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# KNOWLEDGE TRANSFER IN UNIVERSITY-INDUSTRY RESEARCH COLLABORATION FOR EXTENDING LIFE CYCLE OF MATERIALS IN THE CONTEXT OF CIRCULAR ECONOMY

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**Abstract**

This paper addresses the direct transfer of knowledge from university to manufacturing industrial sector, providing solutions to transform production/manufacturing waste into resources and closing loops in the process according to circular economy values. For this purpose, eco-innovation and eco-design were selected and discussed in order to be applied as tools to support knowledge transfer in the context of circular economy. These tools are focused on the re-design of process and products founded on *in-plant* reuse of production waste, followed by Life Cycle Assessment of economic and environmental impacts. Our results emerged in the form of new knowledge for both researchers and users, original publications, new and improved technologies, processes, materials which enhanced skills, experience and know-how. The present study may be helpful in generating systematic policies and monitoring procedures through specific indicators for the benefit of partners involved in knowledge transfer and society as a whole.

*Key words:* cardboard; eco-innovation; eco-design; environmental impact; knowledge transfer; production/manufacturing

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## 1. Introduction

**Knowledge** is "*an organized structure of facts, relationships, experience, skills and insights that generate action*" (Becerra-Fernandez and Sabherwal, 2010). Moreover, knowledge is seen as "*the creative source of the knowledge transfer*" (Mládková, 2011; Pasaribu et al., 2017). After the Second World War, theoreticians and practitioners strengthened their efforts to examine, write, and analyze how knowledge can be used to improve economic, organizations and nations' performance. Since the 1980s, a tacit consensus was established between economists and decision-makers on the central role of generating and accumulating knowledge as a key incentive for economic growth. In the knowledge-based economy, investment in knowledge production - by funding research and development and human capital formation - plays a crucial role for economic progress (Hamdoun et al., 2018; Romer, 1990; Rosli and Rossi, 2015).

Knowledge transfer is seen as a process of transferring technical know-how, ideas, practices, technical knowledge, intellectual property, discoveries or inventions between the involved parties such as a research entity – **university/research institution** as knowledge-holding structure, and **industry/economy**, policy makers, economic

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providers etc. (de Wit-de Vries et al., 2019; Hamdoun et al., 2019; Kooli-Chaabane et al., 2014). Specifically, knowledge transfer involves introduction in the economic circuit of new or improved specific technologies, facilities and equipment, processes, products or services required by the market, including the activity to disseminate information, transferring knowledge, communicate with people who are not experts in the matter of research results, to increase the chances of applying the results, but with the condition that there be an owner of the results (OG, 2002).

This context generates good opportunities for universities to contribute to local and regional progress by their direct involvement in solving key problems for industrial operators in a more extensive and constructive manner than that offered by the classical ones (education and lifelong learning), and this increases the importance of universities as creators of knowledge (Anatan, 2015; Peer and Stoeglenther, 2013). Recently, it has been highlighted that the reciprocal relationship between university and industry about the transfer of knowledge has become a global phenomenon related to environment, health, and economic development (Arvanitis et al., 2008; Chais et al., 2018; de Wit-de Vries et al., 2019; Grimaldi et al., 2011).

Consequently, universities became sources for new solutions for industry, which at its turn, may provide a natural route to increase the use of practical solutions to resolve their prerequisites (Berbegal-Mirabent et al., 2020; Chais et al., 2018). Besides, industry firms are interested to meet different requirements to attract and retain customers but also to stay ahead of competitors in the specific market (Karlsson et al., 2011). In this sense, different European countries have introduced changes and policy initiatives to stimulate technology and knowledge transfer from university to industry (Govind and Küttim, 2016; Petruzzelli, 2011).

In this paper the authors focus on the direct knowledge transfer between university (the Gheorghe Asachi Technical University of Iasi, Romania - UNIV) and industry (the Romanian Manufacturer - RM) with some specific features, in support of knowledge production and transfer, where knowledge sharing and exchange are components of knowledge transfer. UNIV identified the need of RM for expertise and knowledge transfer in closing the loop by revalorization of manufacturing waste in a re-thought and re-designed process and product. As a final result, it is expected that these efforts will enhance eco-efficiency in the context of circular economy and will extend the life cycle of raw materials and waste resulting from the manufacturing process.

## 2. Theoretical background

### *2.1. Channels of knowledge transfer*

According to the literature in the field, we have considered a variety of forms and channels employed by academic researchers to transfer or exchange the generated knowledge to the industry partner, such as: consultancy or contract research; collaborative research; patenting; sharing of facilities; joint publications; participation to conferences, workshops, seminars; formation of spin-off; communication of knowledge through teaching and mobility etc. (Brennenraedts et al., 2006; Rajaeian et al., 2018). These channels of interaction can be perceived as indicators of university-industry partnership performance, where the term indicator involves both quality and quantity measures. These indicators were classified as inputs, outputs and impacts, as specified by Seppo and Lilles (2012). Inputs embraced the available resources (budget, grants and contracts, number of researchers etc.) and researchers or companies' capabilities and motivation. Outputs and impact indicators were taken as proper for evaluation of the cooperation performance between university and industry (Seppo and Lilles, 2012).

### *2.2. Models of knowledge transfer*

Analyzing literature in the field, it was observed that there is a strong connection between research, environmental and economic impacts, and this relationship is influenced by a series of external factors (Holi et al., 2008). Therefore, in this work, the knowledge transfer flow sheet was considered as a general model, particularized in the form of knowledge transfer impact model (Holi et al., 2008) (Fig. 1), which involves three categories of activities: research, knowledge transfer and industrial/economic activities. Based on this model, the two actors from both academia and industry (UNIV and RM), with different skills, goals, responsibilities, and inclinations, along with a host of other factors, contributed together in a joint effort to transfer the research outputs form research to practice, as new knowledge, while researchers were able to gain new experience and knowledge from the industrial environment.

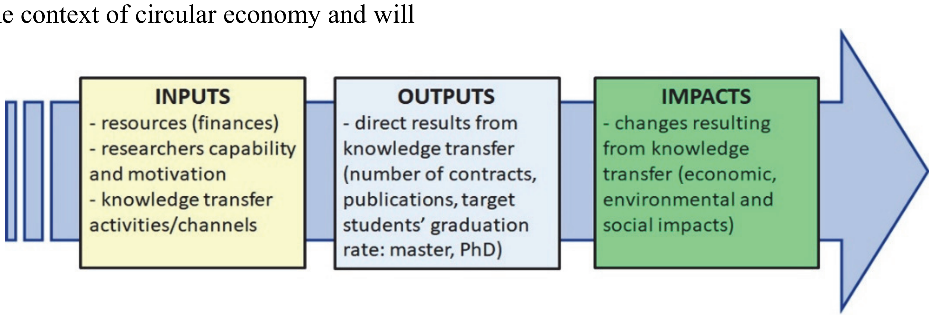


**Fig. 1.** Knowledge transfer impact model (adapted upon Holi et al., 2008; Seppo and Lilles, 2012)

The major components involved in knowledge transfer were: collaborative and contract research, licensing, teaching, learning, training, consultancy and networking. The use of the transferred knowledge by the industrial company entailed the generation of economic benefits, environmental protection and social caution through new processes, closed loop, new products with extended life cycle, new services, all with low environmental impact.

*2.3. Tools for implementation and monitoring*

The increasing impact of the circular economy concept as a proficient approach to achieve sustainable development has stimulated the knowledge transfer in different ways to implement this concept in practice. Scientists underlined that "*the industrial economy should be reshaped from 'linear' (based on fast replacement and disposal) to 'circular' (reuse of products and recycling of materials) in order to stop depletion of resources (abiotic materials)*" (Gavrilescu et al., 2017; Ghinea et al., 2017; Petraru and Gavrilescu, 2010; Wever and Vogtlander, 2015). The knowledge transfer associated to circular economy concept aims to create value in four circumstances (EEA, 2016; Kuijpers, 2015): (i) renewable resources are continuously regenerated in time and are considered infinite (e.g. renewable energy); (ii) rapid development of markets that allow optimal use and access to products and goods; (iii) products are designed to have a long life cycle (Ghinea and Gavrilescu, 2019); (iv) value chains are linked such that do not generate waste in production systems (COM 899, 2011; Gavrilescu et al., 2018).

Putting into practice the concept of circular economy is largely the result of the transfer of knowledge from research to economy and business, founded on cradle-to-cradle approach and some beforehand developed lines (McDonough and Braungart, 2002; McKinsey, 2012; McKinsey, 2013; Wever and Vogtlander, 2015). Prieto-Sandoval et al. (2018) revealed that several outputs: "*a knowledge map of the circular economy, an analysis of the main notions of the concept, principles, and determinants of a circular economy*" are relevant for this concept and highlighted the role of eco-innovation for implementation of the circular economy. Further, in a panel discussion at the Circular Economy Conference organized by the European Commission and the European Economic and Social Committee, it was highlighted the importance of European Union eco-design policy in a circular economy (European Environmental Bureau [EEB], 2015; Ellen MacArthur Foundation [EMF], 2015). Therefore, the knowledge transfer on the implementation of circular economy in industrial systems is largely connected with eco-innovation, eco-design so as to ensure an eco-efficient development of production system. Knowledge transfer addressing eco-innovation and eco-design would be essential for the economy and, in particular for any re-designed product in a closed loop, in particular when manufacturing waste are used as raw material, comparative to the original product made from conventional raw materials.

In terms of knowledge transfer, we have seen eco-innovation alongside three matters (Organisation for Economic Co-operation and Development [OECD], 2009; Shih et al., 2018; Xavier et al., 2017):

- targets (which include, processes, products, methods for marketing, organizations);
- mechanisms (means to make changes: conception, adaptation, re-design, selecting options);
- impacts (environmental consequences of eco-innovation).

Specifically, we addressed eco-innovation approach for re-thinking a product and its manufacturing process so that it can bring both economic and ecologic benefits, relating innovation to the environment.

Similar, eco-design concept (or design for environment, green design, environmental redesign) has been seen as a group of appropriate methods to mitigate environmental impact of the process or product throughout its life cycle (ISO/TR 14062, 2002). Eco-design is today a noteworthy challenge for lots of companies that want to effectively integrate environmental issues into product and process design in a smart, inclusive, knowledge-based context (Cherifi et al., 2017; COM 899, 2011). Our work involved six steps in eco-design (ISO/TR 14062, 2002; Navajas et al., 2017): (i) specification of functions for product (or process); (ii) evaluation of product/process in terms of environmental impacts; (iii) provision of improvement strategies; (iv) environmental goals; (v) product/process requirements; (vi) solutions for technical issues.

In the last decades, more than 150 eco-design tools have been developed (Le Diagon et al., 2014) in order to be applied in design process, being a topic for knowledge transfer. According to their purpose, eco-design focuses on: (i) methods and tools for product/process improvement, (ii) procedures and instruments for environmental evaluation. Some studies reveal that Life Cycle Assessment (LCA) frequently apply as an instrument for quantifying environmental impacts, to ensure a reliable eco-design (Allione et al., 2012; Almeida et al., 2010; Andriankaja et al., 2015; Lindahl and Ekermann, 2013; Navajas et al., 2017; Pigosso et al., 2010). Checklists for assessing environmental aspects of the products are valuable tools in eco-design, as well (Knight and Jenkins, 2009; Masoudi et al., 2012; Wimmer, 1999).

Our analysis addressed technical, economic, environmental and social criteria, so as to facilitate the decision makers to select the best option, in terms of raw materials, manufacturing scenarios, their ranking etc. (Fortuna et al., 2012; Ghinea and Gavrilescu, 2016; Ghinea et al., 2017; Simion et al., 2013).

To assess the impact of our knowledge transfer approach we applied some tools, such as Life Cycle

Assessment (LCA), Cost Benefit Analysis (CBA), Multicriteria Decision Analysis (MCDA) etc. This analysis using the mentioned methodologies, proved again useful in decision making process in terms of the optimum allocation of resources to maximize the anticipated output for the given input and to discern between acceptable and unacceptable alternatives in product eco-innovation and eco-design in the context of multiple assessment criteria (Cerdana et al., 2009; Comanita et al., 2015; Dumitrescu et al., 2014; Ghinea et al., 2012; Park and Tahara, 2008) (Fig. 2).

## 3. Methodology

### *3.1. The context*

In order to illustrate the ways by which universities can support companies in eco-innovation and eco-design, the research group from UNIV evaluated a manufacturer (RM) from paper and cardboard production sector and identified the possibility to capitalize production waste as raw material for a currently manufactured product from cardboard plate ("turning waste into resource") by applying strategies and solutions for in process recycling. This approach makes it possible to close the loop for a part of production cycle and increase process eco-efficient in order to obtain an ecological product with marketable potential and functional flexibility in concordance with the needs of the company.

### *3.2. Research approach*

Our goal and work were accomplished by structuring a work plan based on several main directions:

- ✓ fulfillment of the identified need of the manufacturer for knowledge transfer;
- ✓ integrating the coordinator's expertise with the needs of the manufacturer in selecting and implementing eco-innovation strategies and eco-design solutions for reusing production waste for an eco-innovated and eco-designed packaging product (Eco-P), currently manufactured from cardboard plate;
- ✓ selection of potential indicators and tools for the evaluation of knowledge transfer progress and performance;
- ✓ developing professional experience of young researchers, practical training of master students.

The selection of the paper and cardboard packaging industry as a case study is justified since this is one of the most advanced industrial sector in the implementation of the circular economy principles and practices, being a very good example of industry available and proficient to apply the circular economic model, addressing especially the post-consumption waste. Statistics published by European Federation of Corrugated Board Manufacturers (FEFCO, 2015) estimated that out of 10 packing stuffs, more than eight are recycled, this being beyond the goals set by packaging and packaging waste directive (Campean et al., 2017a; EC Directive 12, 2004; FEFCO, 2015; Gavrilescu et al., 2017).

However, its potential to close the loop is not fully exploited and there are multiple means for knowledge transfer envisaging circular economy and its correlation with eco-innovation and eco-design.

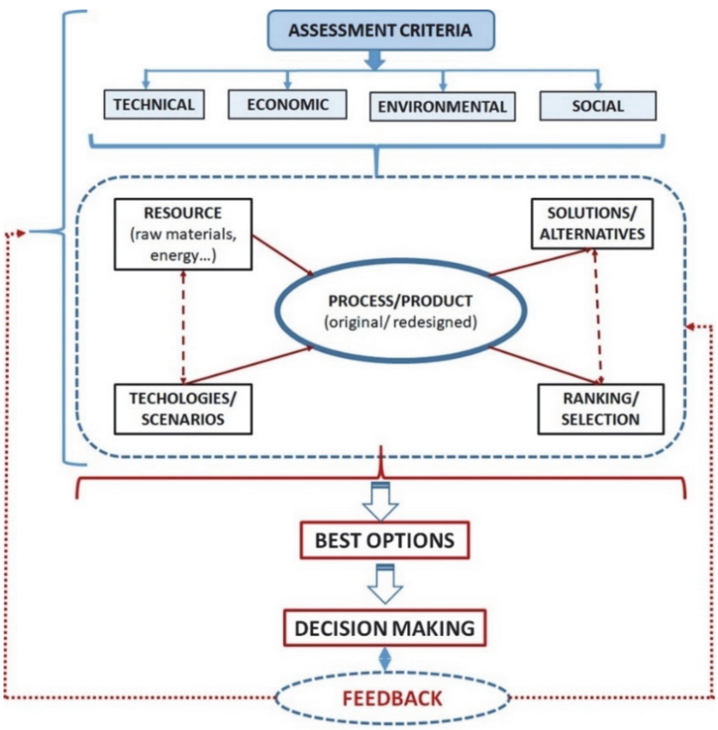


**Fig. 2.** Criteria for eco-efficiency assessment as decision making support for selecting best options addressing adaptability of eco-innovated and eco-designed processes/products

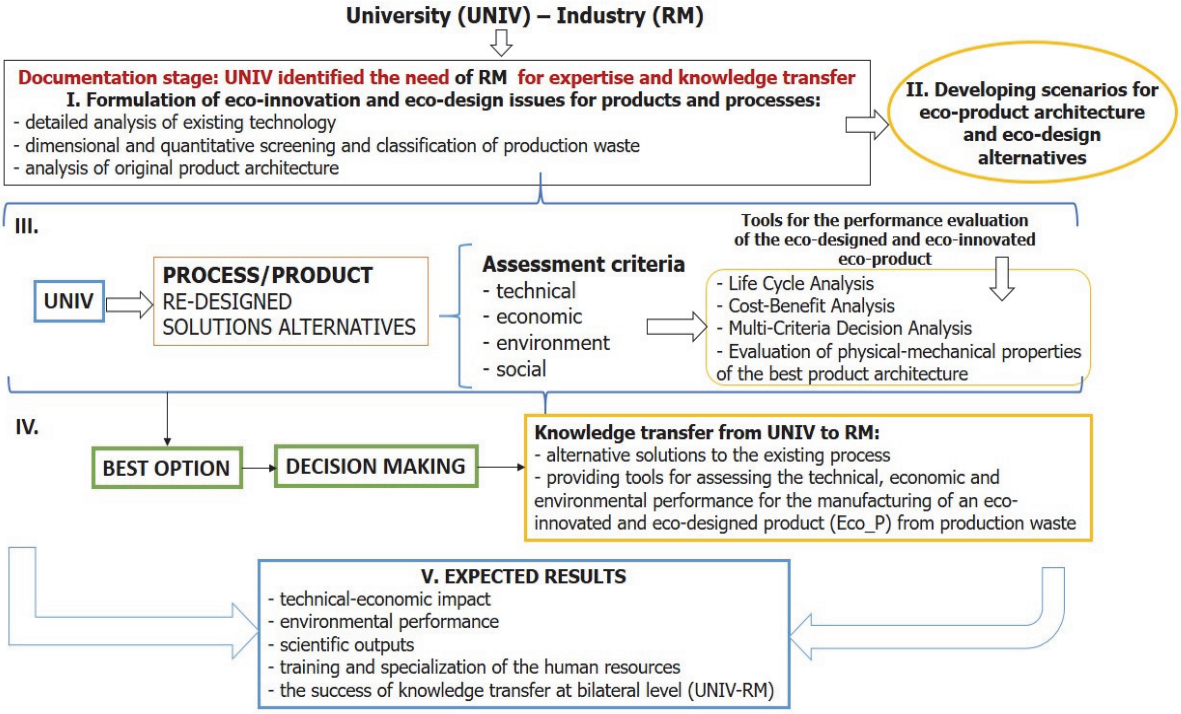


**Fig. 3.** The main steps of the working plan performed in the present study

For a better understanding of the methodology applied in this study a schematic representation of the working plan is given in Fig. 3.

### *3.3. Current situation at the manufacturer and knowledge transfer objectives*

RM has a great potential to close the production cycle by efficient capitalization of recyclable materials produced by the two stages of the production process in the context of existing modern technology. The company can safeguard extended life cycles for both production and product as well as continuous integration of environmental strategies into activities and decisions, considering optimization and development of the production process. This approach and behavior of RM can ensure the achievement of zero emission targets according to the principles of the circular economy and lowering the carbon footprint (COM 112, 2011; European Parliamentary Research Service [EPRS], 2017; Gavrilescu et al., 2017).

Based on these considerations, the main objective of this work consisting in knowledge transfer from the Technical University - UNIV research group directly to the manufacturer (RM) has been accomplished in order to meet the identified need of RM for expertise and knowledge transfer. The RM necessity to close the loop within the production plant was completed by applying strategies and solutions for in process (in plant) recycling, based on eco-innovation and eco-design tools. This was effective by exploiting the manufacturing waste resulting from both the corrugated cardboard manufacturing and corrugated cardboard packaging process as raw material for manufacturing a product (Eco_P) similar with an existing one (P) in the production portfolio of RM. The product P can be any product used in packaging, apart from cardboard boxes, manufactured from cardboard plate (virgin cardboard) by RM. It is expected that, by re-thinking and re-designing the product P through implementing the concepts and principles of eco-innovation and eco-design, the organization eco-efficiency will be improved in the framework of circular economy (lower costs and reduced environmental impacts). This way the life cycle of cardboard and waste resulting from the production process will be extended, because recycling is performed in plant and only a small quantity of waste is recycled to the paper mill (off site) (Figs. 4, 5). The strategy and procedures necessary to perform this work is the subject of direct knowledge transfer in university-manufacturer collaboration, in the frame of a contractual research. The term knowledge transfer was used at first as "*one-way flow of knowledge from researchers to practitioners*" (Zarinpoush et al., 2007). However, throughout the evolution of the cooperation with the manufacturer, some Master and PhD students benefited from the manufacturer knowledge in a collaborative research, while the dissemination of some results by publication or within scientific events were carried out in a joint involvement, UNIV-RM. Therefore, a two-way knowledge delivery between researcher and manufacturer occurred, specifically knowledge transfer and exchange, "*recognizing that knowledge creation is not the sole domain of any one actor in a system*" (Zarinpoush et al., 2007). This means a shift from the linear model of knowledge transfer to a cyclic one.

### *3.4. Strategy of knowledge transfer UNIV - RM*

#### *3.4.1. Development of the strategy for successful knowledge transfer*

In the present study, the strategy adopted for effective knowledge transfer implies the following stages of knowledge transfer:

**A. Identification of opportunities:** RM has a great potential to close the production cycle by efficiently reusing of waste produced by the two stages of the production process as recyclable materials, in the context of existing modern technology. The manufacturer can ensure an extended production and product life cycle and an advanced integration of environmental strategies into activities and decisions regarding optimization and development of the production process, which can lead to the achievement of zero emission targets in accordance with the principles of the circular economy.

**B. Formulation of the knowledge transfer context and motivation:** UNIV research group has identified the necessity of the manufacturer to recover all manufacturing waste by its reuse in the process, in an plant cycle instead of the current off site practice. This is possible in the framework of eco-innovation and eco-design principles, in order to re-think and re-design a routinely manufactured product from cardboard plate, in an ecological way, using manufacturing waste as raw material, with marketable potential and functional flexibility in accordance with the requirements of the beneficiaries. Process and product re-engineering will improve the environmental efficiency of the process and product in an eco-innovative way by reusing manufacturing waste based on the existing experience and equipment, without significant investments.

**C. Measuring and monitoring the eco-efficiency:** LCA thinking and application in assessing process and product eco-efficiency: the previous tasks require the transfer of knowledge concerning the main tools that can offer to RM in order to evaluate the impact of both existing and changed (by eco-innovation and eco-design) products and process. Life cycle analysis enables the examination of environmental impacts of the product or/and process induced in the environment during its life cycle (ISO 14040, 2006). One of LCA's leitmotifs are to get a full picture on the impacts of a product, to find the best solutions for their mitigation, without shifting the impacts to other fields (Lee et al., 2001). Another aspect concerns the characterization of conditions for reuse or recycling of the products, also called design for recycling (Hundal, 2000). LCA was applied by UNIV and recommended to RM as a support to enable its decision making process, to diagnose and judge: (i) the environmental impacts generated any eco-innovated and eco-designed processes/products as a result of using production waste as raw materials; (ii) total cost savings with materials and energy when the proposed alternative is implemented by RM. Therefore, these tools would help the RM on how to make decision and proceed for other similar situations. In a future paper, the study will deal with the application of check lists to measure and monitor the opportunity and efficiency of re-engineered products.

**D. Anticipating impact of knowledge transfer:** UNIV anticipates the impacts of knowledge transfer as: increased manufacturer capacities to apply the acquired knowledge so as to make comprehensive decisions and elucidate any problems effectively; integrating knowledge into the decision-making process (focused on the application of knowledge, weighting different choices and standpoints and revealing possible alternatives or claims); stimulating a cultural change within the organization (by promoting an ongoing dialogue between knowledge producer - UNIV and user – RM, just how the partners perceive their standpoints, understandings and prerequisites); increasing cooperation among knowledge producer and user, ensuring the continuity of knowledge exchange on short, medium and long terms.

#### *3.4.2. Ways planned to achieve knowledge transfer*

Based on a collaborative research, UNIV has developed a strategy to exploit the knowledge generated by academic research to meet industry needs deriving from the requisite of manufacturer to close the loop in the production plant and increase its eco-efficiency. UNIV has established the following ways to achieve the transfer of knowledge:

- knowledge transfer for the assimilation of eco-innovation and eco-design strategies and solutions for conceiving, designing and building product on the existing process;
- knowledge transfer for measurement and quantification of environmental and technical performance for the re-engineered process/product;
- knowledge exchange university - manufacturer through training and valorization of specialists' expertise.

## 4. Results and discussion

### *4.1. Identification of opportunities for knowledge transfer*

The first step consisted in the analysis and evaluation of environmental performance of an existing product P manufactured by RM from cardboard plates. Data collection, on site visits of the UNIV research team members, product identification, elaboration and assessment of a representative model which includes quantitative inputs and outputs that occur throughout the life cycle of product were important milestones. In plant and on site evaluations were focused on material flows in production systems following life cycle phases: raw material selection and use, manufacturing, packaging, and distribution.

The production wastes were characterized and estimated in terms of quantity and production rate, as well as regarding their dimensions based on statistical analysis of suitable samples. At least four stages were covered in the view of waste characterization (Crețescu et al., 2017): (i) pre-investigation; (ii) analysis, design and planning; (iii) implementation of waste analysis; (iv) evaluation of waste analysis and interpretation of results. A number of actions and discussions with the representatives of manufacturer led to the identification of the need of RM for knowledge transfer, addressing economic profits, environmental benefits (by increasing the use of resources with favorable consequences for the reduction of carbon footprint), consequently securing a sustainable manufacturing. After the identification and analysis of the company needs, the project team formulates the work tasks. In the analysis phase, it was identified a possibility of increasing the material efficiency by adoption of in plant recycling strategy, which closes the production loop in the selected process (Fig. 4). In this way the priorities for product design improvement were selected with respect to environment and raw materials availability (considering the valuable materials for recycling) and solutions of eco-innovation and eco-design were explored, identified and evaluated.

After the opportunities were identified, UNIV proposed the valorization of waste generated during cardboard and corrugated board packaging manufacturing so as to develop the eco-product (Eco_P), regularly manufactured by RM from cardboard plates (P) for packaging purposes, and which is currently on the market, showing favorable business trend (Fig. 5). Thus, the manufacturer can extend the life cycle of materials by generating a production loop using waste as resource and almost completely closing the production cycle and avoiding off site recycling of a large part of the generated quantity of waste. Moreover, other pieces and subassemblies can be manufactured from corrugated board sheets, perfectly designed, ensuring their optimum operation and thus reducing required storage space and transport costs, compared to similar subassemblies made from wood, following the information already acquired by knowledge transfer (Gavrilescu et al., 2017). The UNIV research team benefited from the great availability of RM for improving its eco-efficiency in the frame of knowledge transfer. RM owns modern technology and equipment, and has integrated ISO 9000, 14000, 18000 management systems (Gavrilescu et al., 2017).

The drivers for this reciprocal action are materialized not only in knowledge transfer, but also in knowledge exchange lying in both UNIV and RM capacity and availability to be involved in this kind of cooperation, qualified as inputs in the KT model as: resources, researchers' ability, researchers' motivation, manufacturer's skills and motivation (Fig. 6). They are further considered as indicators in an inputs-outputs-impacts model for knowledge transfer (Fig. 1) (Holi et al., 2012).

### *4.2. Eco-innovation and eco-design in the knowledge transfer context and motivation*

In this work, eco-innovation and eco-design is considered and applied as a "*set of processes that transforms requirements into specified characteristics or into specifications of a product, process or system*" (ISO 14006, 2011). The eco-innovative pattern was both scientific and technical, focusing on re-thinking equally the process and the product, considering some market issues, as well.

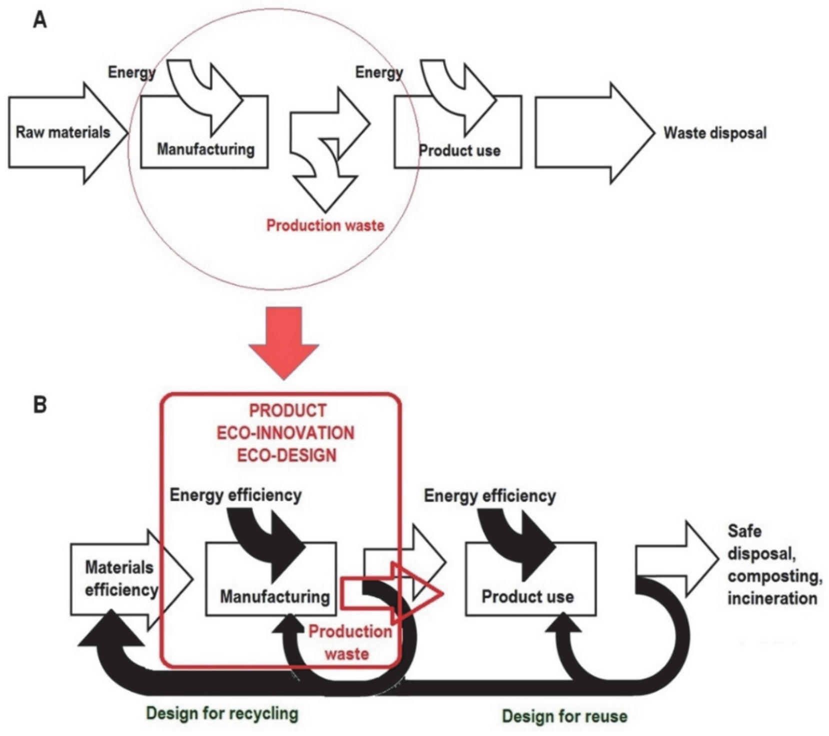


**Fig. 4.** Changing linear production process (A) to closed-loop (B) by design for recycling, design for reuse and production waste revaluation by product eco-innovation and eco-design (the red rectangle)

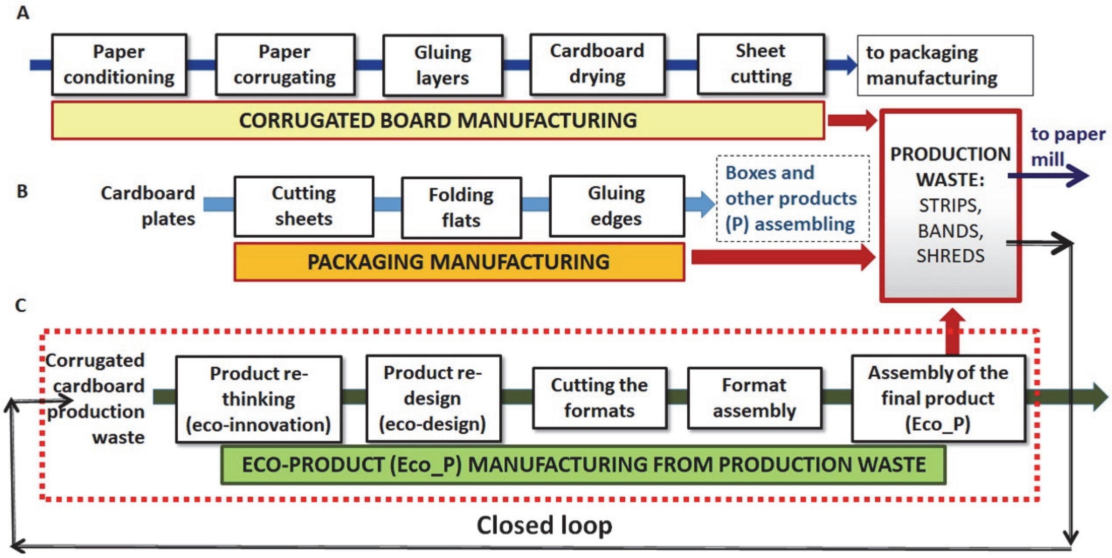


**Fig. 5.** Flowsheets of corrugated board and cardboard packaging manufacturing: A – corrugated board production (existing technology); B – cardboard packaging and other products manufacturing (existing technology); C – manufacturing of the eco-innovated and eco-designed product (Eco_P) from production waste

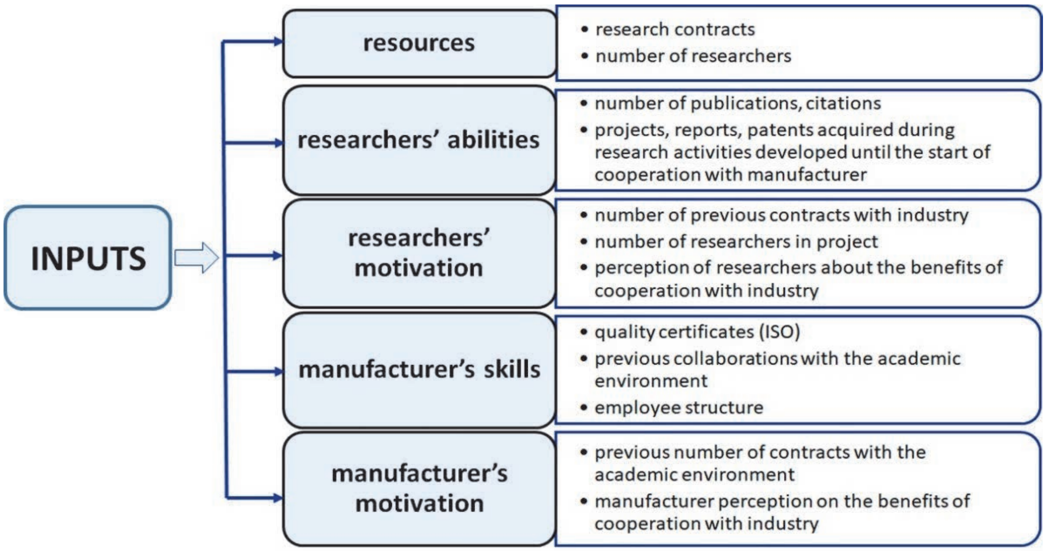


**Fig. 6.** Inputs in the model of knowledge transfer: resources, researchers' ability, researchers' motivation, manufacturer's skills and motivation

"*The mechanism of eco-innovation is related to re-thinking the product by considering also the eco-design of an existing product, following an alternative which substitute the initial raw materials, the cardboard plate in our case (or wood in a general case), with production waste in the form of strips, bands, shreds*" (Gavrilescu et al., 2017). Eco_P is the outcome of a re-design mechanism based on eco-design principles, which confers it the ability to perform the same functions as P, being a successful and sustainable counterpart for the currently manufactured product (P).

Resuming, the Eco-P has resulted using specific eco-innovation and eco-design concepts, principles and methodologies, as rethinking, redesigning and re-engineering strategies of an existing product when other raw materials, in form of waste substitute the conventional ones. One of the major advantage of the solution refers to maintaining the existing experience and equipment, without significant investments (Campean et al., 2017b; Gavrilescu et al., 2017). The success of eco-innovation and eco-design is the result of internal functional cooperation among the all departments of company and their availability and interest for external cooperation with the academic partner throughout the duration of work.

### *4.3. Knowledge transfer on LCA thinking and application in assessing eco-efficiency of the extended life cycle process and product*

From eco-innovation and eco-design perspectives, it is emphasized that the industrial manufacturer would benefit from knowledge transfer in terms of eco-efficiency assessment performed in a life cycle approach and thinking. Life cycle assessment would make able the RM to take into account both environmental aspects and environmental impacts along the successive steps associated to: (i) re-thinking and re-design of any product manufacturing, by extending life cycle of a part of corrugated board which becomes manufacturing waste during process development, (ii) in-plant loop benefits comparative to off-site recycling. Life Cycle Analysis will be a tool for decision making and strategic planning for RM, to assess different scenarios with various borders in cradle-to-cradle or cradle-to-gate approaches. Moreover, LCA can offer information on the ecological footprint of the system and can help RM to reduce carbon footprint, by safeguarding a high degree of use for any raw materials, including waste, and diminishing the usage of resources from the environment, such as wood in this case (Gavrilescu et al., 2017).

The first step in knowledge transfer for a complete LCA study of the eco-innovated and eco-designed process/product at RM is the analysis of methodology according to ISO 14040 (2006), and following the four main steps (Gavrilescu et al., 2017; Ghinea et al., 2014; Joint Research Center and Institute for Environment and Sustainability [JRC & IES], 2010; Petraru, 2012):

- *definition of goal and scope*: the objectives and area of the study are described, and the boundaries of the system and the functional unit are selected;

- *inventory analysis:* all environmental inputs (resource and energy flows) and outputs (emissions and waste) are fully examined and weighted;

- *impact assessment:* environmental impacts are evaluated based on the inventory data and environmental performance of the product/process is appraised;

- *interpretation*: the results are analyzed and understood.

Knowledge transfer related to the application of LCA methodology and exploitation of results would address first the following primary problems (Bingley, 2011; Sustainable Recycling Industries [SRI], 2017):

a) building capacity for LCA in UNIV - RM knowledge transfer collaboration;

b) staff awareness, enrolment and training on: (i) LCA methodologies, data-bases, software in both academic study and practical application; (ii) data collection;

c) data collection and analysis: (i) developing data collection methodology; (ii) identifying and addressing questions with data collection and analysis.

The key activities for LCA development would then address the following issues:

- realistic and creative approach to scenarios selection and modeling;

- defining boundaries: (i) what to take into account and remove from the study; (ii) what is the best approach: cradle-to-cradle, cradle-to-gate, cradle-to-grave, or others;

- selecting the functional unit: the same for all scenarios for their comparison, since it represents a quantified description of the performance requirements that the product system fulfils;

- data collection: (i) directly from the source, based on questionnaires, supplier data requests, design to fit production system; (ii) filling the knowledge gap by using LCI database request that gives users access to the necessary data and allows connectivity between data collected directly from the source and other LCA data resources.

The benefits for company as a result of LCA are the subject of knowledge transfer and can include: carbon, water and cost savings; strategies ecological footprint/carbon footprint reduction; identification of research and development opportunities; positive marketing materials and information for customers etc.

### *4.4. Indicators and impacts of university - industry knowledge transfer performance*

The involvement of researchers from the university in transferring and dissemination of the knowledge generated as research results to industry is projected to strengthen the impact of research for both partners (Franco and Pinho, 2019; Gavrilescu et al., 2017; Rajaeian et al., 2018). In this case study, the research outcomes were used to create scientific, technical and economic impacts, which can be seen as indicators of knowledge transfer.

There are different categories of impacts depending on the type of channels, cooperation and activities involved in knowledge transfer, as it can be seen in Fig. 7. They are essentially associated with the benefits related to the implementation of knowledge transfer activities in the area of eco-innovation, eco-design and LCA thinking and application for the capitalization of manufacturing waste by closing the loop in the envisaged production process, so as to increase its eco-efficiency (Brennenraedts et al., 2006; Rast et al., 2012; Seppo and Lilles, 2012). Furthermore, these indicators underline the role and concern of university during the dissemination of the knowledge generated under research collaboration with industry.

When the model input-output-impacts of knowledge transfer is considered, a balanced analysis is hopeful (Table 1), showing what UNIV has performed or should measure with regards to knowledge transfer to RM, in terms of inputs, outputs and impacts.

The way of approaching the UNIV-RM relationship in the transfer of knowledge is marked by some original aspects. First, our study may contribute to the development of a conceptual model for measuring knowledge transfer performance between university and industry, since the majority of available models and measures of transfer mechanisms are empirically tested or validated so far.

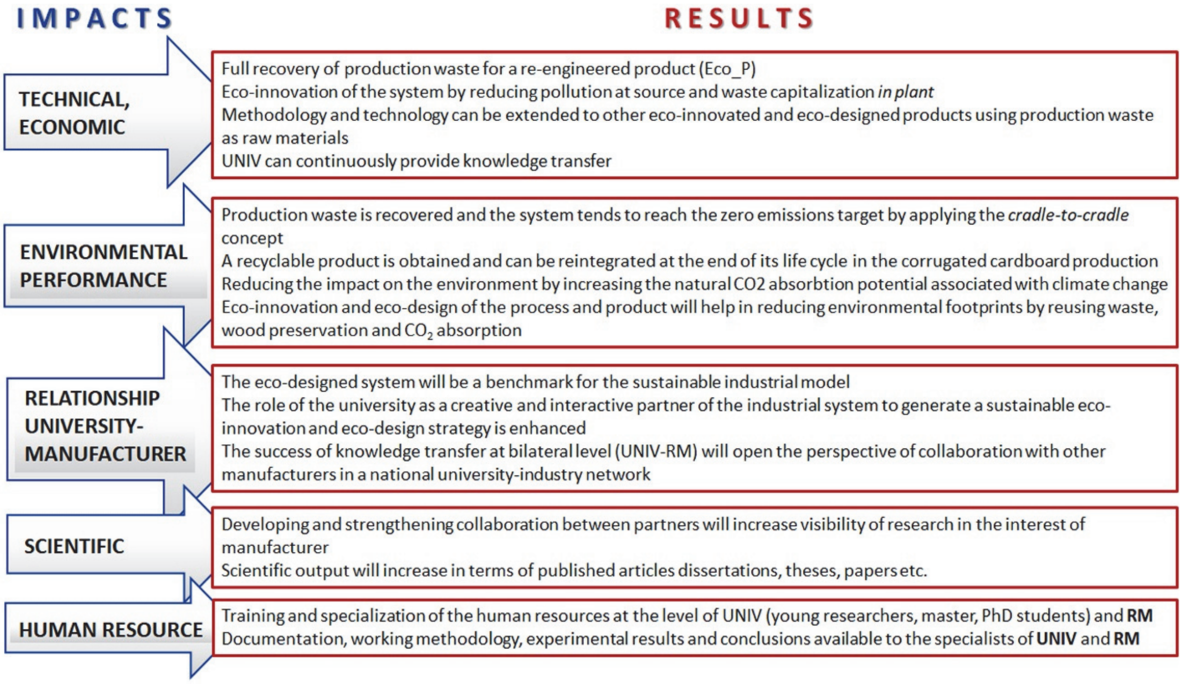


**Fig. 7.** Impacts generated in the transfer knowledge UNIV – RM aimed at closing the loop for the manufacturing of an eco-innovated and eco-designed process/product

Secondly, our study may contribute to local and regional progress by university direct involvement in solving key problems for industrial operators in an extensive and constructive manner and this increases the importance of universities as creators of knowledge. This collaboration generates several direct or indirect benefits to both entities (Franco and Pinho, 2019; Hayter et al., 2020; McCleary, 2015; Seppo and Lilles, 2012): *(i)* knowledge transferred can improve the existing technology in industry; *(ii)* the generated knowledge can be directly implemented in the industrial production process, as prototypes or new processes/technologies; *(iii)* providing competent staff, training activities and researcher mobilities from universities to industry may be completed; *(iv)* dissemination and exploitation of research results (by increasing number of publications, participation in conferences, seminars); *(v)* finding solutions to different problems; *(vi)* productivity growth of firms along with an improvement and enhancement of the quality of the products or manufacturing processes; *(vii)* new jobs opportunities for graduating students; *(viii)* development of new teaching and learning tools, new research directions or new possible collaborations; *(ix)* stimulating academic research.

We observed that the majority of studies from literature are focused on measuring the performance of U-I knowledge transfer activities by using appropriate metrics. Knowledge channels of interactions are divided in different categories depending on the degree of formality and information, and the possibility of consulting the obtained results (De Fuentes and Dutrénit, 2014). Also, limited data on research collaboration case studies between universities and industrial firms based on knowledge transfer are currently available.

However, an interesting study was provided by Rajaeian et al. (2018) which applied mixed- methods research approach (comprising interviews and survey of academic researchers in a specific area) to identify the factors that may contribute to an efficient engagement of academic researchers in dissemination of research as a new knowledge to industry. The authors concluded that even though researches may use a variety of activities to transfer their knowledge to industry, still there is a scarce engagement of academic researchers with industry, mainly due to an improper reward systems in most academic settings. Berbegal-Mirabent et al. (2020) provide a quite new approach of U-I knowledge transfer, specifically from the perspective of the university's teaching mission. The authors revealed that educational platforms may provide powerful mechanisms to fill the gap between academic and industry.

Moreover, a report of European Commission (2017) suggest that university's traditional approaches to teaching must be shifted towards a more pro-active model. This can be performed by a more direct implication of companies in university activities, especially by adjusting university curriculum. In this manner, academics and students may have access to real-world cases giving them the change to apply the knowledge provided by traditional learning.

In conclusion, the U-I relation is a very complex task and undoubtedly, several barriers must be overcome, along with several implications from policy makers side. In this framework, the present study may be helpful in generating systematic policies and monitoring procedures through specific indicators for the benefit of partners involved in knowledge transfer and society as a whole.

**Table 1.** Indicators for measuring the performance of the university - industry (UNIV – RM) relationship in input-output-impact model

| *Categories* | *Performance indicators* |
|---|---|
| **INPUTS** | **Resources:** research contract, number of researchers from UNIV and specialists of RM involved in project cooperation<br>**Researchers' ability:** number of publications, citations, projects, reports, patent etc. acquired during the research activity until the start of project<br>**Researchers' motivation:** previous number of contracts with the industry solved by the project team; number of researchers in the project; perception of the researchers about the benefits of cooperation with industry<br>**Manufacturer skills:** quality certificates (ISO); previous collaborations with the academic environment; employee structure<br>**Manufacturer motivation**: previous number of contracts with the academic environment; perception of manufacturer on the benefits of cooperation with universities |
| **OUTPUTS** | **Applications for patents**: number of patent applications sent to the institution in charge with their evaluation<br>**Scientific outputs**: published articles, doctoral research reports, dissertation and PhD theses, scientific conferences, seminars, workshops, technical literature on the theme of the project |
| **IMPACTS** | **Technical and economic impacts:**<br>- full recovery of production waste for manufacturing a product (Eco_P)<br>- eco-innovation and eco-design of the system<br>- reducing pollution at source and reusing waste as a raw material in the process<br>- the applied methodology can be extended to other similar products, and UNIV can further provide knowledge transfer<br>**Impact and environmental performance:**<br>- production waste is recycled in plant and the production system tends to materialize the zero emission target by applying the cradle to cradle concept<br>- a recyclable product is achieved that can be reintegrated at the end of its life cycle in the paper making process to obtain corrugated cardboard at the level of the RM, according to the principles of circular economy<br>- reducing the impact on the environment by increasing the natural $CO_2$ absorption potential associated with climate change<br>- eco-innovation and eco-design of the process and product help in reducing environmental footprints by reusing waste and replacing (partially or totally) of the product Eco-P, wood preservation and $CO_2$ absorption<br>**Impact of knowledge transfer on university - manufacturer relationship:**<br>- the eco-designed system is a benchmark for a sustainable industrial development model<br>- assimilation of the scientific and legislative concepts related to the circular economy by RM specialists is enabled<br>- the role of the university as a creative and interactive partner of the industrial system to generate a sustainable eco-innovation and eco-design strategy is boosted<br>- the transfer of knowledge contributes to accelerate the research and development process of the RM across the supply-production-sales chain, favorable to the market potential<br>- the producer responsibility is extended by promoting product and process eco-design, supporting public recycling actions<br>- RM benefits from the expertise and scientific support of UNIV for the transfer/ application of instruments for measuring the technical, economic, environmental and social performance (LCA, CBA, MCDA etc.)<br>- the success of knowledge transfer at bilateral level UNIV- RM opens the perspective of collaboration with other manufacturers in a national university-industry network<br>**Scientific impact:**<br>- developing and strengthening collaboration between partners increase the visibility of research in the interest of manufacturer<br>- scientific outputs are intensified in terms of published articles, conferences, dissertation theses, reports etc.<br>**Impact on human resources:**<br>- development of training and specialization of the human resources of UNIV and RM (young researchers, master students, PhD students), including entrepreneurial skills<br>- documentation, working methodology, experimental results and conclusions are made available to specialists |

## 5. Conclusions

Since knowledge is a multifaceted and complex concept, its transfer from university to industry involves a diversity of networks and engagements.

In this work, the model of knowledge transfer (input-output-impact) involves three categories of activities: research, knowledge transfer, and industrial/economic activities, and considers the strong connection between research, ecologic and economic impacts. Since the increasing role of the circular economy as an approach to achieve sustainable development has stimulated the knowledge transfer on the different ways to implement this model in practice, it was analyzed its robust linking with eco-innovation, eco-design so as to ensure an eco-efficient development of production system.

One of the most important knowledge transfer standpoint was to address the relationship between eco-innovation and circular economy, specifically the closed-loop concept applied in the production process. Since eco-design is an integrated part of both sustainable production and consumption, application of this approach for closing the loop in the production systems was considered the subject for knowledge transfer at different levels of innovation and efficiency improvements, to leave the linear, cradle-to-grave production system and create cyclical, cradle-to-cradle industrial production and to confirm waste status as resources.

The work describes some ways by which university (UNIV) research and expertise can support companies in eco-innovation and eco-design, by selecting a manufacturer (RM) from paper and cardboard production sector and identifying the possibility to capitalize + as raw materials for a certain eco-product (Eco_P) by applying strategies and solutions for in-process recycling based on eco-innovation and eco-design principles. This approach makes possible to close the loop for a part of production cycle in an eco-efficient way in order to obtain an ecological product with marketable potential and functional flexibility in concordance with the needs of the company.

In order to solve the matters deriving from the necessity of the manufacturer, UNIV has established the following ways to achieve the transfer of knowledge: knowledge transfer for the assimilation of eco-innovation and eco-design strategies and solutions for conceiving, designing and building an re-engineered eco-product by capitalization of production waste on the existing process; knowledge transfer for measurement and quantification of environmental and technical performance for the re-engineered process/product; knowledge exchange UNIV - RM through training and valorization of specialists' expertise.

The achievements of knowledge transfer on eco-innovation and eco-design in terms of eco-efficiency evaluated in a life cycle approach and thinking is the result of internal functional cooperation among the all departments of company and their availability and interest for external cooperation with academic partner throughout the duration of work. It is emphasized that the benefits of the industrial manufacturer arising from knowledge transfer on Life Cycle

Assessment opportunity and methodology would make it able to take into account both environmental aspects and environmental impacts along the successive steps associated to re-thinking and re-designing of any product manufacturing, and extending life cycle of corrugated board which becomes production waste. In a further cooperation, other methodologies (cost benefit analysis, multicriteria decision making etc.) will be considered for knowledge transfer.

The transfer of knowledge contributes to: developing research staff from academia and beyond; developing new teaching/learning tools; developing new research directions or new possible collaborations; dissemination and exploitation of research results of specific interest of the institution; stimulating academic research, employment of graduates/continuing vocational training; creating new jobs; creation of specialized centers and services for scientific, technological and practical assistance, advice and information that apply the results of research and development programs.

The contribution of university researchers in transferring and disseminating knowledge toward industry can confirm the impact of research, associated with the benefits related to the implementation of knowledge transfer activities in the area of eco-innovation, eco-design and LCA thinking and their application for the capitalization of production waste by closing the loop in the envisaged production process, so as to increase its eco-efficiency.

Finally, based on this analysis which involves multi-disciplinary and practical aspects, the links between university and industry in a national network for knowledge transfer will be strengthened. Our results argue that Universities are sources for new solutions for industry, which at its turn, may provide a natural route to increase the use of practical solutions to resolve their prerequisites.

Unfortunately, in Romania, the cooperation between university and industry strictly depends on the financial support that Government may give for innovation and research activities in the country. This is a limitation for further studies in this area, since the financial support is not very ample and does not always take place, especially in the period of crisis. The cooperation success may be also limited by the availability of the data necessary for the analysis which mainly depends on the openness from the industry side, or by the excellence of the university since it is imperative that the creator to have the ability to distribute its knowledge such that the receiver can properly understand and use the knowledge in practice.

Regarding literature in the field we observed that the majority of studies are focused on measuring the performance of U-I knowledge transfer activities by using appropriate metrics. Knowledge channels of interactions are divided in different categories depending on the degree of formality and information, and the possibility of consulting the obtained results. However, the majority of channels are linked to consultancy or contract research; collaborative research; patenting; sharing of facilities; joint publications; participation to conferences, workshops, seminars; formation of spin-off; communication of knowledge through teaching and mobility. The use of different channels of interaction depends on several factors (e.g. motivation, financing resource, geographic proximity between public research organizations and industrial firms) that are in strong connection with the field of knowledge transfer, technology and industrial sector. Also, we observed that limited data on research collaboration case studies between universities and industrial firms based on knowledge transfer are currently available. Therefore our study may represent an important contribution in the field.


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## References


Allione C., De Giorgi C., Lerma B., Petruccelli L., (2012), From ecodesign products guidelines to materials guidelines for a sustainable product, Qualitative and quantitative multicriteria environmental profile of a material, *Energy*, **39**, 90-99.

Almeida C.M.V.B., Rodrigues A.J.M., Bonilla S.H., Giannetti B.F., (2010), Emergy as a tool for Ecodesign: evaluating materials selection for beverage packages in Brazil, *Journal of Cleaner Production*, **18**, 32-43.

Anatan L., (2015), Conceptual issues in university to industry knowledge transfer studies: a literature review, *Procedia - Social and Behavioral Sciences*, **211**, 711-717.

Andriankaja H., Vallet F., Le Duigou J., Eynard B., (2015), A method to ecodesign structural parts in the transport sector based on product life cycle management, *Journal of Cleaner Production*, **94**, 165-176.

Arvanitis S., Kubli U., Woerter M., (2008), University-industry knowledge and technology transfer in Switzerland: what university scientists think about cooperation with private enterprises, *Research Policy*, **37**, 1865-1883.

Becerra-Fernandez I., Sabherwal R., (2010), *Knowledge Management Systems and Processes*, Routledge, Taylor and Francis Group, London.

Berbegal-Mirabent J., Gil-Doménech D., Ribeiro-Soriano D.E., (2020), Fostering university-industry collaborations through university teaching, *Knowledge Management Research & Practice*, **18**, 263-275.

Bingley E., (2011), *Life Cycle Analysis: A Tool for Decision Making and Strategic Planning? Researching the Value of LCA in Kenyan Horticulture*, Proc. of the Conference Carbon and Water Management in Horticultural Exports from East Africa, Simba Lodge, Lake Naivasha, Kenya.

Brennenraedts R., Bekkers R., Verspage B., (2006), The different channels of university-industry knowledge transfer: Empirical evidence from biomedical engineering, Eindhoven Center for Innovation Studies, The Netherlands, On line at: https://pure.tue.nl/ws/files/1812910/612847.pdf.

Campean T., Grad F., Gradinariu C., Patrascu C., Gavrilescu M., Gavrilescu D.A., (2017a), Eco-friendly corrugated board and sustainable packaging manufacturing, *Environmental Engineering and Management Journal*, **16**, 705-714.

Campean T., Hlihor R.M., Simion I.M., Comăniță E.D., Cozma P., Smaranda C., Roșca M., Gavrilescu D.-A., Ghinea C., Gavrilescu M., (2017b), *Challenges of Circular Economy: Eco-Innovation and Eco-Design in Manufacturing Sector*, Proc. of the 9th International Conference on Environmental Engineering and Management, Bologna, Italy.

Chais C., Ganzer P.P., Olea M.M., (2018), Technology transfer between universities and companies. Two cases of Brazilian universities, *Innovation & Management Review*, **15**, 20-40.

Cherifi A., Gardoni M., M'Bassègue P., Renaud J., Houssin R., (2017), *Knowledge Management and Eco-Innovation: Issues and Organizational Challenges to Small and Medium Enterprises*, Proc. of the 21st International Conference on Engineering Design, ICED17, 21-25 August 2017, The University of British Columbia, Vancouver, Canada, 119-128.

Cerdana C., Gazulla C., Rauge M., Martinez E., Fullana-i-Palmer P., (2009), Proposal for new quantitative eco-design indicators: a first case study, *Journal of Cleaner Production*, **17**, 1638-1643.

Comanita E.D., Ghinea C., Hlihor R.M., Simion I.M., Smaranda C., Favier L., Rosca M., Gostin I., Gavrilescu M., (2015), Challenges and opportunities in green plastics: an assessment using the ELECTRE decision-aid method, *Environmental Engineering and Management Journal*, **14**, 689-702.

COM 112, (2011), Communication from the Commission to the European Parliament, the Council, the European economic and social committee and the committee of the regions. A Roadmap for moving to a competitive low carbon economy in 2050, COM2011 112 final, Brussels, On line at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0112from=EN.

COM 899, (2011), Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Innovation for a sustainable Future - The Eco-innovation Action Plan Eco-AP, COM2011 899 final, Brussels, On line at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0899from=EN.

Crețescu I., Câmpean T., Nechita T.C., Puițel A.C., Măluțan T., Gavrilescu D.A., Smaranda C., Cozma P., Gavrilescu M., (2017), *Dimensional and Quantitative Analysis of Production Wastes from Packaging Industry for their Revaluation. The Case Study of a Romanian Manufacturer*, Proc. of the 9th International Conference on Environmental Engineering and Management, Bologna, Italy.

de Wit-de Vries E., Dolfsma W.A., van der Windt H.J., Gerkema M.P., (2019), Knowledge transfer in university–industry research partnerships: A review, *Journal of Technology Transfer*, **44**, 1236-1255.

De Fuentes C., Dutrénit G., (2014), Geographic proximity and university–industry interaction: the case of Mexico, *Journal of Technology Transfer*, **41**, 329-348.

Dumitrescu L., Maxineasa S.G., Simion I.M., Taranu N., Andrei R., Gavrilescu M., (2014), Evaluation of the environmental impact of road pavements from a life cycle perspective, *Environmental Engineering and Management Journal*, **13**, 449-455.

EC Directive 12, (2004), Directive 2004/12/EC of the European Parliament and of the Council of 11 February 2004, amending Directive 94/62/EC on packaging and packaging waste, *Official Journal of European Union*, L47, 26-31.

European Commission (EC), (2014), Boosting open innovation and knowledge transfer in the European Union Independent Expert Group report on open innovation and knowledge transfer, European Commission, Directorate-General for Research and Innovation, Brussels, On line at: https://ec.europa.eu/research/innovation-union/pdf/b1_studies-b5_web-publication_mainreport-kt_oi.pdf.

European Commission, (2017), Communication from the Commission to the European Parliament, the Council, the European economic and social committee and the committee of the regions. A renewed EU agenda for higher education, Brussels, Belgium.

European Environment Agency (EEA), (2011), Resource efficiency in Europe, (Report No. 5), Copenhagen, Denmark.

European Environment Agency (EEA), (2016), Circular economy in Europe. Developing the knowledge base, (Report No. 6), Copenhagen, Denmark.

European Environmental Bureau (EEB), (2015), A reform agenda for a sustainable Europe, Conference Report, Brussels, On line at: http://www.2015.eebconference.eu/wp-content/uploads/2016/01/EEB-Annual-Conference-Report-20151.pdf.

Ellen MacArthur Foundation (EMF), (2015), Circular economy overview, On line at: http://www.ellenmacarthurfoundation.org/circular-economy/overview/concept.

European Parliamentary Research Service (EPRS), (2017), Towards a circular economy – Waste management in the EU, Study IP/G/STOA/FWC/2013-001/LOT 3/C3, On line at: http://www.europarl.europa.eu/RegData/etudes/STUD/2017/581913/EPRS_STU%282017%29581913_EN.pdf.

European Federation of Corrugated Board Manufacturers (FEFCO), (2015), European database for corrugated board Life Cycle studies, On line at: http://www.fefco.org/sites/default/files/lca-report-2015.pdf.

Fortuna M.E., Simion I.M., Ghinea C., Petraru M., Cozma P., Apostol L.C., Hlihor R.-M., Tudorache Fertu D., Gavrilescu M., (2012), Analysis and management of specific processes from environmental engineering and protection based on sustainability indicators, *Environmental Engineering and Management Journal*, **11**, 333-350.

Franco M., Pinho C., (2019), A case study about cooperation between University Research Centers: Knowledge transfer perspective, *Journal of Innovation & Knowledge*, **4**, 62-69.

Gavrilescu M., Campean T., Gavrilescu D.-A., (2017), *Extending Production Waste Life Cycle and Energy Saving by Eco-Innovation and Eco-Design: The Case of Packaging Manufacturing*, Nearly Zero Energy Communities, Proc. of the Conference for Sustainable Energy, CSE 2017, Visa I., Duta A., (Eds.), Springer Proceedings in Energy, 611-631.

Gavrilescu M. (Ed.), Crețescu I., Măluțan T., Puițel A.C., Smaranda C., Cozma P., Hlihor R.-M., Simion I.-M., Comăniță D.-E., Roșca M., Câmpean T., (2018), *Strategies and Solutions for Eco-Innovation and Eco-Design of Processes and Products from Recyclable Materials in the Context of Circular Economy. Guide to Good Practices* (in Romanian), Polytechnium Publishing House, Iasi, Romania.

Ghinea C., Gavrilescu M., (2016), Costs analysis of municipal solid waste management scenarios: Iasi - Romania case study, *Journal of Environmental Engineering and Landscape Management*, **24**, 185-199.

Ghinea C., Gavrilescu M., (2019), *Solid Waste Management for Circular Economy: Challenges and Opportunities in Romania – The Case Study of Iasi County*, In: *Towards Zero Waste. Circular Economy Boost, Waste to Resources*, Vol. 6, Franco-García M.-L., Carpio-Aguilar J.C., Bressers H. (Eds.), Springer International Publishing, Amsterdam, 25-60.

Ghinea C., Campean T., Gavrilescu M., (2017), Integrating sustainability indicators for tracking anthropogenic pressure on the earth the footprint family, *Environmental Engineering and Management Journal*, **16**, 935-948.

Ghinea C., Petraru M., Bressers H.T.A., Gavrilescu M., (2012), Environmental evaluation of waste management scenarios - significance of the boundaries, *Journal of Environmental Engineering and Landscape Management*, **20**, 76-85.

Ghinea C., Petraru M., Simion I.M., Sobariu D., Bressers H.T.A., Gavrilescu M., (2014), Life cycle assessment of waste management and recycled paper systems, *Environmental Engineering and Management Journal*, **13**, 2073-2085.

Govind M., Küttim M., (2016), International knowledge transfer from university to industry: a systematic literature review, *Research in Economics and Business: Central and Eastern Europe*, **8**, 5-25.

Grimaldi R., Kenney M., Siegel D.S., Wright M., (2011), 30 years after Bayh-Dole: reassessing academic entrepreneurship, *Research Policy*, **40**, 1045-1057.

Hamdoun M., Jabbour C.J.C., Othman H.B., (2018), Knowledge transfer and organizational innovation: Impacts of quality and environmental management, *Journal of Cleaner Production*, **193**, 759-770.

Hayter C.S., Rasmussen E., Rooksby J.H., (2020), Beyond formal university technology transfer: innovative pathways for knowledge exchange, *The Journal of Technology Transfer*, **45**, 1-8.

Holi M.T., Wickramasinghe R., van Leeuwen M., (2008), *Metrics for the Evaluation of Knowledge, Transfer Activities at Universities*, Report Commissioned by UNICO Commercializing UK Research, Library House Kett House, Cambridge, UK.

Hundal M., (2000), *Design for Recycling and Remanufacturing*, Proc. of International Design Conference, Dubrovnik, Croatia.

ISO/TR 14062, (2002), Environmental management - integrating environmental aspects into product design and development, International Organization for Standardization (ISO), On line at: https://www.iso.org/standard/33020.html.

ISO 14040, (2006), Environmental management: Life Cycle Assessment-principles and framework, International Organization for Standardization (ISO), Geneva, Switzerland.

ISO 14006, (2011), Environmental management systems - Guideline for incorporating eco-design, International Organization for Standardization (ISO), Geneva, Switzerland.

Joint Research Center &Institute for Environment and Sustainability (JRC & IES), (2010), *ILCD Handbook: General Guide for Life Cycle Assessment - Detailed Guidance*, European Union, Luxembourg.

Karlsson C., Johansson B., Norma T., (2011), Innovation, technology and knowledge, CESIS Electronic Working Paper Series, Paper No. 247, The Royal Institute of Technology, Centre of Excellence for Science and Innovation Studies CESIS, On line at: http://www.cesis.se.

Knight P., Jenkins J.O., (2009), Adopting and applying eco-design techniques: A practitioners perspective, *Journal of Cleaner Production*, **17**, 549-558.

Kooli-Chaabane H., Boly V., Yannou B., (2014), Monitoring of technology transfer projects in industrial clusters, *Journal of Innovation Economics Management*, **2014/1**, 73-91.

Kuijpers A., (2015), The circular economy - what is it and what does it mean for you?, Arcadis Briefing Paper, On line at: https://www.arcadis.com/media/9/D/3/%7B9D33B0CB-3F9D-4C16-9C74-B763D4BA442C%7DBriefing%20Paper%20-The%20Circular%20Economy_002.pdf.

Le Diagon Y., Perry N., Pompidou S., Pereira Gouvinhas R., (2014), *Integration of End-of-Life Options as a Design Criterion in Methods and Tools for Ecodesign*, Proc. of Joint Conference on Mechanical, Design Engineering Advanced Manufacturing, Toulouse, France.

Lee S.G., Lye S.W., Khoo M.K., (2001), A multi-objective methodology for evaluating product end-of-life options and disassembly, *International Journal of Advanced Manufacturing Technology*, **18**, 148-156.

Lindahl M., Ekermann S., (2013), *Structure for Categorization of Ecodesign Methods and Tools, Re-Engineering Manufacturing for Sustainability*, Proc. of the 20th CIRP International Conference on Life Cycle Engineering, Singapore, 117-122.

Masoudi A., You H., Suh S.-H., (2012), Characterization of eco-design checklists, *Journal of the Korean Society for Precision Engineering*, **29**, 964-970.

McCleary E., (2015), *Academics individual motivation: the knowledge transfer partnerships context*, PhD Thesis, School of the Built Environment, College of Science and Technology University of Salford, UK, On line at: http://usir.salford.ac.uk/37783/.

McDonough W., Braungart M., (2002), *Cradle to Cradle, Remaking the Way we Make Things*, North Point Press, New York.

McKinsey, (2012), *Towards the Circular Economy*, vol. 1, Ellen MacArthur Foundation, Isle of Wright, UK.

McKinsey, (2013), *Towards the Circular Economy*, vol. 2. Ellen MacArthur Foundation, Isle of Wright, UK.

Mládková L., (2011), Knowledge management for knowledge workers, *Electronic Journal of Knowledge Management*, **9**, 248-258.

Navajas A., Uriarte L., Gandía L.M., (2017), Application of eco-design and life cycle assessment standards for environmental impact reduction of an industrial product, *Sustainability*, **9**, 1-16.

Organisation for Economic Co-operation and Development (OECD), (2009), Eco-innovation in industry: enabling green growth, On line at: http://www.oecd.org/sti/ind/eco-innovationinindustryenablinggreengrowth.htm.

OG, (2002), Ordinance no. 57 of 16 August 2002 on scientific research and technological development, *Romanian Official Monitor*, no. 643 from 30 August 2002, Bucharest, Romania.

Park P.-J., Tahara K., (2008), Quantifying producer and consumer-based eco-efficiencies for the identification of key ecodesign issues, *Journal of Cleaner Production*, **16**, 95-104.

Pasaribu B.I., Afrianti A., Gumilar G.G., Rizanti H.P., Rohajawati S., (2017), Knowledge transfer: a conceptual model and facilitating feature in start-up business, *Procedia Computer Science*, **116**, 259-266.

Peer V., Stoeglehner G., (2013), Universities as change agents for sustainability – framing the role of knowledge transfer and generation in regional development processes, *Journal of Cleaner Production*, **44**, 85-95.

Petraru M., (2012), *Integration of economics and pollution prevention practices for a sustainable industry*, PhD Thesis, Gheorghe Asachi Technical University of Iasi, Romania.

Petraru M., Gavrilescu M., (2010), Pollution prevention, a key to economic and environmental sustainability, *Environmental Engineering and Management Journal*, **9**, 597-614.

Petruzzelli M.A., (2011), The impact of technological relatedness, prior ties, and geographical distance on university-industry collaborations: a joint-patent analysis, *Technovation*, **31**, 309-319.

Pigosso D.C.A., Zanette E.T., Filho A.G., Ometto A.R., Rozenfeld H., (2010), Ecodesign methods focused on remanufacturing, *Journal of Cleaner Production*, **18**, 21-31.

Prieto-Sandoval V., Jaca C., Ormazabal M., (2018), Towards a consensus on the circular economy, *Journal of Cleaner Production*, **179**, 605-615.

Rajaeian M.M., Cater-Steel A., Lane M., (2018), Determinants of effective knowledge transfer from academic researchers to industry practitioners, *Journal of Engineering and Technology Management*, **47**, 37-52.

Rast S., Khabiri N., Senin A.A., (2012), Evaluation framework for assessing university-industry collaborative research and technological initiative, *Procedia - Social and Behavioral Sciences*, **40**, 410-416.

Romer P., (1990), Human capital and growth: Theory and evidence, *Carnegie-Rochester Conference Series on Public Policy*, **32**, 251-286.

Rosli A., Rossi F., (2015), Monitoring the knowledge transfer performance of universities: An international comparison of models and indicators, *CIMR Research Working Paper Series*, Working Paper No. 24, On line at: http://www.bbk.ac.uk/innovation/publications/docs/WP24.pdf.

Seppo M., Lilles A., (2012), Indicators measuring university-industry cooperation, *Discussions on Estonian Economic Policy*, **20**, 204-225.

Shih D.-H., Lu C.-M., Lee C.-H., Cai S.-Y., Wu K.-J., Tseng M.-L., (2018), Eco-innovation in circular agri-business, *Sustainability*, **10**, 1-13.

Simion I.M., Ghinea C., Maxineasa S.G., Taranu N., Bonoli A., Gavrilescu M., (2013), Ecological footprint applied in the assessment of construction and demolition waste integrated management, *Environmental Engineering and Management*, **12**, 779-788.

Sustainable Recycling Industries (SRI), (2017), Component A: Life Cycle Inventories, Ecoinvent Center, EMPA Materials Science and Technologies, World Resource Forum and Sustainable Recycling Industries, Switzerland, On line at: https://www.ecoinvent.org/files/call_for_tenders_for_capacity_building_la.pdf.

Wever R., Vogtlander J., (2015), *Design for the Value of Sustainability*, In: *Handbook of Ethics, Values, and Technological Design. Sources, Theory, Values and*

*Application Domains*, van den Hoven J., Vermaas P.E., van de Poel I. (Eds.), Springer Science+Business Media, Dordrecht, 513-549.
Wimmer W., (1999), *The Ecodesign Checklist Method: A Redesign Tool for Environmental Product Improvements*, Proc. of the First International Conference on Environmentally Conscious Design and Inverse Manufacturing, Tokyo, Japan, 685-688.
Xavier A.F., Naveiro R.M., Aoussat A., Reyes T., (2017), Systematic literature review of eco-innovation models: Opportunities and recommendations for future research, *Journal of Cleaner Production*, **149**, 1278-1302.
Zarinpoush F., Von Sychowski S., Sperling J., (2007), Effective knowledge transfer exchange for nonprofit organizations - A framework, Imagine Canada, Toronto, Ontario, On line at: http://www.imaginecanada.ca/sites/default/files/www/en/library/csc/kt_framework-march16-_final.pdf.