three tools dealing with sustainability: LCA, LCC, and S-LCA. The integration between the environment and economy took place through the transformation of environmental damage into externalities, thanks to the guidelines common to the two assessment models (LCA and LCC) defined in the ISO standards. Integration with the social dimension was achieved by assessing the expectations of the main stakeholders with respect to the environmental and economic impact data obtained. Our approach to integration has shown some critical points:

1. the transformation of environmental damage into externalities does not cover the entire economic dimension of an activity; in a strategic dimension, it would also be appropriate to determine the economic-financial sustainability of alternative scenarios.

2. there is still no link, even an indirect one, between the social and economic dimensions, so as to be able to address socio-economic sustainability in a broader sense, and not just the assessment of the social effects of environmental damage.

Both these critical issues provide a natural guide to future research.

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