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BUILDING A GREEN DEVELOPMENT ROADMAP USING 5RS AND TRIZ

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Abstract: *Sustainability is a top priority for the EU community. A valuable innovation framework, that combines TRIZ with sustainability 5Rs principles, can help to meet innovation needs by proving a structured approach to design sustainable innovation solutions.*
The framework suggests strategies to design sustainable and innovative solutions for new and greener products/services or processes. The theoretical approach has been tested with a pilot project with an Italian SME.
The company reached a strong decrease in virgin material consumption, the elimination of high impact material and the opportunity to establish a new "circular economy" business model based on reusable products that previously would have been destroyed.
The adoption of this framework will boost the knowledge, awareness and mindset among companies about sustainability and innovation.
Key words: *5Rs of sustainability, TRIZ-based eco-design, eco-innovation, systematic innovation, product innovation, green innovation*

1. INTRODUCTION

According to the recent European policy programs, sustainability is a top priority for the EU community: the recent Green Deal [1] promoted by the European Commission provides an action plan to boost the efficient use of resources by moving to a clean, circular economy and to restore biodiversity and cut pollution. The plan outlines huge investments and financing tools to support the dissemination and adoption of a new environmentally sustainable way of acting among EU citizens, companies, and institutions.

Italy, whose industrial ecosystem mainly consists of SMEs (they take around 95% of Italian enterprises in 2016[2] providing 38.9% of total GDP), is also addressing the issue of sustainability by adhering at different levels to financing strategies for the ecological transition. As a matter of fact, the Italian government introduced in 2021 a new strategic department dedicated to the green transition, namely "Ministero della Transizione Ecologica" [3].

In SMEs, the incentive to enhance the environmental performances comes from the customers, who ask for better ecological positioning, or from the market competition, which forces toward green certification, etc. In addition, the Italian market is one of the top performers in the circular economy adoption and green strategy implementation [4].

On the other hand, Traditionally the Italian SMEs market is characterized by a lack of innovation research tools that could help accelerating the innovation process: small and medium enterprises are not able to afford huge investments in theoretical studies, tools, and methodologies to support their innovation activities.

The main concern for management of the SMEs is on the core business of the company and the R&D effort is basically dedicated to the "development" phase rather than the "research" part. Consulting companies like Warrant Innovation Lab could support this kind of

enrichment in managing innovation among Italian SMEs.

Irrespective of the reason for the request, SMEs rely on the insightful-ness, expertise and knowledge of their staff in order to innovate, who usually has traditional designing tools, but lacks in systematic methods specialized in innovation. They tend to outsource the R&D projects that are burdensome for the internal staff, both in time-consumption and in skills request. Indeed, the main innovation activities regards testing, rapid prototyping and development related to projects that can rapidly evolve into new business products or services opportunities. This approach negatively affects the growth and development of innovation strategies and methodologies, with negative impacts on green innovation too.

This paper looks at the Italian SMEs market in order to provide a theoretical framework to combine the TRIZ methodology together with the environmental sustainability principles, supported by empirical evidence.

2. APPLICATION FIELD

Circular Economy is widely posed as alternative model of production and consumption, a growth strategy enabling the 'decoupling' of resource use from economic growth, thereby contributing to sustainable development [5]. According to the European Parliament, the circular economy "is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible. In this way, the life cycle of products is extended".
In practice, it aims at reducing waste and reusing planet resources. Moving towards a circular economy framework will also lead to relevant economic benefits such as competitiveness increase and innovation stimulation, an additional 0.5% of European GDP and 700,000 jobs creation by 2030.

2.1 The Rs approach

One of the most common approaches when dealing with lifecycle thinking, green and circular economy is the so called "Rs approach", often cited as "3Rs" or "5Rs" and sometimes enlarged with additional elements defining a "6Rs" or "7Rs" model of waste management [6]–[10].

The first appearance of the Rs model dates back to June 2004, when at the G8 Summit held in Sea Island, Georgia, U.S.A., the Japanese Prime Minister Koizumi proposed the "3R Initiatives" [6] aimed at building a sound material-cycle society through the 3Rs (Reduce, Reuse, and Recycle), winning the consensus of heads of other nations. Based on this agreement, it was also agreed to hold a ministerial meeting in Japan in the spring of 2005 to launch the 3R Initiatives [11].

Later in 2013, Bea Johnson introduces the 5 Rs in her book "Zero Waste Home: The Ultimate Guide to Simplifying Your Life by Reducing Your Waste" [7]. According to the author the five Rs are: Refuse, Reduce, Reuse, Recycle, and Rot, as depicted in the following chart (See Fig. 1).

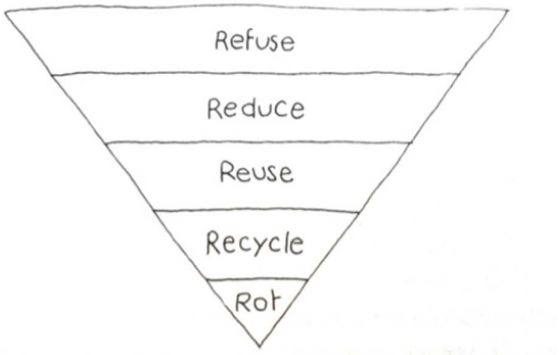

Fig. 1. The 5Rs according to [7]

REFUSE: Refusing means eliminate what is waste, that is deleting any useless thing that will becomes waste. It takes a bit of practice and preparation: all the people are conditioned to accept as many things as possible: the point is to accept only the necessary proposals and refuse the rest.

REDUCE: Reduce the level of purchasing by being conscious about what it is really needed. It asks for a realistic approach to consider what is really necessary: the goal is to reduce the total amount of waste.

REUSE: Reusing and repairing go hand in hand. Before deciding to add a new resource, to purchase a new product, it is recommended to think if there is a possibility to reuse or repair it.

This applies to fast moving consumer goods and to all the products or services at a glance. Reusing also means selling or donating the used items to other people.

RECYCLE: even if recycling is one of the most popular recommendation when it comes to green economy, it is far from the first choices of the present list, namely fourth position out of five. This does not mean that we shouldn't recycle, definitely it is a good choice, but first we need to look at the previously mentioned strategies like avoiding over production.

ROT: when it is impossible to apply one of the previous strategies, the last options is to rot and decompose. There are lots of different ways to compost. The, the last option is to find alternative ways of exploiting the product or resource.

As we can see, the 5Rs rule clearly defines how to select the best option with a stage-gate approach: if applicable, dot it, else, go to the next step.

But, over the last 20 years, there have been provided several versions of the 5Rs of waste and sustainability and many organizations have developed their own versions of the 5Rs [12], [13], hoping to encourage others to live sustainably. For instance, other versions include Respect, Rethink, Reinvent, Recover and Responsibility, among others.

For our purposes, it is not relevant the exact terms and meaning of the different "Rs", rather it is very interesting to focus on the priority of action that this model is willing to provide, in order to combine the hierarchical list of actions with the TRIZ principles, therefore defining a new pragmatic innovation model to boost TRIZ and green practices diffusion among Italian SMEs.

3. RESEARCH STAGES

Aiming to support SMEs in the most strategic phases of an innovation project, Warrant Innovation Lab (WIL) and University of Bergamo (UniBG) have been starting a partnership since 2017, proposing to SMEs the service called Innovation Lab (IL), introduced in TFC 2018 and 2019 [14], [15].

At the same time, WIL offers consulting services regarding environmental sustainability, moving from Life Cycle Assessment (LCA) analysis [16] to the eco-design of new products or the design and development of business models based on circular economy.

These services require a significant innovation effort and high level of knowledge of the companies, both from a technical and business perspective.

Therefore, the 5Rs can help in the way they suggest what to do in order to improve performance, even if they don't explain how to make it happen.

TRIZ can help to fill this gap, by providing a systematic innovation framework. In particular, the IFR principle defines guidelines to find out the most effective solution to reduce the consumption of resources in terms of time and costs but does not provide an ordered list of actions or recommendations.

4. METHODS USED

5Rs are a simple framework immediately understandable by customer with a low level of skills and competences about the environmental impact of products.

They describe well-known elements such as raw materials, energy, components, buildings, etc. that look familiar to SMEs. Another main aspect of 5Rs approach is the priority given to what to do in order to limit the consumption of resources.

Hence, when it comes to reducing the environmental impact with a circular economy approach, all the recommendation and execution guidelines to achieve the project goals are clear. Thus, we can combine the prioritization guidelines provided by 5Rs theory with the innovation approach proposed by TRIZ, therefore obtaining a new powerful model to help companies in their innovation activities and help the Italians SMEs to fill their innovation gap in terms of competences and resources.

When talking about "products" we refer indistinctly to products or services or processes. The method is fully applicable for the three elements.

4.1 5Rs approach as a priority for Problem Solving

The strength of TRIZ is the reformulation of the problem, a phase that allows people to make sure that they are going to propose the solution to the real problem that lies behind a situation that is not necessarily well defined.

Part of the time needed to analyze the problem is spent on defining the priorities between the different aspects to be addressed. The Market Potential tool is specifically dedicated to this [17], [18].

When the intention is to reduce the use of resources through the circular economy model, part of the assessments necessary for the Market Potential are already ready.

Although the evaluation of environmental sustainability is a historically marketing driver, WIL suggests Using 5R as a technical ranking that affects the importance index.

Indeed, the customer may be satisfied or unsatisfied with the product in relation to the impact that a product produces on the environment, but this is the final result of a production process that transforms resources into a finished product.

On the other hand, the environmental impact of a product or processes measured, for example, by an LCA is closely related to the production system under investigation.

In this scenario, the 5Rs suggest the actions to be taken in order to maximize the environmental benefits, therefore defining a list of actions (Refuse, Reduce, Reuse, Recycle, and Rot) ordered by the expected benefits.

According to that, it is possible to define the following parameters related to the Importance level (in percentage):

- 1-20 Rot
- 21-40 Recycle
- 41-60 Reuse
- 61-80 Reduce
- 81-100 Refuse

In the example, the distribution of the slots grows at a constant rate, but it could be revised with more in-depth studies.

As a result, the Importance priority of the different elements is automatically derived from the 5Rs model.

So far, the approach does not consider the different weights of resources in terms of environmental impact. If available, the impact coefficients with respect to the total product can be considered to estimate the contribution of each action and set the minimum actions that allow to correct the ordering or the assignment to the slots of Importance.

For example, if the use of a few polluting material impacts more than anything else, the Recycle of the polluting material alone could be more significant than Refusing all the rest. Without these coming from an LCA study, such evaluations are not easy to make.

We must rely on the customer's knowledge of the sector and their feeling about the market to determine the Satisfaction index.

4.2 How to apply TRIZ on existing products or sustainability programs in progress

Following strictly the priorities provided by the 5R model, is not always possible. For example, if you are designing a new product, you can apply all the 5R suggestions starting from minimizing resources and designing the product in such a way that it can be reused before being recycled and finally disposed.

Conversely, when it comes to an existing organization that intends to activate a circular economy program starting from its current products, it is difficult to apply the actions prior to Reuse. In this case, it is necessary to know how to suggest an adequate approach for each action.

Table 1 highlights with some examples how to select the most appropriate starting point according with the innovation project objectives and activities.

Table 1.

Starting points according to project objectives

Starting point	Application field	Examples of Innovation projects
RETHINK	NEW PRODUCTS or PROCESS	- New product/process design - New product/process development
REDUCE		

REUSE	EXISTING PRODUCTS/PROCESS (END OF WASTE)	- Circular economy: new market identification for existing products - Lifecycle extension
RECYCLE		- New market identification for raw materials - "End of use" process innovation
ROT		

Figure 2. describes how WIL has developed its proprietary approach to combine the IFR with 5R in a flexible and easy-to-use pattern:

1. Problem setting: definition of technical problem and future scenario, project goals and scope. Business requirements collection and prioritization
2. Available resources: Detailed analysis of the available resources. Alternative solutions identification with current resources without introducing new elements. Rough solution guidelines identification
3. New resources: alternative solution identification and possibility range extension by adding external resources to the system. Rough solution guidelines identification.
4. Solution: highlight the most feasible and patentable solution related to the initial problem.

Note: step 2 and step 3 are closely connected each other and they are performed in a circular loop that finally generates alternative solutions.

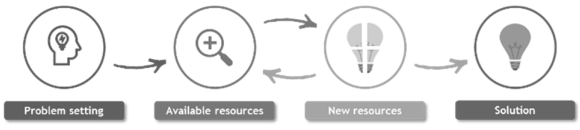

Fig. 2. WIL project method

Table 2 provides evidence of the theoretical framework developed to provide an effective methodology for innovation purposes, aiming to combine TRIZ principles with 5Rs sustainability goals.

The proposed method will provide the following key benefit:

1. Review of the project goals by ensuring that the initial objectives are correct and properly described;
2. Increase efficiency of both project development activities (time and cost reduction) and solution implementation results (resource consumption optimization);
3. Increase effectiveness of both project development activities (results of the innovation project aligned with initial requirements) and solution implementation results (effective innovation results aligned with the desired environmental performance improvement).

Table 2.

Framework of the proposed method

	5Rs	**Proposed method**	**Key questions**
TRIZ tool: Ideal Final Result (IFR)	Refuse (Rethink)	Problem setting: define project goals and scope	Are the starting project goals correct? Are we trying to solve the correct problem? Is there another way to solve the issue? Is the new product (or service) really needed by the final user? Why customer should by the new product?
	Reduce	Available resources: analysis of the available resources to find near-zero extra effort solutions	Which are the minimum valuable resources needed for the new product? Is there a way to solve the problem automatically?
	Reuse		Is it possible to leverage a previously implemented solution and replicate it? Maybe for another industry? How can we benefit from the current available resources? Could the current resources be re-combined to provide the desired functions?

	Recycle	New resources: step-by-step addition of new resources to find valuable solutions	Is the solution applicable to other needs? Does it allow to solve other related issues or to offer new added value features? The resources that will be dismissed could be recycled for other purposes?
	Rot	Solution: identification of the final solution	The rejected solutions could be potential good solutions for other problems? Can they help to define other different products or service?

Table 3.

Key benefit of the proposed method on project methodology and results

Key benefit	Project methodology	Project results
Efficiency	Time and cost reduction	Resource consumption optimization
Effectiveness	Results aligned with initial requirements	Increase environmental performance

To sum up, the extra benefit provided by the present approach consists of determining a prioritized list of actions in to support the development of TRIZ-based innovation projects regardless the starting point and goals of the innovation activities, therefore increasing the expected rate of efficiency and effectiveness (see Table 3).

5. CASE STUDY: AN INNOVATIVE REVERSIBLE FASTENING SOLUTION FOR CLADDING PANELS

To provide empirical evidence of the proposed method, this section will describe a real case study that has been developed to test the theoretical framework and collect feedback from a real use case.

The project has been developed for an Italian manufacturer of cladding panels for furnishing. Active for several years in the production of furnishing products, the company has always been characterized by a strong propensity for innovation and the development of creative solutions that gave them the opportunity to gain a significant competitive advantage over the years.

The traditional delivery process of the products consists of fixing the panel to the wall with a standard glue. This process has two main problems: first, the maintenance operations are not efficient due to the need to perform the maintenance activities directly at the specific place where the product is installed, therefore requiring more effort than working in the internal labs of the company; and second, when the product needs to be replaced due to evident damages or customer requests, the only option available is to remove the glue by destroying the panel, making it impossible to be reused.

Hence, the main goal of the project is to identify an innovative product that can be easily reused. The project has been developed according to the method described above.

The first step is problem setting: starting from the company needs, it is necessary to identify specific business requirements. Thanks to the Market Potential technique, derived from the comprehensive TRIZ tools portfolio, the project goal, scope, and business requirements have been defined.

The output of this phase allowed to confirm the initial business requirements and to determine new product functionalities that could possibly open new business opportunities.

After defining the project scope, the idea generation process started. Following the proposed methodology, the first step consists of an accurate evaluation of the current available resources: the panel, the glue and the wall.

The detailed analysis of the characteristics of these elements led to a first identification of high-level solutions, thanks to a deep knowledge of the materials together with the functions they perform in the related application domain and combined with physical and chemical main phenomena. Secondly, alternative ideas

emerged after analyzing external resources to be added to the current system (i.e., supporting mechanical structures, electrical units).

Finally, a high-level feasibility study enabled the identification of the final solution that has been implemented during the execution phase.

6. RESULTS

Table 4 shows the main project results derived from the application of the proposed method object of this paper: each phase had been investigated combining TRIZ-based principles with the priority given by the 5R approach.

Finally, the results of this project allowed to company to identify an effective solution ready to be tested and prototyped for empirical investigation.

The project solution will provide the following benefits:

1. A relevant revenues increase supported by the new value-added feature of the product;
2. Upselling opportunities if different new features emerged during the project will be implemented and confirmed by following market analysis;
3. Maintenance costs reduction due to the increase of operations efficiency (in-house activities);
4. Reduced raw material consumption and high-impact chemicals elimination;
5. Possibility to exploit a new business model based on circular economy as the new panels are now reusable for different purposes.

Table 4.

Summary of the results

TRIZ	5Rs	Proposed method	Project methodology applied	Project results
	Refuse (Rethink)	Problem setting: define project goals and scope	Confirmed starting goals priority and identified new alternative features for the product	Upselling opportunities for further development (i.e. the product design enables external data collecting and monitoring, or internal room for new features)
	Reduce	Available resources: analysis of the current available resources to find near-zero extra effort solutions	Identified alternative solution with existing resources (high level feasibility)	Reduction of virgin material consumption thanks to the resusability of the product. Chemicals used during the installation and maintenance phases are eliminated.
	Reuse			Products are reusable for different purposes.
	Recycle	New resources: step-by-step addition of new resources to find valuable solutions	New solutions solving different issues Recycle options for dismissed resources	Cladding panels are made of a significant percentage of recycled or recyclable materials.
	Rot	Solution: identification of the final solution	Save rejected solution for different purposes	n.a.

7. FUTURE RESEARCH

This work has introduced some topics that may be further developed. Deeper analysis and investigation about how to link the 5Rs with the application of the methodology, mainly where the green requirements are not well clarified.

An additional research will be also useful to structure and define the solution identification approach; for instance, a further analysis based on the same model but in different market scenarios or industries, as well as testing the model in the same industry with other companies or types of product.

Future research of this work will also include the test of the methodology in case the initial goals of the project are not clear, in order to stress the Refuse/Rethink rule when it comes to re-define the product requirements with a strategic approach.

To conclude it would be interesting to verify the assumption under a B2B market applications, as consumer products provides a better understanding of the green implications and consequences on the society.

8. CONCLUSIONS

The Italian SMEs lack of competences and resources to perform research innovation activities and usually allocate internal resources to the development phase of projects close to the market delivery.

TRIZ provides several innovation tools and techniques that SMEs can leverage to boost their R&D performance.

According to the IFR (Ideal Final Results) principle, the ultimate idealistic solution of a problem comes out when the desired result is achieved by itself. In other words, the new function to be provided to an object, is automatically generated by the object itself.

This is the same theory that guides the 5Rs sustainability approach.

5Rs can help to provide a priority list of recommendation for the requirements evaluations and for defining the action plan to meet project goals.

Empirical evidence comes from an Italian furnishing manufactures. Supported by Warrant Innovation Lab consultants, the company was able to identify an effective solution to address new business opportunities and reduce the environmental footprint of the product, further allowing new additional products generation, market opportunities, and business model related to circular economy.

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Conducerea unui traseu de dezvoltare verde cu 5RS și TRIZ

Rezumat: Sustenabilitatea este o prioritate majoră pentru comunitatea UE. Un cadru valoros de inovare, care combină TRIZ cu principiile 5Rs de durabilitate, poate contribui la satisfacerea nevoilor de inovare, dovedind o abordare structurată de proiectare a soluțiilor de inovare durabilă.
Cadrul sugerează strategii pentru a proiecta soluții durabile și inovatoare pentru produse / servicii sau procese noi și mai ecologice. Abordarea teoretică a fost testată cu un proiect pilot cu un IMM italian. Compania a atins o scădere puternică a consumului de material virgin, eliminarea materialului cu

impact ridicat și posibilitatea de a stabili un nou model de afaceri „de economie circulară” bazat pe produse reutilizabile care anterior ar fi fost distruse.
Adoptarea acestui cadru va spori cunoștințele, conștientizarea și mentalitatea între companii cu privire la durabilitate și inovație.

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