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A sustainability-oriented tool for evaluating servitization business models in the steel sector

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Abstract

The need of undertaking effective actions against the climate change is pushing industrial companies to find new business models and technological solutions to reduce the resource utilization and the waste production. In this context, several companies are moving towards servitization, that has been proved as a promising strategy to enable sustainable business models in a wide spectrum, namely encompassing environmental, economic and social aspects. Nevertheless, companies lacks of tools for evaluating different servitization models with a clear view of economic and environmental benefits. This paper presents a model to estimate the profitability of servitization opportunities by combining economic Net Present Value index and environmental impacts estimation. The model is targeted on the steel sector, for which a preliminary application has been developed and is discussed in the paper. The results show that adopting different servitization business models, several benefits could be exploited both from providers and customers.

Keywords: Servitization; Sustainaibility; Business model evaluation; NPV; Steel.

1. Introduction

Nowadays, servitization represents a well-established concept, but it is still receiving growing attention and interest from both industry and academia [1]. Indeed, global trends that are affecting the industrial markets, such as

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digitalization and environmental impacts reduction, are profoundly changing how companies develop and offer services. In this context, the concept of Digital Servitization [2] and Green Servitization [3] emerged, to depict the interdependences among new technologies and sustainable paradigms in the servitization field.

In particular, recently, scholars researched the potential of servitization to increase the sustainability of industrial processes and supply chains, by boosting a resource-efficiency and circular economy perspective [4]. Several studies have presented encouraging findings that support the notion that servitization contributes to the maintenance, upgrading, and re-manufacturing of products, thereby extending their lifespan and reducing product turnover, thus offering companies incentives by enhancing their value-creation capabilities through the elongation of the product life cycle and mitigating the ecological impact of product usage [5]. Servitization has also a strong link to the circular business models that encompass the recycling and reuse of goods, since recent studies confirmed the positive effects of servitization to promote circular economy, considering that recycled components can be used in the same or other supply chains [6]. Transforming the old take-make-use-dispose system into a take-make-use-redesign-reuse business model by providing product as a service can support companies in achieving more circular production-consumption systems [7].

Nevertheless, the transition towards servitization is still very challenging for companies, since the evaluation of servitized business models is a crucial step in the strategic planning perspective [8]. For this reason, in literature, models to assess different product-service solutions (PSS) in the early design phases have been provided, taking into account the providers and customers' perspectives [9]. Multi-criteria evaluation techniques have been widely used, even if they often require a huge quantity of information related to costs, markets and processes [10]. Furthermore, despite the existence of various proposed methodologies, they fail to offer a comprehensive perspective on sustainability. Specifically, the incorporation of sustainability criteria and Key Performance Indicators (KPIs) within the assessment of diverse servitized business models has the potential to effectively facilitate a transition towards servitization while considering the three fundamental dimensions of sustainability: economic, environmental, and social [11]. Consequently, this integration enables servitization to genuinely contribute to the advancement of a more sustainable industrial landscape and society at large. Finally, it is worth highlighting that sustainability has become a prominent concern, particularly within industries characterized by high energy consumption or resource utilization. These sectors often lack familiarity with the concept of servitization, thereby encountering challenges in identifying the most suitable business models and finally this hinders companies from embarking on the servitization path, which, if pursued, could prove advantageous in simultaneously attaining improved economic and environmental objectives.

Therefore, to cover this gap in the academic literature and support companies facing the transition towards more sustainable and servitized business models, this paper presents a method to evaluate different servitization scenarios using the joint financial evaluation through the calculation of the Net Present Value (NPV), together with a qualitative assessment of sustainability indicators. The model consists in a first conceptualization and it has been applied in a demonstrative case in the steel sector. Indeed, the model has been validated with industrial stakeholders in the steel value chain to support the identification of servitized models that could replace the traditional sale of industrial equipment currently used in the steelmaking.

The paper is structured as follows. Section 2 highlights the links of servitization and sustainability and discusses the most interesting evaluation criteria to consider. Section 3 presents the formulation of the model developed to evaluate servitization scenarios in the light of both economic and environmental assessment. The application of the model to the steel sector is presented in Section 4, where different scenarios are tested. Finally, Section 5 discusses the main outcomes of the research, focusing on the limitations of the study and the further research avenues.

2. Background

2.1. Servitization and sustainability

Servitization and sustainability are two interconnected concepts that are shaping the future of businesses and industries. Servitization is the process through which product-focused companies, typically manufacturers, expand their offerings beyond the core product by incorporating ancillary service offerings or transforming their product offerings into service-based solutions [12]. The level of service sophistication depends on factors like risk, competition, and potential for gaining competitive advantages. Services can be categorized into three types: base services (e.g., warranties, spare parts), intermediate services (such as maintenance and repair), and advanced services, which involve providing performance outcomes to customers, offering complex value propositions and enabling customers to achieve desired outcomes without owning the product itself [1]. To undertake the servitization journey, companies are required to develop new servitized business models, targeting value propositions based on customers' needs and segments, identifying key partners and pointing out novel long-term contractual agreements[13].

Recently, scholars focused on the need to approach sustainable product-service systems business models, in order to take into account benefits related to the environmental as well as the social sustainability dimensions [11]. Indeed, the shift towards servitization fosters sustainability by minimizing environmental impact, enhancing resource efficiency, and promoting a more holistic approach to meeting customer needs while considering the long-term viability of products and services [5]. Moreover, the servitization paradigm fits well the circular economy approach, since offering additional services associated with reuse and recycling materials and components is a practical and necessary step in implementing the key principles of a circular economy [14]. By offering services instead of just products, companies can extend the lifespan of their offerings through maintenance, repairs, and upgrades, promoting a more circular approach. This reduces the consumption of raw materials, minimizes waste generation, and maximizes the utilization of existing resources. Servitized business models, in combination with the principles of the circular economy, encourage the reuse, remanufacturing, and recycling of products, ultimately contributing to a more sustainable and resilient economy. Several industrial cases of companies belonging to the machinery sector or plant manufacturers have been discussed in the servitization literature, and these companies have experimented with servitized business models to offer their customers a range of additional services, including leveraging digital technologies, that can increase the productivity of their products [2]. In a push for servitization, it is also possible to find cases where products/facilities are subject to outcome-based models [15]. In the machinery sector, there are very promising prospects for circularity. In fact, the adoption of use-oriented or result-oriented business models, in Tukker's sense [16], can grant the provider new opportunities related to the end-of-life of its products. If, in fact, through traditional sales, the manufacturer loses visibility over the disposal phase of its products, in the event that they remain its property, albeit transferred for use to the customer through a medium- to long-term contract, the manufacturer can trigger a mechanism of circular reuse of its products, whether in whole or through the disassembly and reuse of some components.

One of the pivotal steps in this process involves the crucial task of determining the most appropriate service model to adopt. This decision must carefully consider the customers' needs and requirements, taking into account both the anticipated value and economic feasibility in comparison to the traditional sales approach. From the provider's standpoint, the primary focus should lie in assessing various service models, considering the broader perspective of sustainability. This assessment should encompass the evaluation of the economic, social, and environmental benefits that can be derived from servitization. Consequently, it becomes imperative to employ comprehensive yet straightforward tools that can equip providers with effective indicators for evaluating diverse service scenarios based on the most relevant evaluation criteria. The subsequent sub-section will delve into the discussion of evaluation methods and criteria.

2.2. Evaluation methods and criteria

Evaluation is a crucial step in service and PSS design and implementation [17]. Evaluating services and Product-Service Systems (PSS) and assessing different alternatives involves considering various criteria to determine their effectiveness, efficiency, and overall value to customers and stakeholders. The criteria for evaluation may vary depending on the specific context and industry and, since a decade, several studies proposing multi-criteria evaluation schemes and methods have published [18]. Evaluation criteria are often divided in two categories, specifically assessing the twofold perspectives of customers and providers [17]. In the work of Mourtzis et al. [19] a first match between different evaluation approaches and criteria is proposed.

Given the growing interest in the topic of sustainability, only recently scholars have focused on integrating sustainability-related criteria for designing and evaluating services and product-services whose value to the customer also consists of minimizing the environmental and social impacts of the product-service itself. In [20], a multi-criteria decision making model is presented to select PSS concepts by considering sustainability as one of the attributes of a design contributing to the overall value of a solution. Similarly, Song et al. [21] propose a rough TOPSIS method embedding environmental, economic and social criteria in the evaluation of PSS, while Chen et al. [22] adopt a fuzzy method to consider uncertainty as well. Mapping the literature on the topic, Nakada et al. [17] identify the subdimensions of economic, environmental and society sustainability that are needed to be integrated into evaluation methods according to the provider perspective. According to an industrial experts' interview, however, the economic and environmental criteria are the most relevant [23].

Indeed, reviewing the literature, it becomes clear that there is a demonstrated need to integrate the assessment of sustainability impacts to support the service and product-service development and implementation. However, although there are several methods for doing service design with sustainability criteria under consideration, few methods have been proposed to support the selection phase among several possible service alternatives [24]. The work of Xing et al. [25] is the only one that embed a synthetic economic evaluation method, the Net Present Value calculation, with an assessment of the environmental impacts through lifecycle cost. Despite the NPV, indeed, is a well-known and widely implemented approach for companies to assess investments, the model of Xing et al. presents a very complex evaluation of the environmental scenario, requiring detailed data that are not always available to companies in the early phase of new servitized business models assessment. Conversely, a simple multi-dimensional assessment of macro sustainability pillars is presented in [26], based on the qualitative and weighted evaluation of the following environmental dimensions: System life optimization, Transportation/distribution reduction, Resource reduction, Waste minimization/valorization, Conservation/biocompatibility, Toxicity reduction.

Merging the advantages of the methods proposed in [25] and [26], therefore, a joint approach that consider the NPV as the major economic indicator and the qualitative evaluation of environmental criteria has been deemed as a powerful but still simple tool to be applied in industry for selecting among different servitization scenarios the most suitable ones. In the following, the detailed model description is presented and applied to a case in the steel industry.

3. Model description

The developed model has the purpose of evaluating servitization scenarios, both from the point of view of environmental and economic sustainability. In this first conceptualization, the intention was to understand which were the endogenous and exogenous variables, how they were related to each other, and then to obtain a model capable of comparing different scenarios. For this reason, with the aim of providing a ready-to-use tool for steel companies, a simple model for calculation was developed in Microsoft Excel. This tool is able to support sales managers in negotiating different service offering scenarios, based on a limited set of input variables, as explained in the following. In a second phase, a future work could consist of refining the model, in particular through the use of simulation software capable of handling the stochasticity of several variables simultaneously, so that a wide variety of scenarios can be analysed. Overall, the model should help service providers in the steel sector when negotiating with customers, to support them in comparing different servitization scenarios in economic and environmental terms, in order to understand the best conditions. The evaluation will therefore begin after scenarios definition.

3.1. Economic assessment

For the economic evaluation of servitization scenarios, especially when it concerns pay-per-unit use or functional result models, which were considered by Tukker [16] to be the most promising from the environmental sustainability point of view, it is simpler to refer all costs (OPEX costs) to the provision of a unitary service. Starting from this, a target demand volume is then defined, based on the quantities the customer is expected to need. Afterwards, a margin is chosen in order to be able to transform the unit service cost in a unit service price.

At this stage, knowing the initial investment (CAPEX costs), the discount rate and the tax rate of the specific case, it is possible to calculate the cash inflow. Thereafter, the number of contract years is established, in order to assess the economic viability of the servitization scenario through the calculation of the net present value (NPV) index. Fig.1. shows the model flowchart distinguishing decision variables from given variables. The NPV is defined as the discounted value given by the sum of the future net cash flows expected from the investment [27]. If the NPV is positive, the project is expected to generate more cash inflows than costs, thus resulting in a financially favourable investment. The NPV is calculated since we are referring mainly to services that are related to machines or equipment that requires an investment to be produced.

Other negotiation components were then included in the calculation: there are indeed some variables that are highly significant during the contractual definition phase. The first one is the volume actually requested by the customer: the model returns a NPV value that heavily depend on how much the customer actually uses the service. It is therefore necessary for the provider to 'protect' itself in the event that the customer requests the service less frequently than expected. Less demanded volume in fact leads to a lower cash inflow, and consequently to a worsening in terms of NPV. Therefore, there will be an expected NPV, i.e., linked to the target volume that was set, and an actual NPV, dependent on the actual volume required by the client. Another important variable for the model is whether the customer decides to withdraw early from the contract. Depending on the specific case to which the model is applied, there will be an expected life of the machines and the model will be calibrated accordingly with a contractual length. NPV is calculated on the basis of this time agreed between the two parties at the contractual stage. In the event, however, that the customer decides to terminate the agreement and withdraw early, the gain from the provider point of view would be less than expected. The provider, once again, needs to 'protect' itself from this eventuality.

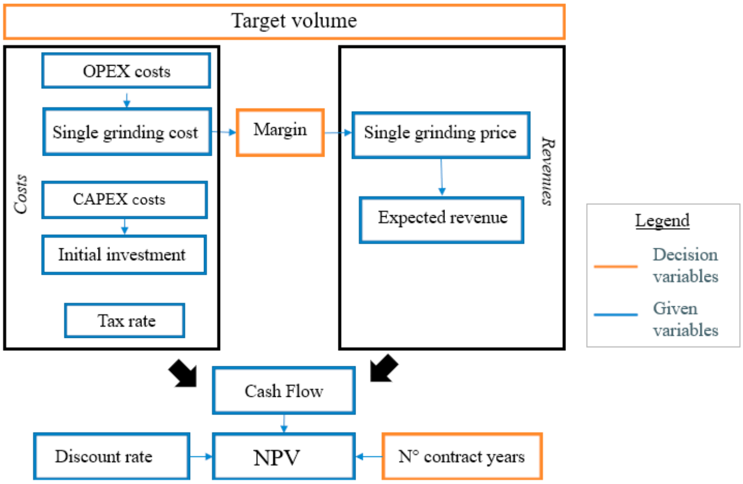

Fig. 1. Model flowchart.

An additional aspect to consider in the economic assessment is that the profit that a company obtain from the implementation of a servitization model is not only attributable to the NPV. In fact, at the end of the contract term, the provider find itself with the ownership of the machines that have been used up to that moment by the customer. There is thus a value associated with the remaining useful life of the asset that has been servitized. It was therefore decided to also include within the model a rough calculation of the residual value of the assets at the end of the contractual term. Taking all these variables into account, it is then possible to evaluate and compare different servitization scenarios, determining the cost-effectiveness of each on the basis of the resulting NPV value.

3.2. Environmental assessment

Since there is limited availability of data at the early design stage of a PSS, it often becomes difficult to conduct the assessment of servitization scenarios. Especially environmental assessment is often complicated: while for economic part, the cost items are usually more accessible and the revenue items can be assumed by composing different scenarios, for the environmental point of view this approach becomes impossible without knowing in detail data such as consumption, emission, or waste. For this reason, this paper adopts a more qualitative method than the one presented for the economic part.

It was decided to start from Doualle et al. [26], since, although applied to a different scope, sustainability assessment in PSS was also carried out in that work to support decision making during the early design phase. This method was then adapted according to the specific case. In addition to the environmental criteria of sustainability proposed by Doualle et al., "reuse of components" was also added, since, looking at the environmental sustainability criteria already present and bearing in mind the three basic principles of the circular economy, i.e. reuse, reduce and recycle [28], it seemed useful to also add a criterion that met the definition of reuse, as reduce and recycle were already represented among the other criteria. The final set of environmental sustainability criteria is composed by: System life optimisation, Transportation/ distribution reduction, Resource reduction, Waste minimisation/valorisation, Conservation/biocompatibility, Toxicity reduction, Reuse of components.

The proposed method is then to have the different sustainability criteria assessed by experts in the field, assigning each of them a different weight, depending on their importance in the specific case. The evaluation of the criteria must be done according to the different scenarios to be assessed: each scenario will see improvements in some of the criteria and worsening in others. From the obtained data, it will be possible to define, qualitatively, which of the scenarios is most promising in terms of environmental sustainability.

4. Case application

The proposed model was validated through a case study in which it was necessary to assess the economic and environmental sustainability of different servitized business models options. The company involved is an Italian multinational company leader in the design, high precision machining and assembly of equipment within the steel sector. Among the technology portfolio of the company, the focus for the purposes of this model is on roll grinding machines, that are used for restoring rolling cylinders to optimal conditions following the wear and tear they undergo during the rolling operations. The company currently operates with a classical transactional sale, according to which it supplies equipment to the customer and receives a payment linked to the value of the asset. All operational, labour and maintenance costs are currently borne by the customer.

The purpose of this study was to evaluate three diverse scenarios, characterized by different revenue models that could be proposed to the customer when providing the grinding machines: (1) traditional sale of the machines (currently adopted); (2) a pay-per-use model characterized by the payment from the customer of an initial fee and periodic rates connected to the actual request of grinded cylinders, over a contractual period of 10 years; (3) a pay-per-use model characterized by the payment from the customer of periodic rates connected to the actual request of grinded cylinders, with a possible transfer of the machine from one customer to another at the end of the 10 year contract, thus exploiting the machinery to the maximum.

The company was interested in assessing how the shift between one business scenario to the other would affect economic revenues and how it would affect the environmental impact during the life cycle of the machines.

4.1 Model application*: economic assessment*

Since the evidences coming from the company are protected by non-disclosure agreements, the data used for the purpose of this paper and presented in Table 1, are similar to the real data but not identical.

Table 1. Production data and fixed/variable costs.

Data	Amount	Unit of measure	Costs	Euro/year	Euro/cylinder
Target volume	30.000	cylinders/year	Operating costs	500.000,00 €	16,67 €
Required number of machines	3		Labour costs	350.000,00 €	11,67 €
Production cost for 1 machine	2.200.000	Euro	Maintenance costs	300.000,00 €	10,00 €
Sell price for 1 machine	3.000.000	Euro			
Installation cost	50.000	Euro			
Disposal cost	100.000	Euro			
Interest rate	8%				
Tax rate	40%				

Variable costs were also expressed in Table 1 as a function of unit of service delivery, i.e., in Euros per grinded cylinder in this case. This is useful to calculate variable costs in the event that the customer requires a volume different from the target. The number of machines required may also change depending on the volume requested by the customer. However, it is not expected to have such relevant variability. This value will therefore be considered to be fixed for this study. Once the main data have been defined, the work begins with the economic analysis of the three scenarios to be evaluated.

Regarding the first scenario, pertaining to a direct sale, NPV lacks significance due to the absence of costs or revenues from the provider's perspective over the years. Instead, there are only an investment cost, corresponding to the production costs of the machines, and a revenue derived from the sale of the machines, both occurring at year zero. The installation and the disposal costs are charged to the customer. In this specific case, therefore, the provider company spends €6,600,000 and earns €9,000,000, for a total gain of €2,400,000. This value is therefore the benchmark against which scenario 2 and 3 can be assessed. If the NPV does not in fact reach this minimum value, servitization will be considered economically unprofitable compared to traditional sales in this specific case.

Similarly to the previous case, the initial investment for scenario 2 is related to the cost of producing the machines, to which €50,000 of installation cost is added. There will then be a further fixed cost to be borne at the end of the contract of €100,000 due to the disposal of the machines. The variable costs, on the other hand, depend on the volume of grinded cylinders requested by the customer. It will be assumed that the customer requires the accorded target volume of cylinders, i.e. 30,000 cylinders per year consistently over the 10-year contract term. As far as revenue is concerned, the scenario envisages the payment of an initial fee, which will be expressed as a percentage of the production cost of the machines, and periodic rates, which will be expressed as a percentage of the variable cost.

Considering a depreciation rate spread over 10 years and taxes, it is possible to calculate the NPV, although this value depends on the percentages chosen as margins to define the initial fee and the periodic rates to be paid by the customer. For this reason, it was decided to iteratively search for these percentage values in order to obtain a NPV close to the 2.400.000€ of scenario 1. Table 2 shows two scenarios that equal scenario 1 in terms of cost-effectiveness.

Table 2. Two cases in scenario 2

Case	Residual value of the machines	Initial fee (% margin on production cost)	Initial fee (euro)	Periodic rates (% margin on variable cost)	Periodic rates (euro)	NPV
With residual value	1.528.538,51 €	50%	3.300.000€	55%	1.782.500€	935.038,19€
Without residual value	Not considered	55%	3.630.000€	80%	2.070.000€	2.422.527,24€

It should be noted that the first scenario, although resulting in a lower NPV, also considers the residual value of the machines. This is because, in this case, the machines have a useful life of 20 years, but the contract only provides for their use for 10 years. For this reason, the provider at the end of the contract would end up with an asset that still has a value. If it is believed that this value can be exploited, perhaps by reselling the machine as second-hand, the residual value of the asset must also be considered.

In the absence of accurate data, it was decided to consider a depreciation of the machines of 5% each year. Thus, considering the depreciation rate, at the end of 10 years the three machines will be worth 1.528.538,51€. Adding therefore the NPV of 935.038,19€ to the 1.528.38,51€ residual value, we obtain a total value at the end of 10 years of 2.463.576,70€, similar to the gain in scenario 1. This means that when concluding the contract with the customer, in order to obtain a profitable deal, the margin percentages should not fall below the values defined in Table 2. Using the proposed model, it is then very easy, if needed, to change the volumes requested by the customer from year to year or to assume scenarios in which the customer decides to withdraw from the contract before the set date. In these cases, a different NPV value than expected will be obtained. This information can be used to make strategic decisions.

The third scenario is very similar to the second, as it involves the same revenue model. The initial investment is also the same. The main difference is that the machines, at the end of 10 years, are moved from one plant to another. For this reason, there will be disposal and reinstallation costs at year 10, and then the final disposal at year 20. In this case, considering a depreciation of 5% per year, there is no residual value in the machines at year 20. Of course, in the case of early termination by the customer, the residual value should be considered instead. To equalise the value of scenario 1, scenario 3 (Table 3) needs margin percentages very close to scenario 2, showing that, when considering the residual value of the machines, there are in fact no major differences between the last two solutions in terms of cost-effectiveness. In conclusion, it can be stated that by applying an initial fee of more than 3.300.000€ and periodic rates higher than 1.840.000€, scenario 3 brings more economic value than scenario 1.

Table 3. Scenario 3

Case	Initial fee (% margin on production cost)	Initial fee (euro)	Periodic rates (% margin on variable cost)	Periodic rates (euro)	NPV
Scenario 3	50%	3.300.000€	60%	1.840.000€	2.577.698,42€

4.3 Model application: environmental assessment

The environmental analysis started with an interview with experts in the steel sector, in which different levels of importance for the proposed criteria emerged. It was therefore decided to assign a qualitative weight to each criterion related to the relevance both from the provider and the customer point of view. The rating adopted is from 1 to 3, meaning low importance (1), medium importance (2) and high importance (3). Results are reported in Table 4.

Table 4. Environmental sustainability criteria weighted from the provider and the customer point of view.

Environmental sustainability criteria	Provider	Customer
System life optimisation	1	1
Transportation/ distribution reduction	2	1
Resource reduction	3	3
Waste minimisation/valorisation	3	3
Conservation/biocompatibility	1	1
Toxicity reduction	3	3
Reuse of components	2	2

Afterwards, two experts working in the provider company rated each of the 3 scenarios according to the environmental sustainability criteria with a grade from 0 to 3, where 0 meant no performance of the scenario with regard to that criterion and 3 very high performance.

The grades, weighted according to the values in Table 4, are summarised in Table 5.

Table 5. Scenario rated on the sustainability criteria and weighted.

Environmental sustainability criteria	Scenario 1		Scenario 2		Scenario 3	
	Provider	Customer	Provider	Customer	Provider	Customer
System life optimisation	0	1	2	0	3	0
Transportation/ distribution reduction	4	3	4	3	2	3
Resource reduction	9	3	3	9	3	9
Waste minimisation/valorisation	9	3	6	9	6	9
Conservation/biocompatibility	3	3	3	3	3	3
Toxicity reduction	9	9	9	9	9	9
Reuse of components	0	0	0	0	4	0
TOTAL	34	22	27	33	30	33

By summing up the values for the same scenario and normalising them to a scale from 0 to 3, it is possible to derive a qualitative environmental sustainability index to be attributed to each of them. The results are shown in Table 6.

Table 6. Environmental sustainability results.

	Scenario 1	Scenario 2	Scenario 3
Total	56	60	63
Total normalized	1,92	2,08	2,18

Having a higher overall score, it can be established that scenario 3 is the most promising from the point of view of environmental sustainability. Even if this result was quite predictable, as the scenario was designed precisely to bring maximum reuse and recycle of machines, the model offers an objective evaluation targeted on sustainability criteria. Furthermore, scenario 1, characterised by traditional sales, is the least environmentally sustainable.

5. Discussion and conclusions

The presented model allows the evaluation of different servitization scenarios characterised by different revenue models, required volumes, termination date, and other variables such as the transport of machines to other plants.

In particular, it is intended to help companies seeking to evaluate servitization opportunities in understanding whether a servitization scenario is more competitive than another in terms of economic and environmental sustainability. Indeed, the model allows to design a servitized business model, tuning the economic variables involved in the negotiation with customers, in the light of the level of environmental impact of each scenario under consideration.

As it has emerged throughout the article, two of the main contingencies that can most influence the economic viability of different solutions are the volume of service units actually requested by the customer and the actual contractual duration. If either of these two values prove to be lower than expected, also the NPV will be lower than expected. One strategy that the provider could use in order not to lose from the occurrence of one of these eventualities could be to demand the payment of a fee corresponding to the difference between expected NPV and actual NPV, i.e., that associated with the client's premature withdrawal or to a lower volume compared to the one expected.

The proposed model is also capable of assessing additional scenarios characterised by the payment of these penalties fee by the customer, in which the provider can assess how the final NPV varies as the penalties fee vary. The model can therefore also be of support in defining the right amount of the fee to be charged to the customer.

Still considering economic viability, while scenarios 2 and 3 were expected to be more cost-effective than scenario 1, a surprising result was the similar cost-effectiveness of scenarios 2 and 3. In fact, scenario 3 was expected to be much more economically viable by maximising the useful life of the machines. The reason probably lies in the fact that, for the firsts 10 years in which there is the asset depreciation due to the purchase of the machines, the taxes from the provider point of view, being assessed on the basis of revenues minus costs minus depreciation of the asset, are much lower. Combining this with the depreciation rate, which reduces the value of money more and more over the years, it can be noticed that the gain across the last years of the contract (from year 11 to year 20) is actually very low.

This opens up further scenarios that could be evaluated that would contemplate a higher initial fee to be charged to the customer using the machines from year 11 to year 20. Indeed, the model allows this value to be modified as well and its cost-effectiveness to be evaluated.

As far as limitations are concerned, a future refinement of the model could concern maintenance costs, which appear to be constant even though they should probably become more burdensome as the years pass.

Revenues were also considered to be known and constant over the years, although this would certainly not be the case. As mentioned, the model provides for the possibility of including this variability. However, a probabilistic function that returns variable revenues from year to year must be studied in future research and incorporated into the model in order to consider this peculiarity.

With regard to the environmental part, on the other hand, the scenarios have so far only been submitted to two experts, so it is clearly necessary to make the assessment more consistent through the evaluation of other experts in the field, both on the provider and customer side. Furthermore, the proposed evaluation method is very biased by the type of criteria chosen in the first place (Table 4). A much more in-depth study of the criteria must therefore be conducted in order to be sure of the output results.

Finally, it should be noted that the proposed model is not able to provide a single indicator to define the best scenario from both economic and environmental point of views, while it is suitable for separate comparison based on either perspective. Further research could concern the definition of a single indicator capable to compare the different servitization scenarios from both the angles considered in this research, with also the possible future inclusion of social aspects in order to cover all three dimensions of sustainability in the assessment.

In conclusion, taking into account the possible implications on the digital servitization matter [2], it should be noted that the proposed model could represent a data-driven decision making tool, useful for service providers to negotiate with customers effectively and understand the economic and environmental implications of various servitization scenarios. As the model evolves and incorporates more data and expert insights, it will become even more powerful in supporting sustainable business decisions, allowing deep personalization and continuous improvement through the evaluation of the collected information.

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