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STRATEGIES FOR THE ENVIRONMENTAL MANAGEMENT OF THE MARBLE DISTRICTS THROUGH THE INTEGRATED CONTRIBUTION OF LIFE CYCLE ASSESSMENT AND GIS

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EXTENDED ABSTRACT

L'obiettivo di questo contributo scientifico è quello di presentare gli esiti di una ricerca relativa allo studio e all'individuazione di possibili strategie gestionali da adottare all'interno di distretti lapidei per favorire il miglioramento ambientale dei prodotti litici. Questa ricerca nasce dalla consapevolezza che attualmente la filiera produttiva della pietra naturale è molto impattante, sia alla scala locale (area di coltivazione dei giacimenti minerari e/o area di lavorazione), che alla scala globale (consumi di energia ed emissioni inquinanti), penalizzando il prodotto litico dal punto di vista ambientale. Alcune delle principali cause sono l'elevata produzione di scarti pre-consumo (in alcuni contesti produttivi per ogni tonnellata di pietra prodotta altrettanto materiale di scarto viene destinato allo smaltimento in discarica) e la notevole richiesta di energia per le lavorazioni. Intervenire su questi aspetti può favorire miglioramenti sial sul piano ambientale che su quello economico. Sulla base di queste premesse la ricerca ha individuato e vagliato quali possono essere le strategie da mettere in atto per favorire un cambiamento significativo (in termini di impatto ambientale) all'interno della filiera produttiva della pietra, ma anche e soprattutto per comprendere la potenzialità di ecoinnovazione della filiera amplificata dalle prospettive del distretto. Infatti, per favorire il cambiamento da un modello produttivo di tipo lineare ad un modello produttivo circolare (in cui i rifiuti sono minimizzati), è fondamentale una strategia condivisa, resa possibile dalla cooperazione che si può attivare all'interno dei distretti industriali. Poter contare su una rete organizzata (unità distrettuali), superando la frammentazione tipica della realtà industriale italiana, fatta di piccole e medie imprese (caratteristica anche del settore lapideo nazionale), rappresenta una condizione indispensabile per poter attuare i principi dell'economia circolare, promossi dalle politiche europee e nazionali. L'economia circolare è basata su un modello di produzione e di distribuzione che pone al centro la sostenibilità del sistema e il riutilizzo delle materie di scarto, con vantaggi economici e ambientali derivanti all'efficiente uso delle risorse grazie alla creazione di sinergie tra imprese, territorio e ricerca, a vantaggio della competitività industriale.

All'interno di questa logica, la ricerca presentata propone la struttura di una piattaforma gestionale, da assumere all'interno del distretto, finalizzata a monitorare il territorio del distretto stesso, per identificare e mappare punti di forza e criticità, con lo scopo di individuare sinergie e scenari strategici di uso efficiente delle risorse, avvantaggiando diverse scale territoriali. Il metodo che la piattaforma gestionale applica per valutare i vantaggi ambientali degli scenari da perseguire a scala locale e sovralocale, è quello di raccogliere dati relativi ai flussi di risorse, di valutarli secondo i principi del Life Cycle Assessment e di contestualizzarli a scala locale/territoriale con il contributo dei Geographic Information Systems. Un sistema così strutturato permette di avere una visione completa dell'incidenza dei processi attivi e/o attivabili su un territorio. Ad esempio, se si fa riferimento all'impatto generato dall'attività di cava dalla produzione di scarti, l'informazione incrociata tra LCA e GIS può fornire indicazioni sui quantitativi prodotti e sulla loro collocazione, e permettere di identificare scenari strategici per il recupero degli scarti, fornendo indicazioni sulla posizione degli scarti sul territorio anche in relazione a infrastrutture di trasporto e a siti produttivi che a scala locale possono diventare luoghi di trattamento/riuso/riciclo degli scarti. Gli scenari strategici individuati possono essere simulati e, tramite l'uso dell'LCA, valutati per verificare i vantaggi ambientali conseguibili.

L'efficienza di un sistema gestionale così strutturato si fonda sulla validità oggettiva del metodo LCA nella valutazione dei benefici ambientali conseguibili e sulla trasposizione degli indicatori relativi ai flussi di risorse e agli impatti ambientali sulle mappature GIS, che consentono di individuare sinergie potenzialmente attivabili a scala locale/territoriale. Questa interpretazione fornisce una contestualizzazione reale degli impatti e rende possibile una valutazione immediata delle strategie attivabili in relazione a diverse aree territoriali di influenza e dei miglioramenti ambientali ottenibili considerando diversi indicatori ambientali (consumo di energia, emissioni inquinanti, rifiuti). Il ruolo del distretto diventa fondamentale per riuscire a governare il processo e per gestire la piattaforma che diventerà un punto di riferimento per tutte le aziende del territorio.

ABSTRACT

The aim of this paper is to show the results of a research work related to a different way for manage stone districts, in order to obtain environmental improvements. The extraction and the processing of natural stone imply a considerable environmental impact, both on the production area and at the global scale, with a consequent penalization of the environmental profile of the lytic products. The research highlights the potential role that a "district" can play on the radical transformation of the current production system (linear model) towards a more sustainable "modus operandi" (circular model) from both the environmental and the economic point of view, through the reuse/recycling of scraps in the same or other sectors.

According to this approach, the research suggests the structure of a "management platform" prototype, aimed at monitoring the district territory in order to find possible new synergies in the supply chain for the benefit of the whole territory. The proposed management platform has the aim to assess the scenarios that can be pursued at a local and national level, by collecting data on environmental impacts and on material flows through the LCA and contextualizing them on a local scale with the use of GIS.

Key words*: eco-innovation, circular economy, LCA, GIS, scraps, reuse, valorization*

INTRODUCTION

The market of the Italian stone sector, despite the economic crisis of the last few years, has been able to record good turnovers and in some case has registered signals of growth (e.g. Gussoni, 2015), ranking among the top three countries in the world for the value of the market. A thriving market, like this one, cannot be overlooked from the environmental point of view, because, typically, a good market, proportionally with the dimension and the importance, drags a lot of environmental issues related to the production chain and to the territory. The stone sector is very energy-intensive and highly impactful for the environment (e.g. Legambiente, 2014), especially in the territories where the quarries and/or the processing centers are located (e.g. Traverso *et alii*, 2010).

One of the most critical aspect in the stone sector is the high production of pre-consume scraps, starting from those coming from quarry up to the outcomes of the production processes. It is estimated that about the half of the extracted amount becomes scrap due to dimensional inconsistency, structural defects and/or chromatic alteration and at present (for the major quantity) it is destined for landfill disposal. However, it is evident that all scraps/waste, coming from activities related to the stone processing, can be fully recycled, both through processes of upcycling, increasing the quantity of valuable products outcoming from the supply chain (e.g. Puppala *et alii*, 2012; Akbulut *et alii*, 2007), and through processes of downcycling (e.g. Dino *et alii*, 2005). Despite this possibilities, it is actually difficult the systematic definition of scraps/waste recovery models. One cause of this difficulty can be partly attributed to regulatory difficulties (need to dispose of the materials that cannot be sold and therefore become waste), but also to logistic and organizational difficulties related to define how and where all the scraps/waste could be recycled. In this regard, in order to govern these processes, it is necessary the definition of an "upper" structure, able to collect and transform different needs of stakeholders involved in industrial activities in the same region, into market demand and offer. These structures could be within the "industrial districts", already known on the national scene and defined by Legge n. 140 of 1999 as local production systems characterized by a strong spatial concentration and a high specialization.

The industrial district becomes the promoter of innovation for companies, and the guarantor of competitiveness maintaining, an actual reference point especially for small and medium-sized enterprises, that fail to have, in their company's staff, a research and development service. In addition to these important tasks, the districts also have the role of interfacing with the territory that is a complex operation, difficult to be managed, especially when it is not possible to have access to monitoring and management tools that can give in real time an idea of what it is happening on the territory. In addition to the aspects mentioned above, the potential usefulness of the industrial districts becomes more important in this particular historical period because the districts (e.g. Giannoccaro, 2015; Jiang *et alii*, 2016) have the ability to guide and influence new forms of economic development, which can facilitate the transition towards economic development models based on the circularity. These issues are at the heart of European environmental policies and of the COM 2015\614 "Closing the loop - An EU action plan for the Circular Economy" about the issue of emissions reduction and efficient use of natural resources.

Circular economy models are based on the use and the valorization of scraps, which never become waste (e.g. Bollini *et alii*, Lovins *et alii*, 2014; 2008; Rota, 2012) but always a resource for a new production system (industrial as natural systems). In this way the products maintain their value longer, waste and disposal costs are reduced to minimum, resources never leave the economic system and they are reused multiple times; moreover, functional strategies for setting up new businesses can be activated from the reuse of scrap/waste. The economic and environmental benefits of the efficient use of resources, derived by the synergies between companies, territory and research, give opportunities to industrial competitiveness. The described goals are the basis of the strategic scenarios that can be introduced within the district, however, their activation is bound by the occurrence of other specific conditions:

- knowledge of the by-products processing;
- tracking and monitoring of processing;

- control and management of material flows from processing,
- easiness of supply.

Other fundamental aspects for the achievement of the proposed objectives are: having a full control of the contextualization scale of the strategies of recycling and enhancement of the scraps (the induced impact must always be lower than the avoided one) and establishing a management system, that supports control and coordination of the territory and of companies established on it, in order to promote proactive relationships.

In reference to the case of industrial districts, the reference scale is very low (typically the area of mineral deposits extends over small spaces), therefore it appears to be appropriate for the activation of a form of shared coordination. Based on these premises, the study focused on the construction of a prototype of "management platform", identifying, as users, the key decision makers and the connections with the territory. Then, the study identified some scenarios for improvement (innovative scenarios and valorization of scraps/waste, enhancement of the supply chain, etc.), that can be implemented with the support of the district, in order to obtain economic and environmental benefits that also have positive impacts on the territory and on other companies. In the last phase, the study has identified an analytical and objective method to assess the proposed scenarios and to monitor the environmental emission related to the conducted industrial activities. Life Cycle Assessment has proved to be the most useful and trusted evaluation system for its objectivity and universality, while the combined use of LCA and GIS has proved to be effective in order to transpose on the territory, through the mapping of the incidence of the impacts estimated by environmental indicators selected.

DISTRICT ORGANIZATION

The peculiarity of Italian stone districts is the dimension of the companies, typically small or medium companies, which in many cases are unable to fully express their productive potential due to the lack of an internal research team for the proposal of process and product innovation scenarios. These aspects in the contemporary world represent pluses if you intend to take part in the markets' competition. In these terms, the idea of giving more importance to the "district authorities" arises in order to be able to provide professional technical services and advices to all companies. An ideal district working team is characterized by the presence of different experts, supported in a shared way by local companies, that pay attention to the needs of companies in order to turn these needs into concrete actions and to guide companies in eco-innovation processes. The aim is to improve competitiveness by fostering an increasing integration between businesses and territory. The role of mediation, wielded by these experts, is a fundamental part of the success of any initiative that aspires to achieve long-term results and the experiences, already carried out in other contexts (e.g. Capò-Vicedo *et alii*, 2013), show that the form of facilitation derive from collaborations with universities and/or research centers.

On the basis of the previous statements, an efficient and competitive industrial district should be organized in a non-hierarchical scheme, but in a scheme characterized by cooperation and permeability of competences. For example, if within the district it was appointed a "scientific commission" (Fig. 1), this commission should contain all the necessary skills to be able to support initiatives of various kinds and to be able to interface with the different realities (in some cases, industrial settlements can generate problems of coexistence with the local housing).

The fundamental skills are those related to: the ability to promote a continuous process of innovation (Research & Development), both product and process; the ability to seek new markets, opening up to international contexts (Internationalization & Partnership) and looking for new industrial synergies; the ability to create an equilibrium with the territory (Territory), because a stable and symbiotic relationship with local communities can promote forms of protection and support to industrial activities; and the ability of becoming sustainable (Environment), protecting the environment from uncontrolled environmental impacts.

Such a system represents the starting point in order to design a model of shared management of industrial companies, because the creation of common points create the possibility for the development of ambitious strategies and the capacity to achieve them. For

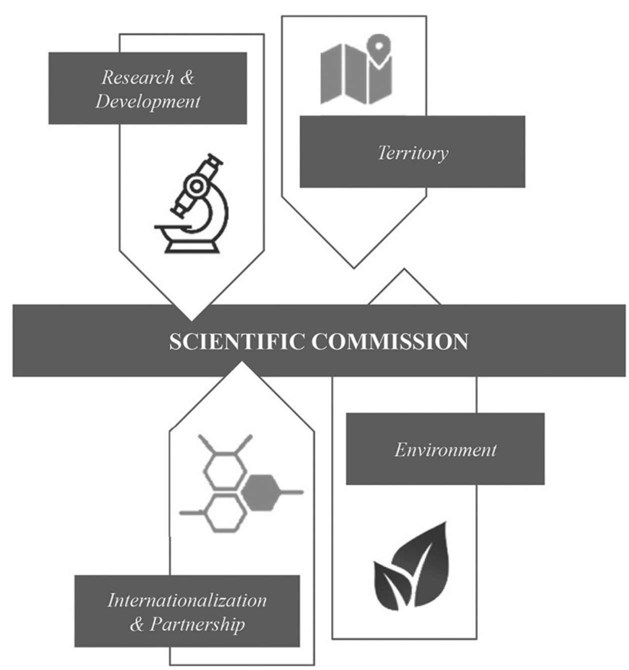

Fig. 1 - Internal expertise of the scientific committee: Research and development (product and process innovation), Territory (relations between the firms and the local municipality), Internationalization e partnership (creation of international network) and Environment (resource control, waste reduction, pollution prevention)

example, if we consider the case of stone districts, the willingness to recover the scraps related to the extraction phase should become a common goal. In this way, the "district authorities", through a system of synergies, have to be able to control the material flows to other production companies. A different way for managing this flow (for example the case of a single company) couldn't guarantee in a long period the compliance with the request scenarios and then could cancel the derivable benefits. For instance the amount of material available is not enough to satisfy the request of other companies and/or there isn't a good monitoring of the quality of the transferred materials. Most of the supporting activities carried out by an industrial district need organized systems, useful to simplify the activities, such as "management platform".

Management platform

The idea of structuring at local and/or at extra-local scale a "management platform" for managing the flows of materials that move on the territory, represents a viable strategy to encourage the reduction of the quantity of waste disposed in landfills. A management system of this type is based on the principles of circular economy (e.g. Murray *et alii*, 2015) and, in accordance with the COM (2014) 398 "*Towards a circular economy. a zero waste programme for Europe" and the COM 2015(614) "Closing the loop. An EU action plan for the Circular Economy*", it is a valuable tool to provide organizational support in the process of synergies' activation between companies.

The Management platform is built on a simple scheme (Fig. 2): on one hand it receives information about waste from companies of the district and qualify the materials and their possible reuse, on the other hand it seeks to identify strategic scenarios in which it could be possible conveniently (both from the economic and the environmental point of view) to transfer the secondary raw material. This operation is not immediate, the scraps are evaluated and filed, in order to provide appropriate information to hypothetical users/buyers. For example, in the case of scraps deriving from the natural stone processes, there are some basic information useful for defining if the scrap can be used for ornamental purposes or as aggregate. In this case its necessary to evaluate the size of the pieces, the chromatic alterations, the technological performance, etc.).

The management platform through this activity of filing of scraps/waste materials, eases to carry out environmental assessments on the territory. For example, it provides useful information to assess the environmental impact of a quarry; this is an useful information if compared with data from other quarries, with the ultimate goal of identifying possible procedures or special characteristics that make a quarry more sustainable than another.

In particular, after collecting information on material flows, the management platform will be useful to make the following evaluations:

- Environmental impacts of the quarries;
- Identification of production contexts with a low productivity;
- Identification of virtuosos production contexts, which can be objects of studies;
- Definition of scraps percentage environmentally tolerable;
- Index of exploitation of mineral deposits.

The information derivable from these forms of assessment will be helpful in terms of strategic planning (e.g. ISPRA, 2013) and, in terms of industrial planning, have a chance to meet with other production companies will be rewarding and will encourage a new way of operating, not only economically but also environmentally advantageous.

The management platform is presented as a point of exchange of information, useful to facilitate a continuous monitoring of local production, functional to propose and to enable new industrial strategies.

The structures of the proposal platform

The platform is structured in different information levels (e.g. Migliore *et alii*, 2015).

- *Supply chain*. In the first level are listed the supply chains and the relating production phases. They are classified with a code which derives from Ateco 2007 (a typical Italian filing system created by ISTAT, the national statistic centre accordingly to the European classification "NACE Rev. 2 - Statistical classification of economic activities").
- *Scraps/waste*. In the second level, for each production phases, scraps/waste typologies are recognized with a specific code, which derives from CER catalogue (a European method to

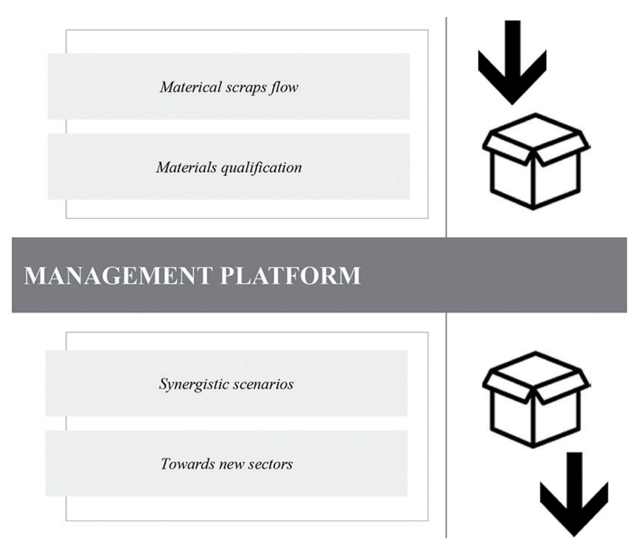

Fig. 2 - Schematic flow of the management platform. From the first stage in which it receives and qualifies the materials flow, to the second stage in which identifies strategic scenarios in which is possible to transfer the second raw material

classify the typology of waste), and in some cases with an additional code for a better identification. The identification and the classification of the secondary raw materials potentially available (scraps/waste as resources) enable the stakeholders to understand if they could develop new production process.

- *Location*. The third level of the platform provides information related to the possible geographical collocation of the material and about its quantity. This information is more useful in order to create synergic scenarios between companies. In this way it is possible to create a very good collaborations among companies achievable the entire production chain, in order to set conditions for the institution of form of circular economy or "Eco Industrial Park" (e.g. Lowe, 2011; Lowe *et alii*, 1997; Lowe *et alii,* 1996; Chertow *et alii*, 2000; Biali *et alii*, 2014). With this type of information, an hypothetical users/buyers, could identify both the area of higher concentration of the secondary raw materials more responding to his needs and especially the quantity of available material.
- *Best practices*. In the fourth level of the platform are collect contributions and original experiments conducted starting from a specific waste/scraps in other productive contexts.

Indeed, by identifying similar characteristics between scraps and virgin raw materials, it is easier for the stakeholders to assess the replacement of virgin raw materials with secondary raw materials. From this consciousness can be activates strategic scenarios.

STRATEGIC SCENARIOS

In the development of the research, once the structure of the platform has been defined, some scenarios have been drawn and evaluate in order to simulate the use of the platform by the experts of the districts. The proposal scenarios can be divided into process scenarios and product scenarios concerning radical and incremental innovations. The first ones concern forms of innovation aiming at the change/enhancement of the current processes, and to the realization of new products. The second one concerns forms of enhancement that can take place in current production system, without radical changes or through the development of the machinery.

Product innovations

The platform can evaluate product innovations that can be divided into proposals for "up-cycling" and proposals for "down-cycling".

The up-cycling proposals are:

- *Re-use of small size scraps* (stone without chromatic and/or physical defects). The small sizes are often discarded because they do not meet the dimensional standards typically recognized in the field of natural stone processes, however it is clear that these wastes can be treated fully as a secondary raw material and their recovery leads to a reduction of 40% in energy consumption (e.g. Traverso *et alii*, 2010) and 90% for emissions of CO_2eq (considering the avoided impact related to the disposal and to the extraction of new virgin raw material).
- *Re-use of scraps with defects* (stone with chromatic and/or physical defects). It refers to all those products that can be made starting from pieces of stone (both pre- consumer scraps and post-consumer waste) for the implementation of technological elements that can be used in the building sector, such as metal gabions used for the realization of permeable facades (e.g. Bozzola *et alii*, 1995). Such scenarios allow a total recovery of stone scraps and a complete cost reduction of disposal in landfills.
- *Reduction of slabs thickness*. The reduction of the thickness of the processed slabs would increase the amount of finished material available up to 300%. Currently is possible to cut the slabs in thicknesses of 4 mm, against the typical 2-3 cm slabs (e.g. Migliore, 2015).
- *Artificial stone or composite stone* (e.g. Galetakis *et alii*, 2004; Lee *et alii*, 2008; Borsellino *et alii*, 2009). It is obtained through the mixture of resin and stone, it may be armed and strengthened, and currently it looks like a very innovative material according to its technical characteristics.
- *Re-use of sludge*. Currently it is possible to recover the sawmill sludge in various ways, some studies (e.g. Chang *et alii*, 2010) have provided some proposals, but equally interesting are the results of the project Recyslurry conducted in Carrara (Italy), that showed a wide range of possibilities, ranging from the horticultural industry to the paints and paper productions.

The down-cycling proposals are:

- *Re-use of scraps for environmental restoration*. It is a type of re-use already implemented, but it could be supported for encourage a systemic re-use of waste materials, also for naturalistic recoveries of abandoned quarries (e.g. Bagnato *et alii*, 2013).
- *Re-use of stone scraps as aggregate*. Actually it is possible to reuse the stone scraps such as aggregate for the production of other building products (e.g. Corinaldesi *et alii*, 2010; Hebhoub *et alii*, 2010; Abukersh *et alii*, 2011; Bilgin *et alii*, 2012); typically it is necessary to crush the raw material to transform it in an integral part of mixtures and/or other composite materials.

Process innovation

In the same way the platform can support the evaluation of scenarios of process innovations, that can be divided into proposals for incremental innovation and proposal for radical innovation.

The incremental proposals are:

- *Optimization of excavation techniques*. Many studies (e.g. Gazi *et alii*, 2012; Mancini *et alii*, 1997) have proven that the excavation process through the use of a detonating cord can lead to several damages to the lytic quarry system. This situation aggravates the already critic situation of the big quantitative of scraps\waste.

- *Optimization in the project of the cut of the block*. This technique, which is based on the ancient stereotomy, (e.g. Salvatori *et alii*, 2012), aims to avoid scraps from cutting for dimensional adjustment of blocks and slabs. Many architects, interested in this issue, have produced very interesting results, one of the strategy pursued is the cutting of the slabs not in a standard size, but in several sizes (defined and designed on a specific modulo) (e.g. Migliore, 2015).

The radical proposals are:

- *Three-dimensional scanning of the quarries*. This innovative procedure (e.g. Vanneschi *et alii*, 2014; Careddu *et alii*, 2015) is aimed to assist in managing the facades of the quarries, in many cases bumpy and characterized by constantly modifying of the internal connection system. A three-dimensional quarry management could help to reduce the risks involved during the extraction and the processing and it can give significant positive contributions in terms of hydrological monitoring.
- *Blocks laser scan*. The scanning of the blocks simplifies the study of block before cutting, and it promotes the use of numerical control equipment to assess the cutting face. Such procedures can contribute substantially to the reduction of waste and can increase considerably the profit derivable from the sale of finished products, which increase in quantity.

The proposed scenarios are all valid and actionable, and they find greater value if they were prosecuted jointly, because the entire natural stone supply chain could have benefit from the outcomes derived from their application. It can be estimated that if all scenarios could be pursued, the index of return of a quarry could grow of the 30% and the environmental profile of the lytic product could decrease well over 50%.

EVALUATION AND MONITORING SYSTEM

The proposed strategies, to achieve a higher degree of sustainability of the natural stone products, are all as useful and efficient, but, to better evaluate/monitor the impacts of each one, an environmental evaluation should be applied. In these terms, the Life Cycle Assessment was the most effective and globally recognized (e.g. Lavagna, 2008). The proposal platform collect information in relation to the management of LCA indicators.

LCA evaluation

The Life Cycle Assessment is a scientific procedure that allows to identify the environmental impacts associated with a product, process or activity, evaluating and following the object of evaluation throughout its entire life cycle. The analysis, conducted both before and after the use phase, starts with raw material extraction, through all phases of production, distribution, use and reuse of product, and it ends with the final disposal of the product, identifying and quantifying the raw materials consumption, the energy consumption and the emissions caused in the environment. It is an excellent method of evaluation, since, through the use of environmental indicators (global or territorial) can be representative of the current industrial scenario on a specific territory.

For the specific case of the natural stone industry, the indicators used are:

- GWP_ Global Warming Potential
- ODP_ Ozone Depletion Potential
- POCP_ Photochemical Ozone Creation Potentials
- EP_Eutrophication
- AP_ Acidification Potential
- Land Use

The selected impact categories describe the potential effects on humans health and the environment; among other things, they differ in relation to their spatial contextualization (global, regional and local effects).

An interesting aspect about environmental data is the contextualization in territory. Too often environmental data refer to a global

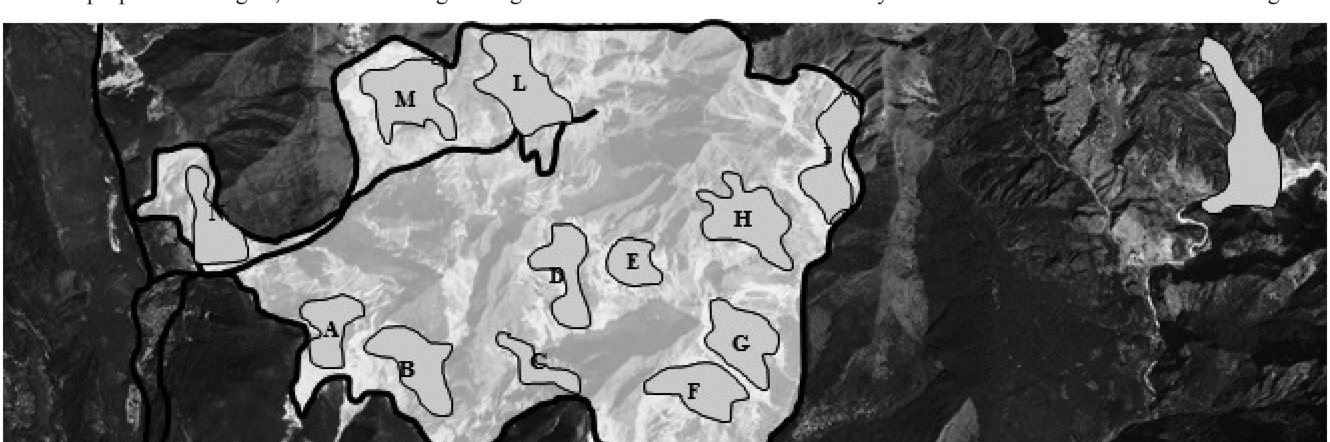

Fig. 3 - Representation on a specific territory (dashed line represent the area of the marble basin) of quarries areas (indicated by the letters). Within the file associated with the quarry, you can file different types of information that will allow to do different types of evaluations

scale, giving little consideration to the impacts that take place at the local scale. The proposal platform take into account to transfer the results of the environmental evaluations in the territory to have a direct perception of what happens after the activities that occur.

Indeed, for a district organization it is absolutely necessary to be able to refer the evaluations of scenarios to specific areas and territories.

G.I.S. application

An additional contribution of the proposed management platform is the use of GIS mapping to refer data to the territory. In the recent years, the potentialities of the use of GIS for georeferencing environmental data were object of studies (e.g. Blengini et alii, 2010; Oh *et alii*, 2011; Swetnama *et alii*, 2011). Currently GIS can be used in several ways, and the researches about its versatility explain that it can be used in sectors completely different from the spatial and territorial planning (information about the transport network, hydrography, characteristic of the population, economic activities, political jurisdiction and other characteristics of the social and natural environment). At present GIS is widely used for environmental studies, such as the management of resources (natural habitat, rivers, desertification, forest, farmland, flooded areas, etc.), promoted by Municipality, Region, State. In some cases, the GIS was used in strategic ways, for example, in China (e.g. Liu *et alii*, 2014), a study has been carried out in order to identify areas potentially usable for urban development, in which there were three types of examined parameters: those purely related to the environment (slopes, altitude, geo-morphology), those related to water bodies (rivers, annual precipitation, etc.) and those socio-economic (population density, road density, infrastructure systems). The combination of all these factors gives as result a strategic assessment that will enable this area to grow further in the coming years, impacting, as little as possible, on the already compromised territorial reality.

The purpose of the mapping realized through the Geographic Information System is to create relationships with the territory, in order to help the institutional decision-makers and create an interface with the planning realities, to allow to take common unique information and management directives (e.g. Blengini *et alii*, 2010).

In reference to the context of scraps, GIS is useful both to represent the presence of scraps/waste on the territory (Fig. 3 and 4) in relation to specific reference units (companies, district, etc.), but also to have an active role in the underlining how much secondary raw material is available to be reused., It is also suitable, in association with LCA, for representing the impacts associated with the industrial activities carried out on the territory (e.g. Kozak *et alii*, 2008; Mutel *et alii*, 2009; Mutel *et alii*, 2012; Mutel *et alii*, 2013).

For example comparing the environmental data of two quarries that have similar morphological features (extension, depth, etc), if there are substantial discrepancies from the point of view of emissions you can investigate the causes and identify strategies to improvement.

CONCLUSIONS

To highlight the role of the central organs in order to achieve important goals in a perspective of circular economy. Recognizing in the district authorities the general reference for the companies that are settled on a specific territory. The research starts from the role of shared supports for the experts in order to achieve long term results (economic profit, competitiveness, more sustainable productions), is important that the companies give a shared support to the district.

The special attention given to the pre-consumer scraps is a choice motivated by the fact that this is a reliable and constant source (as far as we can work on the reduction of scraps, anyway they will be produced) from which to start in order to recover the largest amount of secondary raw material and to feed continuous-

Fig. 4 - Schematic representation of roads linking quarry areas (indicated by the letters) and landfills (marked with numbers). The aim is to be able to control the flow of material in the territory

ly other businesses. The specific case of the production of natural stone is even more interesting because the deriving scrap is sufficiently homogeneous and suitable for various forms of reuse.

The proposed strategies for getting results start with the proposal of the construction of a management platform for the coordination and monitoring of flows of material moving within a district, and it is completed with the proposal of strategic scenarios that can be activated at the local scale or at extra-local scale.

The idea of proposing a system of hybrid environmental assessment, which considers both the contributions of Life Cycle Assessment and the contributions of the Geographic Information System, was born from the need to make valuable and contextual the impacts of a specific strategic choice, as well as to map and monitor the virgin resources and secondary raw materials on the territory. The control of raw material (virgin raw material or product) also favors greater guarantee both on the final product and on the secondary raw material (that is relocating to other production companies); the results concern both protection of the territory and the quality of the products.

Moreover, by attributing impacts to specific productive activities (through the use of environmental indicators resulting from LCA), the transfer to the thematic mapping of the territory become simple, with the aim of simulating and making clear what could happen after the choice and the application of a strategic policy.

The outcome expected from this type of approach is to contribute to a greater sharing of intents between the parties, since, through the transparency of the productions, it is possible to make more informed and conscious choices (within companies, within districts and within the area), aligned with the environmental and market needs. Moreover, if the presented study example could be transferred to several productive sectors, probably it will encourage a continuous environmental improvement, because, thanks to the possibility of checking the material flows of several supply chains, the intersectorial transfers of secondary raw material becomes more easier, (exactly as now happens in Eco Industrial Park), promoting greater sustainability and the actual development at circular economy.

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