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Educating T-Shaped professionals to meet substitution challenges and developing business models for substitution and recycling

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Abstract. One strategy to overcome the challenges related to critical raw materials (CRMs) is their substitution and recycling. However, the bright scientific idea, proof of concept or laboratory demonstration need to cross the valley of death in order to become stated as ‘a substitute’ instead of ‘a potential substitute’. Most PhD students and Post Docs specialize within a given thematic area; for example on specific materials or on substitution in a certain application. This specialization could limit the ability to generate innovations and profitable business models if there are not enough tools and skills to transform new knowledge and research results into an appealing value proposition towards customers and to a business opportunity for the current markets. The project proposes a framework for developing substitution and recycling related cross-sectorial skills and tools. These are applied for training business-related competences e.g. teamwork, management, communication, value proposition and business models design, especially within RTOs and industries. The proposed learning itinerary can radically improve the path from scientific proof of concept into innovation and lean start up or industrial market launch. The developed framework is tested by a pilot group having several topics within the areas of substitution and recycling of critical raw materials.

1. Introduction

While the concept of T-shaped profile is not so new, it is now more important than ever. The world is becoming more and more complex and T-shaped skills are a razor that can cut through the complexity. Over the past decade, research has emphasized the need for today’s young professionals to possess deep disciplinary knowledge along with a keen ability to communicate across social, cultural and economic boundaries. These “T-shaped professionals” are in high demand for their ability to innovate, build relationships, advance research and strengthen their organizations.

Currently many college and university graduates have been trained to be productive in one field, but employers are placing increasing importance on skills that reach beyond a single discipline or focus. Upon graduation, students should be able to handle information from multiple sources, advance professional relationships across different organizations, contribute innovatively to organizational practices, and communicate with understanding across social, cultural, economic and scientific disciplines. Tomorrow’s workers will build their careers in a globally interconnected and constantly changing world with smarter technologies in an effort to effect positive global change [1].

A T-shaped skillset must constantly become broader (general knowledge) and narrower (specialized knowledge) as the world becomes more complex, nevertheless having T-shaped skills is one of the



biggest competitive advantage an employee can have in the creative society when contributing value for the markets or when achieving goals [2].

In this paper a methodology called “T-DoRe itinerary to develop T-shaped profiles” is presented together with its application to a substitution and recycling case: Neodymium recovery from spent magnets and the corresponding business case.

The definition and implementation of this methodology has been developed under the project T-shaped Doctors in Residence – Doctoral training in RTOs and Industries (T-DoRe) with the support of the European Institute of Technology of Raw Materials, and by a consortium of VTT and Tecnalia Research and Technological Centres, Lappeeranta University and Mondragon University, and the company Outotec.

2. Methodology: T-DoRe itinerary

The situation today is that PhD students and Post Doctorials specialize in certain thematic areas, acquiring a deep technical knowledge. However, they find difficulties when addressing customers’ needs, business perspective and lack holistic knowhow that leads to breakthrough innovations.

T-DoRe proposes a general framework based on learning-by-doing methodology to develop T-shaped profiles. This framework describes a global learning itinerary and the main drivers are:

- **Self-development:** It has to do with the capacity to take responsibilities, to take initiative and be proactive, to guide others, to work in teams, to lead and plan a personal and professional project, to learn constantly and to create networks. It is a reflection space for the participants to think about the present and the future needs in order to become T-shaped and think about the type of professional career they want to develop.
- **Ideation for industry and society.** This is about transforming knowledge into innovations. It is about training the capacity to see opportunities and take ideas into action, to value creativity for prototyping solutions (products or services) that can be transferred to the industry, and to experiment in real context with orientation to get results (Value). Bringing research results to the market has to be in the centre of the learning itinerary, and while the participant develops and progress with the project, the research itself is the main tool to create the learning environment for co-operation, thinking out of box, problem solving and innovation.

2.1. Educational approach

The learning methodology proposed in T-DoRe has the following elements:

- **Learning by doing and experimenting.** It means learning by working in real projects, learning from actions done and from direct and frequent contact with industry customers, users, providers and other stakeholders. Learners must be proactive in setting goals, choosing paths and searching for the right tools and skills to develop in each case. It is a pull model (active behaviour of participants) versus push model (passive behaviour as in regular lectures).
- **Learning communities - learning with others.** Learning in teams or in networks/communities allows a faster learning process and the results of the projects may have greater impact. The right environment and context to provide opportunities to learn from regular lectures or traditional learning tools is very important. Participants learn from sharing their own experiences and from others’ experiences. The action and reflection model applied continuously provides a change in the learner mind-set, who starts to see any situation related to the project as a real learning opportunity.

While working in a project or thesis, participants acquire knowledge and skills that generate specialists in the raw materials processes and technologies, including the environmental and sustainability aspects. Participant’s project is the vehicle to develop transversal/cross skills such as leadership and teamwork, communication, customer development, market validation, prototyping solutions to contrast with industry and see the business perspective to create innovations. And the only

way to learn is being led by customers and by end-users. This means the construction of a user-led open innovation ecosystem and especially seeing end-users as an integral part of the innovation process [3].

The learning is based on a participant's project. It can be a research project, an specific project for a company, a PhD thesis itself, or even specific actions needed within regular project activities. The topic of the project is a technical subject related to EIT Raw Materials themes of interest, which are raw materials resource assessment, mining, new mineral and metallurgical processes, recycling methods, substitution of critical and toxic materials and substitutions for optimized performance, and design of products and services for the circular economy [4].

2.2. Structure of the T-DoRe itinerary

The concept of the itinerary is like a journey plan with special places to visit. Within the project a general itinerary is suggested. Depending on the need of the RTO/industry and the background or experiences of the future PhD, this general itinerary may be customized to the participant. It is conceived as learning-by-doing path. Also projects and thesis have different levels of maturity. They could be in their early stage or nearly to be finished. This means that there is one general itinerary but different ways of living it.

While participants are working in the agreed project within the RTO/industry, they have to create new ideas that will lead to innovations. In addition, participants are expected to create the associated value proposition and business model. The lean start up concept and tools together with value proposition and business model approach will be the basis for an iterative project development process.

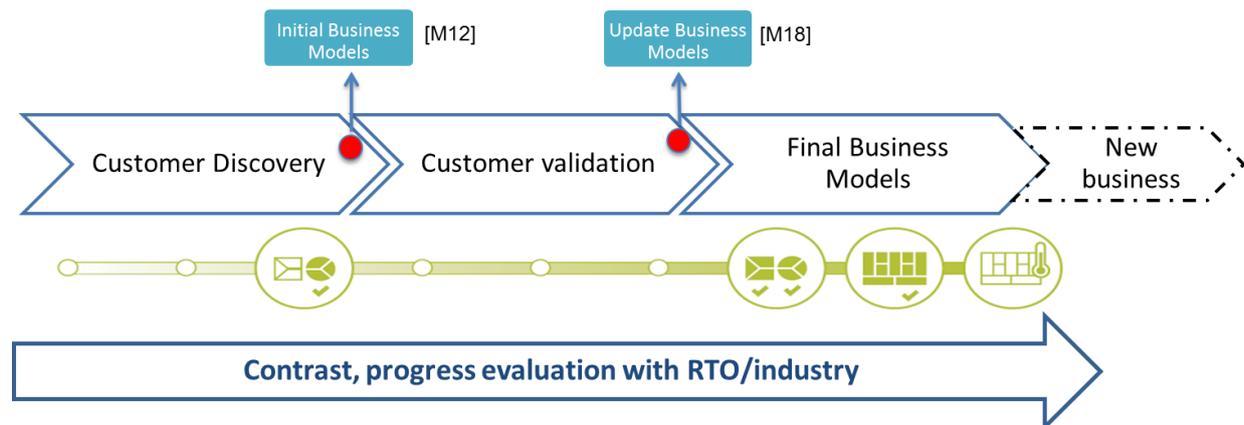


Figure 1. Process to create a business model for the innovations

Figure 2 describes the project development process which evolves and progresses along with the relation with the market. Steve Blank, a Silicon Valley serial-entrepreneur and academician, has described this process in his books. Blank is recognized for developing the Customer Development method that launched the Lean Startup movement. He says that customer discovery is about going out of the building to learn about your customers' jobs, pains, and gains. This has to do with understanding needs and problems of potential customers and investigate what you can offer them to kill pains and create gains. Customer validation is about testing if customers value how products and services intend to alleviate pains and create gains [5].

Customer discovery and customer validation is iterative in a loop; it is a searching activity until "customer creation" where customers are in the sales channels. That is why during all the process there will be contrast and progress evaluation with industry and RTO [5].

Within the scope of T-DoRe this customer creation is represented by a final business model. T-DoRe itinerary produces a business model at the end of the process. Customer visits for feedback, development and prototypes, and customer/user validation is part of the itinerary

During visits to RTOs and industries, participants will have the opportunity to develop or to strengthen the skills defined in their personal learning itinerary. One topic T-DoRe will stress is the frequent contact with Industry. It can be in the form of frequent visit, communication, or in shorts internships.

Based on Blank's customer development approach, a general description of the process is: It starts with the definition of a value proposition hypothesis that should be tested with stakeholders several times; learning from this testing will help to update the business model. Participants during the project have to work on the business models, workshops and coaching sessions are the moment to share the progress with other participants.

The itinerary starts with the presentation of the objectives, the activities to perform, the workshops to attend, how the process will be measured, and the communication dynamics with their mentors in RTO or industry, and with the coaches.



Figure 2. Workshops in the itinerary

Participants will meet at several workshops with the aim of:

- Learning about a specific topic and share progress in their practice/projects.
- Sharing results from their projects and learning from others' experiences.

As shown in Figure 3, workshops focus on specific general themes relevant to all projects, as innovation, marketing and so on. The number of workshops may vary but they normally would occur every 6-8 weeks, giving some time to participants to make progress in the project (customer visit, testing a prototype, etc.).

2.3. Coaching sessions and follow up

At the beginning of the itinerary, participants elaborate a learning contract where their learning plan is stated which represents the seal a commitment to fulfil it. The activities during their project will be guided by this plan.

T-DoRe itinerary proposes coaching sessions between the workshops. The aim of these sessions is to follow up actions, set new objectives if necessary and share practices among participants. It is a way to be connected to the community.

Participants during the project have to work on the business models and workshops and coaching sessions are the moments to share the progress. A monthly 4 hours coaching session, is maintained and it can be done presently or it can be virtual, using Skype or other tool.

3. T-DoRe itinerary in practice

Eleven participants (PhD candidates) have done the itinerary to acquire a T-shaped profile. One important activity of the T-DoRe itinerary has been the elaboration of the Business Case which is a container of the results of actions taken and reflects the progress in the way to bring the research results to the market.

Participants were invited to develop their research project business case. In this sense the 11 participants (PhD candidates) first created a value proposition canvas, covering the main aspects of the value proposition resulted from their research for an specific customer segment.

The value proposition canvas is a simple way to understand the customers' needs, and design products and services they want. This tool was created to help business builders to be very clear about whom a business is for and how it delivers value to them [6].

So for the participants this tool forced them to think like the customer would do and then figure out why their product or service is valuable. Once the customer is selected, they start with the Wants, Needs, Fears and Substitutes in order to understand the problems the customers are willing to solve, and the gains or values the customers would like to achieve. In parallel, participants think about their project main features, benefits that produce and customer experience and satisfaction. This exercise was done supported by the analysis and visits done to potential customers.

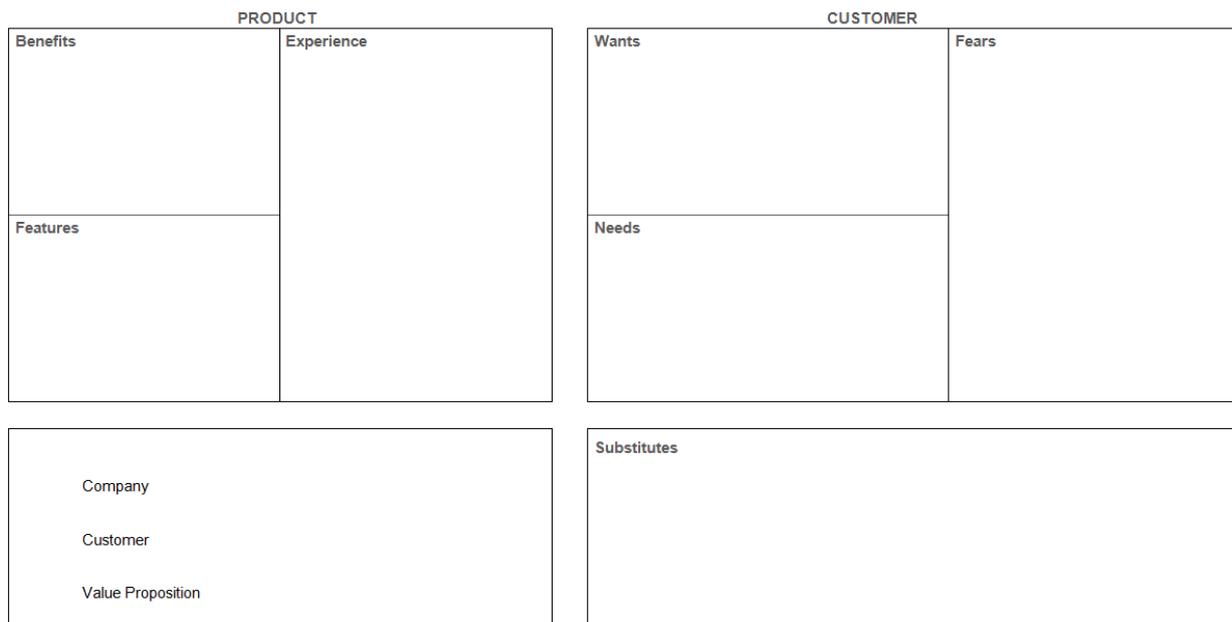


Figure 3. Value Proposition Canvas

Also during the workshops the participants could work in the templates, supported by the T-DoRe coaches and they also shared their own experiences in order to receive feedback from other participants.

The next tool they had to use was the business model canvas. This canvas is used to describe, design, challenge, and changes in a business model. It covers the following: Customer Segments, Customer Relationships, Channels, Value Proposition, Revenue Streams, Key Activities, Key resources, Key Partners and Cost Structure [7].

As a result of the itinerary, the 11 PhD participants developed a complete first version of their research project business case, including the value proposition canvas, the business model canvas, and also the validation board. This last element allowed the participants to formulate, analyze and validate hypothesis for the customer's problem and for the solutions to that problem in an iterative way. Through customer interviews, participants could collect direct feedback regarding the different hypothesis and then evolve it by discarding invalid hypothesis in order to progress in the definition of what is called minimum viable product (MVP).

3.1. Neodymium recovery from spent magnets business case

There is growing concern about the availability of rare earths as the demand for electronic devices and high technology products increases [8]. Amongst the rare earths, one of the most critical is neodymium (Nd), used in permanent magnets for applications such as turbines, hard disk drives, electric cars and electric storage systems. At present, toxicity and the complex energy intensive multi-stage processes limit the implementation of existing Nd recovery technology [9–11].

Electrochemical deposition of Nd metal is an interesting technology for the production of Nd from both, primary and secondary sources. However, it requires a suitable electrolyte media as the electrolysis of Nd is not possible in aqueous electrolytes due to the insufficient electrochemical stability at the very negative potentials involved. Nd electrodeposition has been achieved in high temperature molten salts, but at temperature of 700 to 1000° C which also requires significant amounts of energy [10,11].

Ionic liquids (ILs) are purely ionic compounds, many with melting points below room temperature that are an interesting alternative media for Nd electrochemical recovery due to electrochemical stability. In recent years, the chemical separation and recovery of rare earths in ILs has been investigated, focusing primarily on those with imidazolium, betainium and ammonium cations [9,12–16]. However, the electrochemical recovery of Nd in ILs has been scarcely investigated [16,17].

The objective of the PhD project associated to this business case is to develop a low temperature Nd electrodeposition process using ionic liquids as electrolytes as a greener and less energy intensive alternative to existing processes.

3.1.1. Value proposition. The customer segment targeted in this business model is that of metal producers and especially those focused in precious metals although it does not exclude metal producers of common metals.

The value proposition canvas reflects customer requirements (needs, wants, fears) and the products/services that deliver value to that customer (benefits, experience, features). The following figure shows the value proposition canvas of this business case.

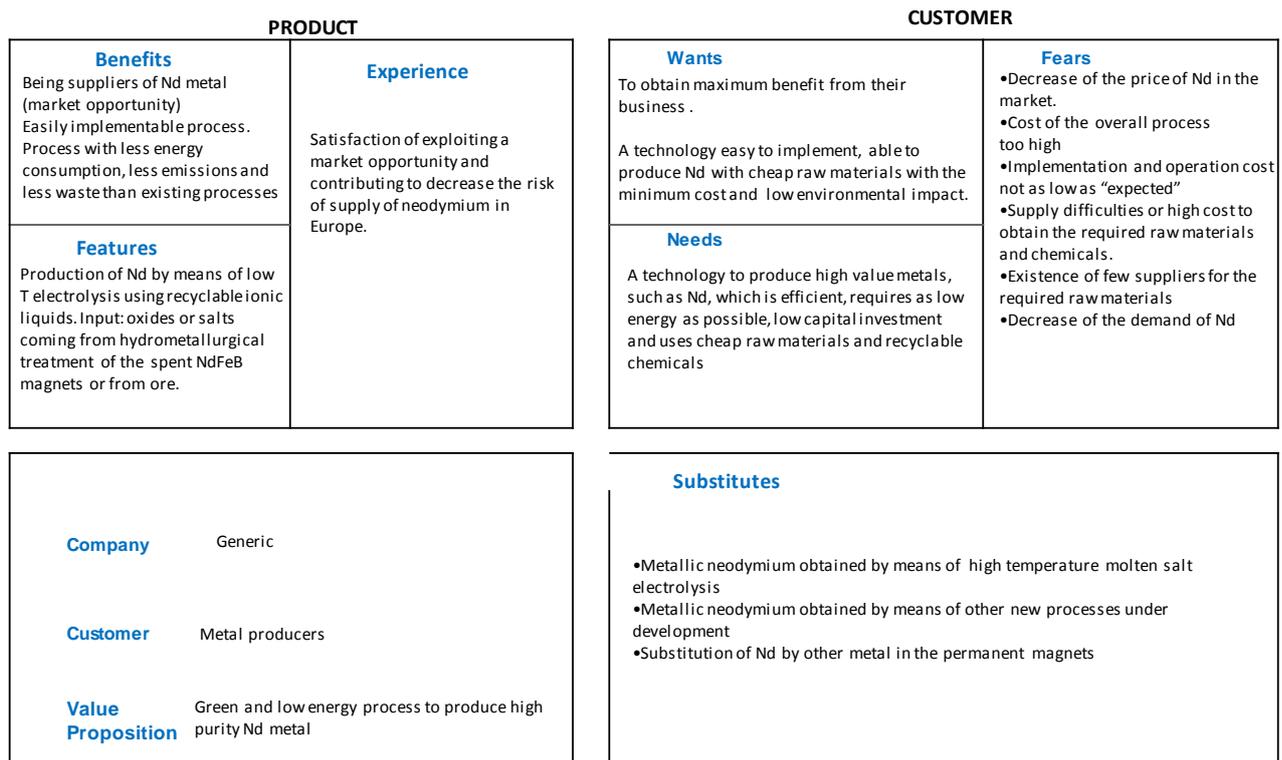


Figure 4. Nd recovery from spent magnets

Interviews with several customers allowed the researcher to obtain direct information of the needs and wants in order to understand them, prioritize and validate hypothesis.

The researcher identified aspects related to the potential market, and verified if the research was addressing the right issues.

3.1.2. Business Model Canvas. This canvas addresses the different elements that are related to the business model for a particular customer segment.

This canvas identifies the nine elements that explain the business model: Customer Segments, Customer Relationships, Channels, Value Proposition, Revenue Streams, Key Activities, Key resources, Key Partners and Cost Structure.

The customer segments identified are the metal producers, which is an important market segment because its large size, recyclers which already have hydrometallurgical plants and/or pyrometallurgical plants, rare earth metal and alloy producers, and electrolysis plants. This business model study has been carried out considering the customer segment of metal producers only because of its large size and because it has been the only one for which the researcher has found data about the size and other economic aspects.

The following figure shows the business model canvas of this business case.

<p>Key Partners</p> <p>1. Ionic liquids manufacturers 2. Engineering company (for plant desing and mechanical treatment optimisation) 3. Manufacturers of components for the electrolysis plant</p>	<p>Key Activities</p> <p>Consulting/ provide our knowledge to implement the technology</p> <hr/> <p>Key Resources</p> <p>1. Experts on the technology 2. Well equipped laboratories</p>	<p>Value Propositions</p> <p>Green and Low T process for the production of high purity Nd metal by means of ionic liquid electrolysis (using recyclable ionic liquids)</p>	<p>Customer relationships</p> <p>Consulting/ provide our knowledge to implement the technology</p> <hr/> <p>Channels</p> <p>1. Meetings & visits to their plant 2. Technical support and discussions by email or telephone</p>	<p>Customer Segments</p> <p>Metal producers</p>
<p>Cost Structure</p> <p>1. Office for the experts 2. Salary of the experts</p>			<p>Revenue Streams</p> <p>1. Payment for the license of our process 2. Our knowledge, consulting services to implement the technology 3. Agreement with Ionic Liquids manufacturer to obtain some commission from each tone of ionic liquid sold</p>	

Figure 5. Nd recovery from spent magnets Business Model canvas

The business model has been supported by calculations of revenues and costs considering some assumptions related to the customers, their problems and the proposed solutions. Although Technology Readiness Level (TRL) is still low, this exercise provided a wider vision in the PhD research.

Analyzing the complete value chain new questions and aspects to be treated arose, e.g. concerning the availability of raw materials for the proposed fabrication process, and therefore the researcher identified new elements that need to be analyzed as well as new stakeholders.

3.2. Impact of T-DoRe itinerary.

The impact of the methodology applied in the 11 business cases varied depending on the stage of the research and on the previous educational background and working experience of the researchers.

In general, several benefits have been detected, from the development of strategical and communication competences, to the analysis of new aspects in the project, covering the complete value chain of the project.

In the particular Nd recovery case, the researcher mentioned the positive impact of the methods and tools to incorporate in the analysis and development of the research, like the Value Proposition and Business Model canvases, and also other tools as the “Motorola” tool to prepare and afterwards analyze the visits to potential customers and to other stakeholders in the value chain.

In addition, the researcher highlighted the importance of having a good community learning environment during the itinerary. The community learning process made the itinerary more motivating and richer, as researchers had the opportunity to share reflections and questions, to learn from each other’s experiences, as more contributions could enrich the business case of each participant. Last, the participation in a community learning process is a way to enlarge the network in the field of Raw Materials, and it can provide opportunities for future collaboration.

4. Conclusions

This paper explains the T-DoRe itinerary and how this methodology has helped the participants to widen their profile with traversal skills as teamwork, innovation and business orientation. Acquiring these skills has allowed participants to take ideas into action and to transform their PhD research knowledge into solutions (products or services) that can be transferred to the market. All this process has crystallised into each participants’ Business Cases.

Some interesting results have been obtained. The business cases developed by candidates has shown that the creation of new holistic innovation champions through training of T-shaped professionals from Universities, RTOs and industry in the raw materials sector with knowledge in applied sciences, practice, and market innovations is possible.

The action oriented activity “customer interviews” has promoted the interaction of the participants with industry and stakeholders to understand real needs related with their research knowledge. This wouldn’t have occurred without the T-DoRe itinerary.

The eleven participants have created their value proposition and business model with the same success that the Neodymium case. PhD participants have thought on their thesis as a product, process or service that a potential customer might need and likely buy.

The business model creation activity has helped them to better focus the research (in case of low TRL researches) and therefore define the future transferable research results. On the other hand, for higher TRL projects, the itinerary has helped to improve the value proposition for customers.

Future research value for low TRLs depends on the value propositions by these researches, and the advantages of focusing is clear. Technological value for companies depends on the business value that the company gets from that technology. For higher TRLs the approach is more straightforward as the focus is based on the short term. Anyway, technology is seen by companies as a means to an end, and not an end in itself.

About the types of business models developed, the results obtained have underlined the importance of the services as an innovation approach for the industry, as well as the fact that Scientific R&D consulting remains the most important approach for spin-outs.

Moreover, the fact that most of the business models have focused their market in the machine and equipment market underlines the idea that although raw materials industry is both product and process based, innovations in this sector are based equipment capable of creating and processing new materials and new products. Besides, the innovations proposed also emphasise the idea that opportunities for this industry are associated to the servitization and personalization of their business. Initially coined by Vandermerewe & Rada [18], servitization means the process of creating value in products and goods by adding services. Another trend in industry, and reflected in the business models, is personalised customisation. This trend is related with the creation of services to meet customer (or even individual) specific requirements with the implementation of highly personalized advanced services.

Finally, the business models developed have also highlighted the idea that although the innovations proposed vary depending on the position in the value chain, opportunities for the raw material industry to develop new business are business-to-business (B2B, in line with the fact that business-to-business (B2B) has seen an increase in private equity investments and investments in B2B start-ups.

The next step is to look for patterns among the business models defined by participants in order to have basic templates to help to think in how to bring the research results to the market with successful results and create innovative business.

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