Towards sustainability in the steel sector: identifying criteria for assessing early design servitization opportunities

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Abstract: Steel is one of the materials most present in people's lives, with many and various applications, such as buildings, infrastructure, transport, machinery and consumer goods. However, steel production is a highly energy-intensive industrial activity, which makes the steel sector one of the most closely watched in this period of great attention to sustainability issues. Despite several measures can be implemented to limit industrial processes' impacts on sustainability, many authors pointed out that the shift from selling products to providing services could be a successful choice to incentivize companies to adopt more sustainable business models and operations. Since the steel industry is still quite backward in terms of servitization, the objective of this paper is to boost the adoption of sustainable servitized business models, by identifying a set of evaluation criteria for servitization opportunities in the early design phase within this sector. The investigated criteria are expected to be able to feed several methods to assess all the sustainability performance of a servitized business model, according to the triple bottom line definition, thus taking into account the economic, environmental and social dimensions of sustainability. A systematic literature review was conducted, followed by expert interviews with specialists in the steel industry. The review identified 51 distinct criteria from the literature, which were categorized based on provider and customer perspectives, as well as the three dimensions of sustainability according to the triple bottom line definition. The expert interviews validated and rated the criteria set, revealing the significance of economic ones from both customer and provider perspectives. The findings provide guidance for steel companies in evaluating servitization opportunities.

Keywords: Servitization; Business Model Assessment; Sustainability; Steel production.

I. INTRODUCTION

Being essential in many applications, steel currently represent one of the fundamental building blocks of modern society. Nevertheless, due to the high energy request and CO_2 emissions coming from the production process, it is also one of the materials with the highest environmental impact [1].

For this reason, in the last years, more and more studies are focusing on improving the steel production process, through the optimization of process parameters or through the implementation of new technologies able to reduce the leverage of some of the most critical factors [2], [3].

Another approach capable of tackling this environmental problem could be the adoption of servitized solutions, namely business strategies in which a company shifts its focus from selling products to providing a combination of products and services. By employing new business models, rather than selling a standalone product, the company extends its offering to include a range of complementary services that add value to the customer [4].

Many authors have already pointed out that a shift from the sales of products to the provision services, may be able to reduce resource consumption by incentivizing companies in adopting more sustainable business models and operations [5].

In spite of the opportunities, the literature shows that the steel sector is actually quite backward from the servitization point of view and there is a gap in the currently available methods to assess the product-service solutions related to steel production technologies in a sustainability perspective.

To partially fill the literature gap on this topic in this sector, the purpose of this article is to investigate, through a literature review followed by an expert interview, the most suitable criteria to be applied for the evaluation of servitization opportunities in the steel sector during the early design phase, based on the triple bottom line's three sustainability dimensions.

II. BACKGROUND

In the steel sector, companies are mainly following a product-centric approach, where providers design, manufacture, and sell products (i.e., machines and equipment) to steel producers.

However, under the servitization model, companies could differentiate themselves in the market, enhancing customer satisfaction, and generating additional revenue streams by offering a comprehensive solution that addresses their needs beyond the initial purchase. This may involve bundling services with the product, for instance providing installation, maintenance, repairs, training, consulting, or other related services. Alternatively, customer needs could be met through the development of use-oriented or result-oriented solutions, which enable the creation and consolidation of long-term relationships between provider and customer [6].

Ideation and early design of the services or product-service systems (PSS) are crucial phases to successfully adopt servitized business models, since during these first stages, companies need to develop the solution that fits best within the as-is company context [7]. At this stage, therefore, the company have to choose between different servitization opportunities, and it is not always immediate to establish which is the best with respect to the specific case.

Despite this need, the literature about the techniques for PSS assessment shows that the majority of the current evaluation approaches require a great amount of data [8]. Since in the early-stage PSS development, information about costs, markets, prices and processes are rarely available, these evaluation methods result hardly applicable for this purpose [9].

To address this gap, some authors have already studied methods for evaluating PSS opportunities in the early design phase [9], [10]. These approaches frequently exploit multi-criteria evaluation techniques, which require as *conditio sine qua non* the definition of the criteria themselves.

Although there are already some research on criteria definition with a view on evaluating the sustainability performance of PSS [11], [12], studies assessing the servitization in the steel industry are not available in the literature.

It is worth mentioning that, according to the triple bottom line definition [13], being "sustainable" means to expand the traditional focus of businesses and organizations beyond solely financial considerations to incorporate social and environmental dimensions. Therefore, the organizations should be accountable and evaluate their performance based on three interconnected pillars: economic, social, and environmental.

It must also be taken into account that each company may evaluate the sustainability of its service offering using all or a portion of the broad set of criteria that may be proposed. It is indeed common that, depending on the different objectives each company has, the three dimensions of sustainability are assessed using diverse indicators, choosing to emphasize some criteria over others. [7].

Therefore, to address the topic of servitization to improve the sustainability of the steel sector, a clearer overview of the most relevant criteria that should guide the industrial practice to choose and adopt servitized business model is required. To this purpose, this research represents the first step for the formalisation of a method to assess servitization opportunities in the steel sector during the early design phase, in order to boost the adoption of servitized business models and finally improving the sustainability of this crucial industrial sector.

III. METHODOLOGY

In order to identify which are the most suitable criteria for the evaluation of servitization opportunities in the steel sector, a systematic literature review was conducted. This method consists in a comprehensive and rigorous approach to collecting, evaluating, and synthesizing existing research studies, in order to have a complete vision of the state of the art on that specific topic [14].

The research was conducted on the Scopus database during the months of March and April 2023. The search string employed was "(TITLE-ABS-KEY (criteria OR kpi) AND TITLE-ABS-KEY (evaluat* OR assess*) AND TITLE-ABS-KEY (servitization OR pss OR "product-service system*"))". After selecting articles written in English concerning the subject area of engineering and business,

management and accounting, the search produced a total of 129 documents.

It should be noted that the keyword "steel" was not added to the search string. It was chosen to proceed in this way in order to obtain a more comprehensive set of criteria, bearing in mind that the steel context would be added to the study at a later stage.

Subsequently, titles and abstracts of the papers in the corpus were read, paying attention to which of them dealt with the evaluation of servitization opportunities. After this preliminary reading, the papers corpus was reduced to 18. These 18 articles were then integrally read, resulting in 13 papers presenting a set of criteria for assessing servitization opportunities. Figure 1 shows a brief summary of the review process.

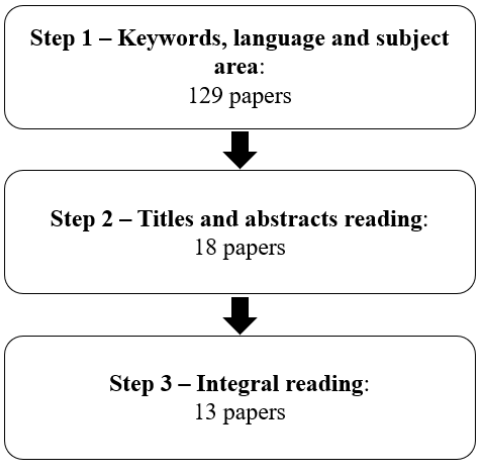

Figure 1. Systematic literature review: papers results

As many as 744 criteria for evaluating servitization opportunities results from the 13 selected articles; since many of them repeated or were quite similar, a merging exercise was first performed, so that duplicates were eliminated, leaving only criteria distinct from each other. This filtering activity resulted in 288 criteria.

Subsequently, any strongly sectoral criteria that were barely applicable to the steel industry were removed from the collection, along with all the highly operational criteria, that would be hardly applicable during the early stages of design, due to the paucity of data typical of this stage. As summarised in Figure 2, after this last step, the number of criteria was reduced to 51.

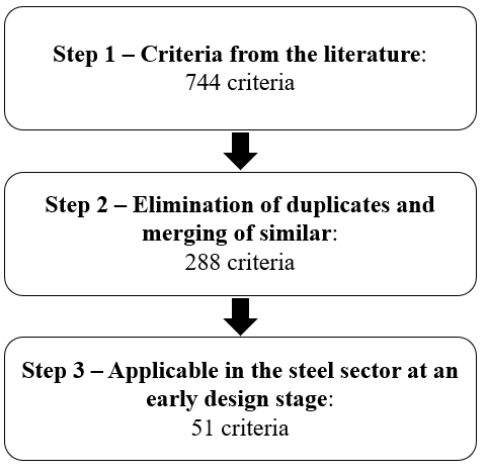

Figure 2. Systematic literature review: criteria results

With the purpose of contextualising the study to the field of interest, three expert interviews were conducted with industry specialists in the steel sector, in order to understand which criteria could be more significant within this specific industry. The three experts have a many years' experience in the steel sector and currently work in a multinational company located in the north of Italy that sell technologies and solutions for the steel production. They are in charge of R&D and innovation related to the steel value chain.

To perform the interview, an accurate description was provided for each criterion, so that respondents were not biased by pre-conceived notions or personal interpretations [15]. Firstly, the experts were asked to evaluate each criterion, defining which ones, in their opinion, could be more suitable to assess early design opportunities in the steel sector, giving a score from 1 to 4. The score was meant to be: 1 - low relevant criterion; 2 – not very relevant criterion; 3 – relevant criterion; or 4 - very relevant criterion.

After the individual assessment, the three respondents were invited to analyse their respective answers in a group discussion, during which they examined the main discrepancies between their ratings and useful insight for further investigations emerged.

This methodology made possible to define a set of criteria based from the literature and with a preliminary industrial validation by experts in the steel industry.

IV. Results and Discussion

In order to give a logical order to the selected criteria, thus allowing an easier evaluation by the

experts, the 51 criteria were categorised in groups as showed in Appendix A.

As far as rows are concerned, this categorisation stems from the idea of separating the criteria capable of evaluating the provider's perspective from the client's perspective. This is a quite common dimension to classify the value categories that characterise different PSS scenarios (see, for example, [9]).

The columns, on the other hand, highlight the three triple bottom line dimensions of sustainability, dividing the criteria according to whether they focus on economic, environmental or social aspects.

As a first simple descriptive statistics obtained by the expert criteria evaluations, the average of the ratings for each group of criteria were calculated and are summarized in Table I.

TABLE I. MEAN OF RESPONDENTS RATINGS DIVIDED BY CRITERIA GROUPS

Perspective	TBL dimension	Mean
Provider	Economic	3,03
	Environmental	2,25
	Social	2,14
Customer	Economic	3,21
	Environmental	2,67
	Social	2,72

The first evidence emerging is the higher value, on average, of the customer-side criteria, which might suggest a higher relevance of these criteria compared to the provider-side ones. This slight difference between the values, however, could be attributable to the expert background and industrial experience. Actually, the three respondents hold managerial positions in a multinational company that design and develop technological solutions for metal processing. Therefore, in the event of the application of a servitisation opportunity, they would find themselves in the role of provider. According to their perception, currently, customer needs might be the main barrier to the adoption of servitization, given reluctance and general unawareness of the potential benefits to adopt servitized models, so it is of utmost importance to put the proper emphasis on customer-side criteria when evaluating new product-service offerings.

In addition, Table I shows that economic criteria are more significant in the respondents' eyes, having a higher average score in both perspectives. Furthermore, the only criteria that received a rating of 4 from all respondents were economic ones, namely *return of investment* for the provider perspective and *service price*, *reduced operational cost*, *return of investment* and c*onvenience of the solution* for the customer perspective. This could be due to the backwardness of servitization in the steel sector which, being still in its earliest stages, finds it appropriate to focus firstly on the economic dimension, to justify disruptive choices in term of business model that, in turn, could open issues for enterprises from an operations and organizational point of view as well. Sectors that are already well established in terms of service offering might indeed be able to focus their efforts on aspects more related to the social and environmental dimension.

However, it must be considered that, of course, not all costs were found to be highly significant. In fact, the *disposal cost* criterion, for both perspectives, received very low ratings from all three respondents. From the focus group, this was justified by the fact that the disposal cost is a not-recurring (*una tantum)* expense, which is why it does not seem to be so decisive in the decision-making process.

Other criteria that received a low score were *expanding employment opportunities* and *reducing layoffs*, both from the perspective of the provider and the customer. However, this should not be interpreted as a lack of attention to the social aspect, especially since criteria such as h*ealth and safety of the workers* and *expected number of incidents* received a high rating. These specific criteria would therefore seem to be simply less relevant compared to the others.

A debate emerged during the focus group regarding one of the criteria just mentioned. Two respondents rated the health and safety of the workers from a customer perspective more relevant than from a provider perspective. The third respondent argued that it should be the other way around, as the servitisation of a technology in a steel plant could involve placing the provider's workers in the customer's working environment. In the latter case, the provider would then have less control, thus exposing its own workers to greater potential risks. For this reason, during the evaluation of several potential service offerings, different scenarios of workforce management must be properly taken into account.

V. CONCLUSION

The paper dealt with the definition of criteria to guide steel companies in the evaluation of servitisation opportunities with a view to increasing sustainability.

A systematic literature review was conducted to identify relevant criteria, resulting in 51 distinct criteria from 13 selected articles. These criteria were then evaluated by industry experts through interviews, leading to the validation and refinement of the criteria set. The criteria were categorized based on the provider and customer perspectives, as well as the economic, environmental, and social dimensions of sustainability.

The findings indicate that economic criteria hold higher significance for both provider and customer perspectives. This suggests that in the early stages of servitization adoption in the steel sector, the focus is primarily on economic aspects. Nevertheless, it emerged that also social aspects cannot be neglected since the re-organization of the workforce location that can be required in servitized solutions could prove critical.

From a managerial perspective, the most significant identified criteria can be a reference to help companies in the steel sector to understand which are the most relevant factors on which the effort should be focused during the design phase of servitisation opportunities. In particular, the research could offer useful insights mainly for steel technology manufacturers, which are recently entering new business models and developing new solutions that can support better the sustainability of the whole steel value chain but have not gained proper considerations by customers.

The limitations of this paper are mainly related to the preliminary validation that has been conducted by involving only three experts from a single company which can be considered to have mostly a provider perspective. Further research could consider a larger sample, including both provider and customer perspectives and a broader range of interviewees. Moreover, further research directions concern the orchestration of the criteria evaluation in the decision process that companies should undertake to shift towards servitization, by identifying the most suitable qualitative and quantitative methods to evaluate and weight them, in the light of the most crucial aspects characterising the steel sector.

VI. REFERENCES

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Appendix A. FIRST APPENDIX

TABLE II. CORPUS OF SELECTED CRITERIA

	Economic	Ref	Environmental	Ref	Social	Ref
Provider	Compatibility with government policy	[16]	Energy consumption	[17], [18], [7], [16], [19], [20]	Health and safety of the workers	[7], [20], [16]
	Engineering/design cost	[16], [9], [10]	Resource consumption	[7], [10], [18], [21], [9], [19]	Need for training program for the workers	[9], [20], [10]
	Implementation cost	[9], [10], [18]	Water consumption	[7], [20]	Expected number of incidents	[20]
	Operational and support cost	[9], [20], [10], [7], [16], [12]	Greenhouse gas emission	[20]	Employee satisfaction	[21], [7]
	Disposal cost	[16], [9], [10]	Waste generation	[19], [21], [18], [7]	Expanding employment opportunities	[16], [10], [7]
	Network cost	[9], [10]	Increase the lifecycle of the product	[7], [21], [12], [16]	Reducing layoffs	[16]
	Return of investment	[7], [16], [12], [21], [17]	Transportation of goods	[19]	Need for partnership	[21], [19]
	Revenue stabilization	[17], [9], [10]	Amount of recycled material	[16], [9], [10]		
	Market opportunities	[19], [10], [9], [16]				
	Advantage over competition	[17], [16], [9]				
	Risk	[19], [12], [17]				
Customer	Willingness to pay	[20]	Energy consumption	[20],	Health and safety of the workers	[7], [9], [10], [16]
	Service price	[19], [10], [7], [9]	Resource consumption	[9], [10]	Expected number of incidents	[20]
	Reduced operational cost	[9], [10], [12]	Water consumption	[20]	Employee satisfaction	[21], [7]
	Reduced disposal cost	[19], [10]	Greenhouse gas emission	[20]	Expanding employment opportunities	[16], [10], [7]
	Flexibility in transaction mode	[7], [16]	Waste generation	[20]	Reducing layoffs	[16]
	Return of investment	[10], [20], [12], [9]	Increase the lifecycle of the product	[9], [10], [20]	Need for partnership	[10], [9]
	Convenience of the solution	[16], [18], [12], [20], [22]	Transportation of goods	[19]		
	Maintenance costs	[21], [20], [10]	Amount of recycled material	[16]		
	Assurance on the offer	[16], [22]				
	Risk	[17]				
	Provider readiness	[20], [16]				