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Product-Service Systems across Life Cycle

Technology-based product-services for supporting frugal innovation

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Abstract

In recent years, European manufacturing companies are gradually applying innovative PSS (Product Service Systems), as strategic opportunity for differentiating from competitors, offering an integrated bundle of products and services, targeted on specific needs of different customers. At the same time, frugal innovation has also surged as a new business concept based upon an intelligent use of resources to fulfill region-dependent customers' needs. Both approaches bring forth rethinking of established business models, which in turn asks for an in-depth analysis of the implications on the company organization and infrastructure, at supply chain and plant levels, urging towards manufacturing networks and reconfigurable assembly lines. This paper presents a formalized framework to support product-service design and the related business model characterization, in the context of frugal innovation. The methodology is applied to three real industrial scenarios respectively in the aeronautics, the domestic appliances and the machinery industry, which are analyzed within the framework of the H2020 European funded project 'ProRegio'.

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Keywords: product-services; frugal innovation; business models.

1. Introduction

Recent findings of WTO [1] show that manufacturing global supply chains are shaped into regional blocks, i.e. European, Asian and North-American. This reflects on customer demands and requirements in product and services offering, which assume strongly different regional characterization. Mastering global production and distributed customer networks means addressing in a hub-spoke structure the different needs arising from markets, providing targeted products and services. It is the base of frugal innovation, which aims at exploiting the concept of intelligent use of resources, turning the related constraints into advantages and driver for products (and related services) innovation [2]. In fact, frugal innovation systematically works its way towards target customers' needs, addressing different requirements in terms of product design, functionalities, quality, prices etc, which shows a regional dependency. Diverse implementation examples arise especially in emerging markets (see [3]), emphasizing the frugalization great potential; nevertheless industrial applications appear as fragmented and far from being structured. This asks for business approaches, which are able to provide locally adaptable offering, without loses in terms of efficiency, in a systematized manner. The development of product-related services with high technological content permits supporting the customer-driven innovation of frugal products, reducing time-to-market and delivery times, fostering the ability in dealing with distributed networks of customers and of production facilities. This is the idea on which ProRegio EU funded project is grounded. It aims at developing product-services, related advanced ICT and cloud-based tools for supporting frugal innovation, allowing the co-evolution of products (and services)-processes-production systems, according to localized

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customers' needs and production sites capabilities. It relies on manufacturing intelligence solutions (e.g. augmented reality) for integration and adaptation of shop floors and production networks, with ad-hoc re-design, based on active feedback and knowledge exchange among producers, suppliers and end-users.

Thus, this paper aims at presenting a formalized framework for the definition of technology-based product-services and related business model, for supporting frugal innovation. Within the context of ProRegio project, structured and semi-structured questionnaires, meetings and discussions are used to gather information from industrial partners in order to define product-services for the different application domains, i.e. aeronautics, domestic appliances and machinery industry, following a bottom-up and iterative approach. Hence, in Section 2 we discuss how the frugalization of the offering (either products, services or a combination of both) can be tackled within the product-services generation and business model definition, which is presented in detail in Section 3. It is followed by the presentation of the ProRegio product-services, their classification and the detailed analysis of one representative example in Section 4. Section 5 points out the main conclusions and draws possible future work paths.

2. Frugalization-oriented product-services

2.1. Frugal innovation in the context of product-services

Frugal innovation is a process of adapting goods and their production, tailored to the target customers' requirements. It discovers new business models, reconfigures value chains and re-designs products, based on intelligent use of resources and high industrial efficiency [3]. Although the majority of works on this topic deals with emerging countries (e.g [4],[5],[6]), whose unsaturated, huge and fast growing economies reproduce the perfect conditions for the implementation of frugal innovation strategies, the developed economies can benefit from this approach successfully too. In fact, environmental and resource constraints can be drivers to innovate products (and services), increasing their affordability and sustainability performances during their design and [4], according to specific reference market preference. Since it's a customer-centric perspective, the possibility to actively include users and offering providers products and services design and delivery, allows a co-creation of the value associated [7] and, definitely, the establishment of long-term collaborations. It matches perfectly the re-thinking of business models and value chains which characterize the product-service paradigms. They are often defined as "a mix of tangible products and intangible services designed and combined so that they jointly are capable of fulfilling final customer needs" [5]. This implies the overcoming of the product-focused technical offering, based on transactional relations, towards a service-centered selling grounded on long-term relationships and value added proposition [6]. Operationally, these collaborative relations require innovations in business models and related technical enablers (advanced ICT solutions, manufacturing intelligence and Internet of Things [7]), at different levels, i.e. plant and network level, in an integrated fashion. The implementation of such solutions reduces the innovation costs, enabling the accumulation of knowledge which has, in turn, scale effects. This promotes customer-oriented and less over-engineered product variants design and manufacturing and improves the optimal collaboration and coordination in the production networks.

2.2. Framework for supporting frugal innovations in products and services

The goal of frugalization in the context of product-services is responding to target market cluster needs with appropriate product-service packages. This is triggered by the definition of the target markets and their segmentation into clear clusters, using key characteristics (e.g. regional criteria).

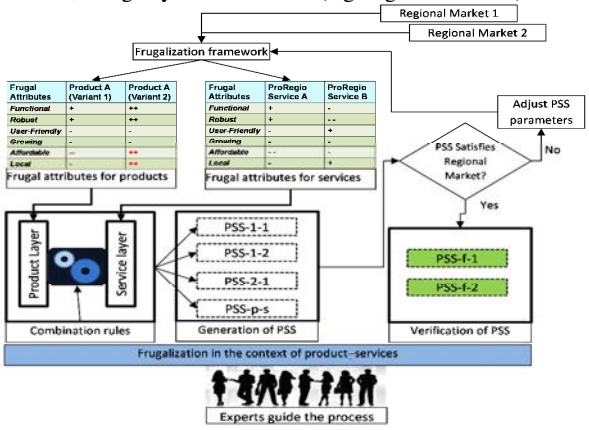

Figure 1 Frugalization in the context of product-services

Through the frugalization framework (Figure 1), each market cluster and related needs are transformed into frugal attributes, namely "functional", "robust", "user-friendly", "growing", "affordable" and "local" [3]. They represent the drivers for frugalizing products and services. These can be fulfilled by the product dimension (product layer) or by the service dimension (service layer), which shows mutual interdependency. For example, the selection of a product variant can impact on the associable service packages, and vice-versa. Combinations rules are needed to create feasible and optimal mix of product variants and services, thus defining product-services. The process can be automated or guided by multi-disciplinary experts. Using the combination rules, a list of candidate product-services can be generated. Each product-service plan is evaluated in order to verify if it meets the regional target market expectations. Expert evaluations are required on various aspects of the product-service offering, including financial benefits for providers and receivers. Therefore, during the verification phase, the final proposals are selected.

3. Framework for business model in ProRegio product-services

The constitutive elements of the product-service business model framework, proposed for ProRegio product-services,

are derived from Osterwalder and Pigneur [14] and modified to suit technology-based product-services definition for supporting frugal innovation, within the process reported in Figure 1. It is composed by building blocks, clustered in (i) *Value proposition*, (ii) *Architecture* and (iii) *Profitability*. Solutions and considerations presented in [11],[12], [13] are further elaborated for including the product-service main features, such as: (1) co-presence of product and service in offered value; (2) orientation and nature of the interactions ([15],[8],[16]) among provider(s) and receiver(s); (3) co-creation and collaboration in product-service design and delivery, with impacts on the level of integration and the degree of dependency of the engaged partnerships; (4) division of the work and assignment of responsibilities, according to individual capabilities/resources; (5) assignment of property rights and connected risks.

VALUE PROPOSITION						
Description: A value proposition settles the value delivered to specific target customers, which can be a product, a service or a combination of both [12]. It relies on an infrastructure (capabilities, relationship structure and related interactions, risk distribution etc.) of the relations established.						
It is composed of a set of one or more PSS-OFFERING(s).						
1.PSS-OFFERING						
AT.1.1	**Description:** It describes a company bundle of product and services, emphasizing the marginal value with respect to the current solutions.					
AT.1.2	**Reasoning:** It expresses why a certain value proposition could be attractive for the target customer(s).					
AT.1.3	**Life cycle:** It describes at which stage of the lifecycle of an offering the value is created.					
	Creation	*Appropriation*	*Consumption*	*Renewal*	*Transfer*	
AT.1.4	**Orientation:** It describes the orientation of the product-service offering.					
	Pure Product	*Product-oriented*	*Use-oriented*	*Result-oriented*	*Pure Service*	
		Integrated product-service				

Figure 2 Value proposition

ARCHITECTURE			
Description: The architecture describes the structure, the enablers (internal and external) and the interconnections needed to create value and maintain the relations with the target customers and the network of other actors involved in the value proposition (e.g. company providers).			
The architecture is settled according to the specific TARGET CUSTOMERS. The VALUE CONFIGURATION relies on PARTNERSHIPS established among the offering provider(s) and receiver(s).			
1.TARGET CUSTOMER			
AT.1.1	**Description:** Target customers segments define the type of customers to which the value proposition is addressed to.		
AT.1.2	**Classification:** It describe the criteria on which the segmentation is based.		
2. VALUE CONFIGURATION			
AT.2.1	**Description:** The value configuration describes the arrangement of activities for mapping and representing the value proposition delivery/fruition.		
AT.2.2	**Coverage:** It represent the set of activities represented in the value configuration mapping and is dependent on the actors involved in the delivery/fruition of the bundle of products and services offered by a company. It represents the extension of the analysis.		
AT.2.3	**Capabilities:** It represent the set and the type of capabilities/resources made available for the value proposition implementation, by the different actors.		
AT.2.4	**Distribution:** It refers to the distribution of the value configuration activities.		
	Provider	*Co-operation*	*Receiver*
3. PARTNERSHIP			
AT.3.1	**Description:** It identifies the roles and tasks, within a voluntary initiated cooperative agreement among actors, involved in value creation or co-creation, coordinating the necessary capabilities, resources and activities.		
AT.3.2	**Reasoning:** It describes the reason why actors engage partnerships.		
AT.3.3	**Nature:** It is referred to the nature of interaction between the provider and customer of the value proposition, focused on the mode in which transactions are defined between the parties.		
	Transaction-based	*Relation-based*	
AT.3.4	**Degree of integration:** It describes the level of-co-creation of the value created.		
	Transactional	*Co-design*	*Co-operation*	*Integrated supply chains*
AT.3.5	**Degree of dependency:** It defines the level of ease in switching partners. It is strictly related to the degree of integration.		
AT.3.6	**Risk sharing:** It defines the distribution of the risks among the actors involved in the offering.		

Figure 3 Architecture

PROFITABILITY						
Description: This pillar is derived from the rest of the BM framework. It regards how the company is rewarded for the offering proposed. A business model can be effective and successful if and only if it is attractive for all the parties involved, which benefit from its exploitation. It means that the company should notice an observable impact on its performance in terms of increasing of the revenue flows or of cost efficiency, in a direct or an indirect way						
It is broken down in REVENUE STREAMS and COSTS.						
1. REVENUE STREAMS						
AT.1.1	**Description:** It describe how the value proposition is translated into an economical value.					
AT.1.1.4	**Pay-per mechanism:** Is the mechanism through which the provider(s) is paid for its offering.					
	Transaction-based	*Fee*	*Unit-based*	*Availability based*	*Use-based*	*Result-based*
AT.1.1.5	**Revenue parameters:** It represents the variables that influence the revenue creation.					
AT.1.1.6	**Parameters impact:** It represents the influence (negative or positive) of the identified parameters on the potential revenue creation.					
2. COSTS						
AT.2.1	**Description:** It relates to costs, potentially modifiable by the value proposition .					
AT.2.1.3	**Importance:** It represents the relative importance of the cost element for the company.					
AT.2.1.4	**Cost parameters:** It represents the variables which affect the costs modification.					
AT.2.1.5	**Parameters impact:** It represents the intensity (negative or positive) of the identified parameters on the potential cost modification.					

Figure 4 Profitability

Each element of the proposed framework is described in the form of a table and decomposed into further sub-elements. Finally the lowest level sub-elements are described by their attributes (AT). Although the framework proposed in ProRegio project privileges the completeness, the version presented in Figure 2, Figure 3, Figure 4 is adapted by considering the modelling requirements and the availability of information at this phase of the study of ProRegio product-services.

4. ProRegio product-services definition and classification

ProRegio product-services are defined considering the effective frugalization needs observed in the different use cases. They are grounded on the exploitation and sharing of information and knowledge, via manufacturing intelligence technologies, such as: (1) web-cloud technologies, (2) augmented reality tools, (3) digital and virtual factories, (4) knowledge-based applications, (5) analytics and simulation-based tools. Each product-service scenario is characterized by high customer involvement and regional dependency of the offering. The manufacturer plays the role of the product-service provider and the customers (or clusters of them) are the receivers. A list of the proposed product-services is reported in Table 1, while related description in section 4.1.

Table 1 ProRegio product-services

ID	Industrial sector	ProRegio partner	Product-service proposed
1	Aeronautics	Airbus	1. Just-In-Time-Specification/Customization
			2. Visibility of Production Status
			3. Virtual Customer Inspection
2	Domestic appliances	Arcelik	1. Frugal product design/re-design for region dependent markets
3	Machinery industry	Comau	1. Production system design/re-design with virtual tools
			2. Digital Production System Visualization
		Gizelis Robotics	3. Remote maintenance and diagnosis service

4.1. ProRegio product-service: fields of interest and definition

The first set of product-services, ID 1 (Table 1), refers to the aeronautic industry. This sector is characterized by significant demand growth (mainly driven by Asia-pacific markets) which boosts the increase of product variants, especially for single-aisle aircrafts, whose usage span the domain between the economic flights and the VIP/government missions. This comes along with increasing logistic complexity, required by high product customization (with regional characterization), which should be handled while meeting the planned delivery dates. Thus, the main aims in this context are: (i) Quick reaction to changes and reliability of due dates, whose associated uncertainties can be mitigated by active customer interaction and integration in the order fulfillment process; (ii) Flexible production network planning and control for dynamic order assignment and local production (re-)scheduling, based on local capabilities.

- *Just-In-Time-Specification/Customization* (Table 1, 1.1)
  The aircraft manufacturer offers to his customers the possibility of distributing the selection/modification of pre-defined product features, to customers at different points in time. The customer is continuously involved in

the product configuration process, with reference to the assembly of the aircraft. A variant management tool supports the service, with region-dependent level of integration and range/type of product reconfigurations. In addition to the specification requested by the customer (pull approach), the aircraft manufacturer can also offer upselling options, based on the actual production status and the available information from his ERP system (push approach).

- *Visibility of Production Status* (Table 1, 1.2)
  The service provides production progress information during the order fulfilment process, supporting varying customers' needs. It enables customers to track their own orders, check the production status and act (e.g. planning customer inspections) within the order fulfillment process. The customers are able to track the assembly progress and location of their aircrafts as well as the delivery status and, potentially, the location of the components delivered by suppliers. The visibility of the production status helps in reducing waiting time for customers.
- *Virtual Customer Inspection* (Table 1, 1.3)
  This service offers the option of virtual customer inspections with augmented reality (AR) technologies (e.g. tablet PCs, webcams, smart glasses, smart gloves etc.). Alternatively, on-site inspections are offered. The virtual mode is executed by workers, equipped with AR technologies and receiving instructions from the customer. The data of the virtual customer inspections could be stored and analyzed in order to improve product quality, production and logistics. By integrating the customers in the improvement processes, individual preferences can be considered in advance, resulting in less re-work.

The second set of product-services, ID 2 (Table 1), is related to domestic appliances industry which is characterized by fluctuating demand and increasing strong positioning in emerging markets. The possibility of offering regionalization, with frugalized product design, interferes with increasing importance of the production network efficiency. This use case, mainly focused on white goods, aims at integrating the product design with the production network operability, accommodating and including different market segments' feedback.

- *Frugal product design/re-design for region dependent markets* (Table 1, 2.1)
  This service enables the adaptation of key product design/re-design to specific regional markets. It is based on pre-purchase virtual product experience offered directly to the end-customers or with the intermediation of retailers. Dedicated tools with appropriate GUI (Graphical User Interfaces) support the acquisition and analysis of the relevant region-dependent marketing and technical information. The identification and clustering of these factors have, in turn, impacts on the classification, selection, monitoring and grouping of suppliers. Moreover, the identification of specific patterns inside customers' clusters permits the manufacturer to proactively propose design targeted solutions.

The third set of product-services, ID 3 (Table 1), is related to machinery industry, whose automation trends are actually characterized by high flexibility of the production systems, but at the same time by effectiveness of (new) technology costs, low environmental impact and lean manufacturing concepts. Moreover, manufacturing systems productivity and quality targets compliance could also be achieved by effective maintenance planning and implementation, supported by advanced technologies. Depending on the different regions, these dimensions can assume diverse importance. This asks for customer-driven design of manufacturing systems with region-dependent features and related support services. The main objective is to "do it the first time right".

- *Production system design/re-design with virtual tools* (Table 1, 3.1)
  The product-service consists in a proactive production system design, by proposing possible technical solutions that already embody the intrinsic preferences of specific clusters of customers/markets, avoiding generating solutions from scratch. The manufacturer identifies regional-dependent or market-segment-dependent distinctive features. Starting from a cluster-driven standardized design and adding the requirements coming from RFQ (request for quotations), customized designs can be achieved. A knowledge-based production system design tool, accessible by the manufacturer, receives the customer information and feedback (provided through customized GUI). A list of feasible solutions is generated, and then evaluated in order to finalize the best solution.
- *Digital Production System Visualization* (Table 1, 3.2)
  In this product-service the production system manufacturer makes available to his clients a sort of virtual production system configurator GUI, accessible with credentials and pre-defined grants, according to the type of customer. Within the digital environment, the customer can "walk-through", drag and drop components and see the animations, and thus be involved in the production system design definition.
- *Remote maintenance and diagnosis service* (Table 1, 3.3)
  Remote maintenance and diagnosis service is provided from remote maintenance centers to the production site that faces technical difficulties. By using ICT data gathering and transmission systems, linked with audio-visual systems and appropriate AR tools, on-site repair crew gets active and passive assistance from the central maintenance experts for performing maintenance operations.

4.2. Frugal-oriented product-service classification

In this section, a simplified classification map is proposed, allowing a general characterization of ProRegio product-service scenarios using four relevant dimensions. Three dimensions are chosen from the attributes of the building blocks in the framework reported in Section 3. The fourth dimension indicates the frugalization focus of the product-services. The first dimension relates to the *life-cycle positioning* of a product-service, i.e. the phase in which the associated value is created. This dimension can be BOL (a), i.e. beginning of life, MOL (b), i.e. middle of life and EOL (c), i.e. end of life. In the first case, the value delivered to the customers emerged mainly in the design and engineering of the solution, while in the MOL and EOL cases, respectively in

the usage and in the disposal. The second dimension focuses on the product-service *offering orientation* proposed in [8]. It consists of three main categories, i.e.: product-oriented (a), use-oriented (b) and result-oriented (c). In the product-oriented solution, services are provided as add-ons, while in the use-oriented solution products and services are intertwined. In the result-oriented solution, the focus is on functional results, rather than on the product-service offering itself. This dimension impacts on the design and management of production sites and networks. The third dimension outlines the *nature of interaction* between product-service provider and receiver. According to [15] and [16], two classes can be recognized: transaction-based (a) and relation-based (b). The transaction-based interactions assume usage or mark-up price settings, while relation-based pricing relies on time or other jointly achieved performance. In both cases, this dimension embeds the associated risks for both the receiver and the provider. The fourth dimension considers the frugalization focus of the product-service, i.e. which is the main subject of the adaptation to the different market requirements. Therefore, the *frugalization levels* refers to product offering (a) and service (b).

Table 2 Classification of ProRegio product-services

ProRegio PSS	Life-cycle	Orientation	Nature	Frugal. level
1.1 Just-In-Time-Specification/Customization	(a)	(a)	(b)	(a)
1.2 Visibility of Production Status	(a)	(a)	(b)	(a)
1.3 Virtual Customer Inspection	(a)	(a)	(b)	(a)
2.1 Frugal product design/re-design for region dependent markets	(a), (b)	(a)	(b)	(a)
3.1 Production system design/re-design with virtual tools	(a)	(a)	(b)	(a)
3.2 Digital Production System Visualization	(a)	(a)	(b)	(a)
3.3 Remote maintenance and diagnosis service	(a), (b)	(a)	(b)	(a)

The preliminary mapping (Table 2) shows that all of the product-services proposals are product-oriented. The nature of interactions between the provider and the customer remains in the relation-based domain, with slight variation of intensity (e.g. 1.1 is highly relation-based, while 3.1 is less relation-based). Moreover, all the proposed product-services support frugalization of the products, rather than the associated service, even if it could be considered a subsequent evolution, once established enabling technologies and having gained sufficient knowledge on regional markets' service preferences. Finally, although the majority of the proposed solutions focus on the BOL, 2.1 and 3.3 provide value for their target customers also in the usage phase, because these product-services can continue even after the effective transfer of the product to the customer.

4.3. Focus on: Just-In-Time-Specification/Customization

The context of this service (see Figure 5) focuses on Mass Customization solutions in assemble-to-order production environment, i.e., in the final assembly of the single-aisle aircraft. It is offered to airlines and leasing companies, which are considered as target customers. The customers' requests influence the customization of the aircraft and the subsequent allocation of the orders within the production network. Low-cost carriers are characterized by less inflight entertainment and more seats, while network carriers have more inflight entertainment and great variety in cabin layout. The guided process of differentiation (as described in section 4.1) promotes the creation of long-term partnership with customers, especially in the mid-low segment in which the fragmentation of the competitive context is higher.

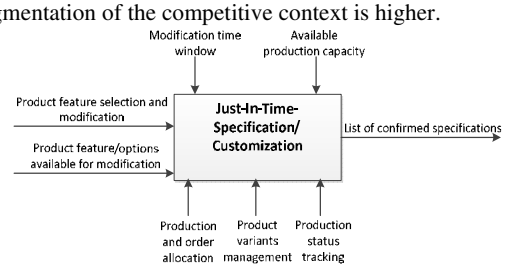

Figure 5 Just-In-Time-Specification/Customization - IDEF0

The relevant elements of this product-service are summarized considering the framework presented in section 3. Stakeholder benefits and SWOT analysis are reported in (Table 3, Table 4 and Table 5). These tables are extracted from *Value Proposition*, while roles and tasks in Table 6 present the main aspects of established partnerships, belonging to *Architecture* building block. Besides, associated risks and opportunities are presented in Table 7.

Benefits. The motivation for engaging in a partnership within the context of this product-service value creation is settled for both provider (1) and the receiver (2) of the offering, respectively in Table 3 and Table 4.

Table 3 Identified benefits for the product-service provider

Benefits for (1)
• Potential reduction of additional costs caused by late changes. • Possibility for upselling. Enhanced configuration items can be offered to customers depending on availability of production resources and product parts/components. • Late decision package. Impacts on the production network and order allocation, changing dynamically from longer lead time site to shorter lead time site. • Better production planning accuracy at plant and network level (less re-planning), using both shop floors information and customer information /feedback.

Table 4 Identified benefits for the product-service receiver

Benefits for (2)
• High customization and possibility of product re-configuration, hence, less risk of taking wrong decisions. • Guided customization during the order fulfilment process, which ensures higher control and guarantees that the actual modifications are as close as to the desired ones. • Reduced cost and effort for late change requests. Information, risk sharing and collaborative planning of the customization process lowers the associated total costs. • Reduced delayed deliveries due to late changes. This service enables the decrease of unexpected changes, allowing advance consideration for capacity and production planning ahead. • Customers could potentially choose to purchase "late decision package". The availability of late decision package ensures customer capability to react against unexpected market and external changes.

The SWOT analysis is reported in Table 5: to each entry a score is associated, according to the respective impact (1=low; 5=high).

Table 5 Product-service SWOT analysis

Strengths	Weaknesses
• Customer satisfaction (4) • On-Time Delivery (4) • Quality (3)	• Information flow (2).

Opportunities	Threats
• Long-term relationship (4) • Higher production rates (5) • Cost reduction (4)	• IT Hardware (1) • Data handling and evaluation (3) • Master new technologies (2)

Roles and tasks. In the product-service proposition roles and tasks are defined for the manufacturer (1) and the customer (2), as reported in Table 6.

Table 6 Roles and tasks

Role	Tasks
(1)	• Guaranteeing distributed region dependent options selection for customizing the product. • Set up and maintain necessary ICT and other infrastructure tools. • Processing and analysing data, with synergies with the other possible services, for increasing customization and reducing disturbances.
(2)	• Interacting actively within the project of the aircraft. • Provide feedback about products and needs. • Successively specify the product features just-in-time as required for further processing.

Risks and opportunities. In the context of this service both the manufacturer (1) and the customer (2) bear some risks. In Table 7, a summarized list of the risks is presented.

Table 7 Risks associated to the product-service

Role	Risks
(1)	• Set up ICT architecture for enabling the provision of the service. • The information flows, data handling and processing, as well as the access rights to the different software suites defined.
(2)	• The ownership of the product remains to the customer. • The customer late selection/modification is enclosed within the boundaries established by the service.

5. Conclusions

In this paper a formalized framework for describing product-service business models in the context of frugal innovation is proposed. ProRegio solutions are briefly presented, followed by a focus on the Just-In-Time-Specification/Customization product-service, which allows to manage efficiently demand of customized product variants. Additionally, a classification is provided, according to four selected dimensions. Future works can address: (i) further analysis, focused on product-services' enabling technologies; (ii) in-depth application of the proposed formalized frameworks to other cases in the context of frugal innovation.

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