Achieving Circularity through Novel Product-Service Systems in the Mining Industry: An Opportunity for Circularity

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Abstract: The evolution toward sustainable mining can be achieved by implementing circular economies (CEs), and one way forward is via product-service systems (PSSs). However, applying PSSs in the mining industry is an area with little extant research. We seek to contribute to CE and sustainability research by proposing a model by which mining companies can achieve circularity through their suppliers: something which has not yet been explored. First, we present a critical literature review of published papers about the barriers and benefits in industries where servitization or PSS has been applied. We discuss barriers impeding PSS implementation in the mining industry, along with related concepts including CE and PSSs in digital technologies. With this study we hope to draw more discussion to the topic of PSSs in the mining industry and provide useful guidelines to academics and industry professionals for PSS implementation in mining: an important step toward circularity.

Keywords: circular economy; mining industry; product-service systems; servitization; sustainability

1. Introduction

Modern civilization consumes more than what the planet can regenerate, surpassing the mark for 2021 on 29 July. In other words, during 2021 humanity consumed the equivalent of 1.75 years of resources from planet Earth [1].

Pearce and Turner [2] introduced the concept of circular economics in modern economic studies. These environmental economists declared that to maintain the sustainability of human life on Earth, a closed system is necessary. In other words, we need a system with no major interchanges with the external environment, following the first two laws of thermodynamics. It is necessary to abandon the current linear model of take-make-throw away and move toward a circular resource management model. Circular economics (CE) is defined as an industrial economy that is restorative or regenerative by design and on purpose [3].

Modern corporations are offering more and more combinations of products, services, support, self-service and knowledge. Services are beginning to predominate, though, in a movement which was termed “business servitization” in 1988. Servitization is defined as the process of creating value by adding services to products [4]. Goedkoop et al. [5] define a product-service system (PSS) as a marketable set of products and services that together can satisfy customers’ demands. According to the Dutch PSS policy document, PSSs are recognized for offering favorable perspectives for sustainable mid- and long-term economic growth [5]. The concepts of PSS and servitization are closely related, with the difference being that the latter is a concept closely tied to debates about sustainability and
reducing environmental impact [6], while PSS is a business model representing the most sustainable model for achieving servitization [7,8]. PSS can be considered a valuable facilitator of CE at a business level [9]. Bocken et al. [10] took the studies by Stahel [11,12] dealing with closed and open resource cycles and the work by McDonough and Braungart [13] with their cradle-to-cradle concept (closed cycles for materials) and made a linear and circular categorization to reduce resource use. Thus, there are slowed-down resource cycles (long-life designs and extended product life) and closed resource cycles (recycling). In their study, they mentioned that PSS is a circular business model strategy type and part of the slowed-down cycle business model strategy. Its specific type is the “access and performance model”, where customer needs are satisfied without the customer holding property over the product. To achieve a change in the consumption paradigm and pass from a linear resource model to a circular resource model, it is necessary to support design with servitization, which is the underlying facilitator for the phenomenon [14]. PSS is described as one of the archetypes of sustainable business models of the “deliver functionality instead of property” type, which requires a social-type innovation component. These can include innovation in offers to customers, which change their behavior. Potential benefits include breaking the tie between earnings and production volume, possibly reducing resource consumption, manufacturers retaining property which, in turn, creates a motivation to handle long-term problems until the end of the service life of the product, improved efficiency in use, improved longevity/durability and material reuse [15]. The circular business models (CBM) based on PSS are recognized in the scientific and industrial community as the most appropriate way to achieve circularity [16]. According to the analysis by Rosa et al. [17] the most common CBMs are recycling practices and use-oriented PSS, but PSS oriented toward products and results also show strategic potential for a CE.

Behrendt et al. [18], Brezet et al. [19] and Zaring et al. [20] share a common element, as their PSS proposals use three principal categories. The first is “product-oriented services” where the business model is directed by selling products, but with some extra added services. The second is “use-oriented services” where the traditional product still plays a central role, but the business model is no longer led by selling products, the product remains in the possession of the supplier, and is made available in a different form, sometimes being shared by a varying number of users. The third category is “results-oriented services” where customers and suppliers agree on a result, and there is no predetermined product involved. PSS oriented toward use and results can have environmental benefits including extending product life, changing consumption patterns, and reducing total product and material use [21].

To move toward a CE, companies should invest in IoT with big data and analytical technologies that can extend product service life [22]. A transition toward smart product-service-software systems facilitates value creation and capture via monitoring, control, optimization and autonomous function, which is called digital servitization [23]. Paschou et al. [24] emphasized the following about digital servitization: the implementation of digital or ‘smart’ services, movement toward new business models, creation of co-value with customers, knowledge implementation, product-service sustainability, and improved performance for the company and customers. To reach increasingly strict sustainability goals, IoT use helps close the cycle by making PSS improvable with new functionalities that can be used to reduce critical success factors such as cost and environmental impact. It can also help reduce risks by predicting said factors via big data analysis [25].

Digital servitization produces asymmetric dependencies that empower down-stream companies when resources are not immutable. If a supplier has immutable re-sources, upstream companies may alter power interdependencies in their favor. Having a dominant position in the value chain and moving downstream through the supply chain are not necessarily related events. One important condition for product firms to successfully implement services is to maintain their competitive advantage by ensuring their control over the difficulty of imitating elements of what they offer [26].
PSS can offer value via using the product or the results that it produces, doubly decreasing environmental burdens. First, companies have an incentive to make an efficient PSS, e.g., by offering a service with a low-consumption washing machine. Second, consumers who realize all the costs involved in the service will have an incentive to change their consumption behavior. For example, with a delivery service the customer pays for each kilometer travelled, but when they use their own car, it becomes more difficult to quantify the costs involved [27]. In business models where companies are oriented toward services, material and consumable products become cost factors. Thus, companies have an incentive to lengthen product lives, maximize their use, decrease costs and materials, and reuse pieces when the product finishes its service life. These elements can lead toward minimizing material flows in the economy, while maximizing services or customer satisfaction [28].

According to what we have just seen, there is a need to reduce resource consumption, since the current model is unsustainable. To do this it is necessary to move toward a more circular economy. One way to do this is via changing toward a service-centered economy through PSS, which is a business model that incorporates sustainability. The objective of the current study is to perform a systematic literature review regarding PSS and propose a diagram for its application in the mining industry.

We therefore set forth the following general research questions to answer in this article:

a. How has PSS evolved?
b. How can PSS be implemented in the mining industry?

2. Materials and Methods

2.1. Search Strategy

This systematic review was implemented in accordance with the PRISMA declaration to improve publication quality. PRISMA was created as a tool to help improve the clarity and transparency of systematic review publications [29].

Based on the aforementioned general research questions, and with the objective of carrying out a briefer search, we set forth the following specific research questions:

a. What benefits does PSS contribute, and what are its implementation barriers?
b. What other concepts are related to PSS?
c. How has PSS been adopted in the mining industry?

2.2. Inclusion and Exclusion Criteria

The keywords used for searching were principally related with PSS/servitization. The first search set included ‘PSS’, ‘Servitization’, ‘Servitisation’, ‘Mining’, ‘Equipment’ and ‘Product-Service System’. The second keyword set was related to digital technology adoption, process improvement and sustainability, all concepts related to PSS and defined in Table 1. The second keyword set included: ‘Circular economy’, ‘Digitalization’, ‘Digital’, ‘Smart’, ‘Lean’, ‘Modular’, and ‘Modularity’. Some definitions of these second set terms can be seen in Table 1. No time interval was considered for narrowing down searches; the search engine used was Google Scholar.

2.3. Data Collection

The next stage in the procedure was to identify the publications for filtering (see Figure 1). We ruled out papers from nonrecognized journals and only considered texts published in English. A total of 408 papers were identified during the search, which after passing through the abstract reading stage were filtered and reduced to 170 papers. Next, a full reading of the 170 papers was undertaken to find benefits and/or barriers regarding the implementation of PSS/servitization, with 110 meeting this definition; the other 60 papers were excluded. The final 110 papers were analyzed with the objective of answering the stated questions, proposing a diagram for PSS implementation in the mining industry and identifying gaps and opportunities for future research.
Definitions related to PSS.

| Item | Definition | References |
|------|------------|------------|
| Servitization | The transformational process where a company changes from a product-centered business logic and model toward one centered on services. | [30] |
| Circular economy | An industrial economy that is restorative on purpose or by design. | [3] |
| Product-service systems (PSS) | A system of products and services supporting networks and infrastructure that is designed to be competitive, satisfy customers’ needs and have lower environmental impact than traditional business models. Products that decompose into subassemblies and components. This division facilitates component standardization and increases product variety. | [31] |
| Modularity | Integrating smart products and e-services in unique solutions. Smart products use ICT (information and communication technologies) to gather, process and produce data, while e-services are web portals, apps and media, which aid supplier-consumer communication. The transition toward smart product-servicesoftware systems that aid in value creation and capture via monitoring, control, optimization and autonomous function. | [32] |
| Smart PSS | The Internet of Things | [33] |
|servitization | Intelligence inserted into software integrated in industrial products and systems | [34] |
| Digitalization | High volume, velocity and variety. The practice (or group of practices) of eliminating and avoiding waste, adding more value to products and processes. | [35] |

Figure 1. Data obtention procedure.
2.4. Data Synthesis and Analysis

The 110 articles considered relevant were ordered by year and descriptively and thematically analyzed. For descriptive analysis, the papers were classified by publication year, originating journal and citation number. Thematic analysis was centered on analyzing the PSS system, its benefits/barriers and the type of industry where it was adopted. In particular, the focus was on: (1) Understanding the benefits/barriers of PSS; (2) Identifying the concepts related to PSS and its complements; and (3) Identifying the methodologies/technologies facilitating PSS implementation.

2.5. Descriptive/Thematic Analysis

The 110 papers selected were descriptively analyzed by publication year, number of citations and journal. This allowed us to identify trends within the paper selection and to study the temporal distribution of the literature, the journals to which it belonged, the industrial sectors and the benefits/barriers for PSS implementation by citing some examples for each case.

2.6. Temporal and Journal Distribution of the Literature

Figure 2 shows the papers’ time range from 1988 to 2021. While the term PSS was coined by Goedkoop et al. [3], it has a close bond with servitization [4] since PSS is a special case of servitization [37]. It is notable that the more recent literature (2014–present) represents 68 papers (61.8% of the literature analyzed) related to the increased adoption of PSS by digital technologies [38,39] along with a greater emphasis on sustainability [40].

![Figure 2. Citation and publication distribution over time.](image)

The following table (Table 2) shows the distribution of journals in the selected literature. The predominant journal is the *Journal of Cleaner Production*, followed by *Procedia CIRP* and a third-place tie for *Sustainability* and *International Journal of Operations & Production Management*. These first four journals represent 38.18% of the total, with all other journals apart from “Others” representing 31.82% of the sample. This indicates a certain fragmentation in the literature due to the wide variety of journals involved in the topic.
Table 2. Journal distribution.

| Journal                                      | # of Articles | %    |
|----------------------------------------------|---------------|------|
| Journal of Cleaner Production                | 20            | 18.18%|
| Procedia CIRP                               | 8             | 7.27% |
| Sustainability                              | 7             | 6.36% |
| International Journal of Operations & Production Management | 7             | 6.36% |
| Industrial Marketing Management              | 6             | 5.45% |
| International Journal of Production Research | 5             | 4.55% |
| International Journal of Production Economics | 4             | 3.64% |
| Journal of Manufacturing Technology Management | 3             | 2.73% |
| Business Strategy and the Environment        | 3             | 2.73% |
| CIRP Journal of Manufacturing Science and Technology | 2             | 1.82% |
| Journal of Marketing                        | 2             | 1.82% |
| International Journal of Service Industry Management | 2             | 1.82% |
| European Management Journal                  | 2             | 1.82% |
| Technological Forecasting and Social Change  | 2             | 1.82% |
| Advanced Engineering Informatics             | 2             | 1.82% |
| Journal of Business Research                 | 2             | 1.82% |
| Others                                       | 33            | 30.00%|

2.7. Industrial Sectors

Figure 3 shows that the most common industry type in the literature is the automotive industry, with the example of Tesla [23,41,42], followed by the machinery/equipment industry in second place with the recurring example of Caterpillar [43,44]. The most common example in office equipment is Xerox [7,30,40]. IBM is the most frequent example for the computer industry [30,45]. Electrolux is the most common example for the appliance industry [46–48], and Rolls-Royce leads the examples for the aerospace industry [28,40,45,49].

![Figure 3. Industry types in PSS.](image)

2.8. Benefits

The benefits/barriers were analyzed via the four dimensions used by Beuren et al. [46]; these were focused on suppliers, customers, environment and society. Upon reviewing the 110 papers, identifications were made of the benefits and/or barriers encountered, generating a database to make the corresponding histograms.

Figure 4 shows that the most frequently mentioned benefits are for suppliers, due to improved consumer trust/loyalty [31]: increased differentiation factors against the
competition \[38,50\]; potential for innovation while the product/service system is used; reduced costs and resource use; maximized results; knowledge sold off as consultancy and training services; and reused products together with various services \[51\]. As incomes rise, cash flows’ vulnerability and volatility are reduced \[52\].

Figure 4. PSS Benefits.

The second most frequent benefits are for consumers. These include personalized services; product and service quality advantages \[53\] and improved relations with consumers due to greater contact and information flow about consumer preferences \[31\].

Environmental benefits come third. There is reduced consumption via alternative product use; suppliers are responsible for products and services through returns, recycling and remanufacturing, reducing wastes throughout the life of the product \[37\]. Services are planned with products’ life cycles \[51\]. Innovation can change consumer behavior to reduce the environmental impact of consumption \[34\]. Results-focused services aim at reducing extant systems’ material intensity by selling a “result” instead of a product \[55\].

In last place, we find the benefits for society, including government support for adopting sustainable businesses \[37\] and new jobs requiring expert knowledge and social skills \[51\].

Adopting PSS involves new types of investor and/or partner relations, new convergences of economic interests and optimizing concurrent systemic resources \[56\].

2.9. Barriers

Figure 5 shows the various barriers, with supplier barriers in first place. Greater investment in personnel is required, as costlier labor is involved \[45\]. To provide digitalized PSS, a company must learn to work with highly complex algorithms and an external digital infrastructure as it evolves \[57\].

A “service paradox” can occur where a substantial investment to extend the service business leads to a greater range of services offered and higher costs but does not generate correspondingly greater returns \[58\].

There is also the need for greater customer understanding and closeness and difficulty with moving from sales to contracts which operate over a period of time \[59\]. Product-services portfolios require both knowledge from a “hard” technical perspective and “soft” customer-oriented skills \[60\].

PSS requires a precise design process that considers product design problems along with communicational, social and economic aspects \[61\]. Manufacturers can be concerned about pricing and knowing the costs of services \[52\].
Suppliers can be disinclined to take on risks and organizational changes [37].

There can be a lack of experience regarding incorporating services into general company strategies [4]. Introducing service elements into businesses traditionally dominated by goods requires strategic change management with top-down leadership [62]. Compared with physical products, services are generally under-designed and inefficiently implemented [63]. Renting often generates different behavior among less careful customers toward equipment that they no longer own [28].

Consumer-related barriers are in second place. There is resistance among consumers to giving up property over the product [45], and consumers perceive lower value [31].

In third place, environmental barriers can cause a “rebound effect”, as they can make products (or their components) have shorter lifespans [51] or change customers’ behavior by making them consume more [5]. Radical changes for the environment can only be expected in PSS, which promises functional results [64].

Finally, for society, one barrier mentioned is the need for a social system or infrastructure that accepts or supports the suggested product-service scenario [31].

As we have seen in the previous figures, more benefits and barriers appear for suppliers, followed by customers and then (to a lesser degree) the environment and society. We can affirm that there are more benefits than barriers present in the literature.

3. Results

One objective of this study is to propose a business model that incorporates PSS in the mining equipment and services industry. To do this, some examples from three companies related to mining will be reviewed, along with their approach to moving toward a business model with a higher proportion of services, sustainability and digital technology. Based on the examples considered, a business model which incorporates the concepts and knowledge necessary to successfully apply PSS in the mining equipment industry will be proposed.

Caterpillar, as previously mentioned, is one of the most representative examples in the machinery/equipment industry for offering services [44,65]. This company is moving toward digital business models, data-based value chains and more flexible organizational forms [43]. There is also an interesting focus on a more circular economy via remanufactured and reconstructed products, which extends products’ service lives, decreases losses and total property cost, and increases product investment value [66].

Paschou et al. [24] found that digital technologies are principally associated with providing intermediate services (e.g., remote monitoring) or advanced services (e.g., customer support agreements), with less attention for the base services (like spare part supply). Our next example is a business which uses digital technologies to offer intermediate-type services.
Komatsu is a company related to equipment for heavy mining and construction vehicles, where machinery (in this case a bulldozer) forms part of a smart system that allows for remote maintenance via a monitoring and forecast system centered on evaluating and predicting the condition of the diesel component in the motor. The benefits include reducing the amount of time that the unit is out of service and using the captured information to optimize manufacturing management, maintenance scheduling and machine safety, which ultimately makes industrial management more organized and transparent. It can cut costs and create a better working environment, ultimately reducing costs by saving energy, optimizing maintenance scheduling and supply chain management [34].

Atlas Copco (currently Epiroc for mining) is another example. It produces a diverse set of machines in a variety of industrial applications. In recent decades, it has extended its innovation trajectory toward services, aiming at reliability and energy cost reduction across the functional product group. From its initial role as a spare parts supplier, it has expanded into a portfolio of services, ranging across various maintenance services and total solutions contracts. Visnjic Kastalli and Van Looy [65] found that small levels of services led to a sharp rise in benefits, after which an increase in services led to a drop in temporary benefits. Upon reaching a certain critical mass of service activities, a positive relation with benefits reemerges.

Smart mining PSS is based on four points seeking to improve the sustainable characteristics of PSS (see Figure 6), improving its performance with the aid of digital technologies, modular design incorporation and lean principles. The points are:

1. Regarding the environment, the definitive goal of servitization is to have a smaller environmental impact to achieve sustainability in a circular economy. Smart PSS has great potential to deal with sustainability problems such as improving resource efficiency, extending service life and closing cycles [40]. To strengthen this effect, various results-oriented services are proposed, since in contrast to product-oriented services or use-oriented services, they have the highest environmental improvement potential. Using materials becomes a mere cost factor, where using more materials or creating more products does not lead to higher incomes. This creates an incentive to reduce costs for materials, using less, using them for longer periods, etc. [28].

2. Incorporating digital technologies contributes other improvements apart from sustainability. Digitalization increases supplier-customer interaction, facilitating value cocreation [67]. With an IoT-based PSS, suppliers can track machine conditions and act to prevent or correct any current or additional technical problem [68]. Thus, once they have a well-planned, IoT-supported servitization strategy, companies can create a solid value proposition based on reliable data about product use and performance. Services can also be created or adjusted to increase profitability and improve customer satisfaction [69].

3. Due to the complexity and range of various PSS offers, developing integrated business solutions with long-term success requires implementing modularity [70], which can satisfy requirements for personalized solutions [71]. Process modularization has been identified as a promising approach [51]. Product units should implement common technology and standardized product platforms which can be easily arranged to provide more efficient solutions for customers’ needs. The modular reusable approach cuts costs and improves integrated solutions’ reliability [72]. Different PSS can also be formed by combining modular components’ design [28,73].

4. Lean engineering practices have emerged as possible solutions to support effectiveness (improved product quality) and efficiency (time to market and lower development costs) [74]. To complement environmental performance of the model, lean bundles are considered (JIT: just-in-time, TQM: total quality management, and HRM: human resource management). When these bundles are simultaneously implemented along with a servitization strategy, they significantly improve sustainable development, although individual application does not always deliver positive performance [75]. Lean thinking also prevents wasting time and efforts during manufacturing activities.
and service operations [76]. Any activities that do not add value to the product/service and waste knowledge, time and resources must be eliminated from the process [77]. It is also important for the Lean PSS life cycle to be circular, which is fed from the start by customer value, leading the integration of products and services from the conceptual phase. This integration is supported during the design phase via problem-solving methods such as design for X (DfX) and TRIZ, encouraging the concurrent engineering of PSS and allowing engineers to consider new aspects under innovative management. The life cycle is divided into various stages: development, production, service use and operation, and end of life/disposal [78]. Including lean and DfX improves PSS, making the product components better suited to handle service characteristics from the beginning of their development process [79].

![Smart Mining PSS](image)

**Figure 6.** Smart mining PSS.

4. Discussion

From value propositions based upon services, product-service systems (PSS) are commonly understood as a way to achieve a circular economy, although there is a lack of guidance for incorporating circularity in PSS design [80]. This complicates achieving circularity. PSS is also not an implicit guarantee of CE, and CE strategies do not necessarily lead to decoupling of economic growth from resource consumption in absolute terms. Strategies are required for the PSS objective of resource reduction to qualify as a CE strategy and to ensure the absolute decoupling of resources: ensuring net resource reduction, avoiding displacement of the load between life cycle stages, and mitigating rebound effects [81]. As we have seen, to reduce environmental impacts, PSS must be intentionally designed. Although three different PSS types exist, only the results-oriented type has real contributions to resource efficiency and circularity [82]. Implementing PSS is thus not always more sustainable and does not necessarily lead to a circular economy without being previously designed to do so. Results-focused PSS is important to have real sustainability improvements and draw closer to a CE.

Digital service transformation also requires companies to have a more holistic perspective on their strategy and service business. While conventional manufacturing and R&D activities can be centrally managed to achieve global efficiency and standardization, services require more local responsiveness and relations with the closest customers [83]. Adopting technologies including IoT involves significant efforts in terms of knowledge acquisition, product innovation and business process definition and implementation [68].
While the literature presents PSS cases in equipment/machinery manufacturing, it is still not clear how many of these are directly related to the mining industry. Although there are studies relating CE and the mining industry, there is still a gap in the PSS field linked to mining which must be studied. This study has tried to narrow that gap, and we hope that the proposal described here is useful for researchers and practitioners.

With that being said, PSS implementation in mining is oriented toward suppliers of services, materials and machinery. This is because mining is inherently only capable of circularity in its subprocesses such as water recirculation in concentration processes, among others [84], since as a primary economic activity its global process is linear, extracting a resource to obtain an economically profitable product.

Suppliers, on the other hand, can apply circularity in all of their processes. This is obviously strengthened by applying PSS, since by having complete dominion over their products, circular economy concepts can be applied: reusing, service life extension, re-designing and recycling, among others. These points are strengthened by changing the business model from selling a product to providing a service in the three aforementioned categories proposed by Behrendt et al. [18], Brezet et al. [19] y Zaring et al. [20].

In this case, while the supplier or service company that has greater control over products can apply EC considering that this will in turn improve their corporate profitability, all the preceding facts go hand in hand with lengthening their service life or favoring their reuse and always diminishing intake for their productive processes.

Thus, to give an example, the Doña Inés de Collahuasi Mining Company, which has 10.9% of Chilean copper production and 4.3% of total global copper production [85], reported in November 2021 that it would incorporate circular economics in service contracts and supply purchases [86], which from this perspective indicates an implementation of PSS in mining service companies.

An Approximation to a Road Map

The mining industry definitely needs to move from comparative advantage to competitive advantage via an integrative strategy based on servitization, allowing companies to base their business on services beyond mere production of tradable goods. This will require innovation on business models and adoption of shared value creation.

One initial approximation is to identify opportunities within the industry value chain to incorporate servitization criteria and establish traction centers, i.e., challenges such as adequate tailings management, increasing smelting and refinery process efficiency and strengthening environmental protection, among others.

On the other hand, establishing “habilitating centers” considers the development of smart mining by implementing monitoring systems and the formation and insertion of advanced human capital.

5. Conclusions

This review has identified, presented and summarized PSS literature with the objective of understanding how the concept has evolved, and what applications it has had in the mining industry, as interest in a more sustainable business model has risen. PSS benefits and barriers were reviewed, both of which can affect the model proposed for the mining industry. We also identified the concepts or trends that support and have aided the evolution of PSS, including adopting digital technologies, circularity and lean approaches. Several cases were found of mining industry businesses that have applied a higher proportion of services, but these are few in number, indicating that the topic is still new in the industry.

Mining companies are increasingly obligated to fulfill more rigorous environmental regulations, making it imperative to advance in the transition toward a more sustainable business model. A model has been proposed (smart mining PSS) to implement PSS in the mining industry, considering a sustainability focus based on offering results, using digital technologies and modularity to improve equipment performance, and including lean thinking to improve service by minimizing losses and creating continual improvement.
We hope that this model will help practitioners implement PSS in their business model where they hope to propose a more sustainable, effective and intelligent service.

Considering what was already said in this article, PSS development in the mining industry will come from the hands of its suppliers, who should gradually modify their business models toward PSS-inclined models, as these will favor incorporating EC in their organizations. While up to now some large mining equipment supplying companies have approached PSS along with EC-oriented policies, it is still not a generalized mining industry requirement. We can see the example of the Doña Inés de Collahuasi Mining Company in Chile as a window into the future of the industry, but this is obviously insufficient. On the other hand, the mining industry will also have to get used to these new requirements, as it is undeniable that all the preceding points will bring changes to mining activity. For example, the open pit mine typical of large-scale mining for copper, iron or other metals demands a large amount of equipment for exploitation and production from various suppliers, which will doubtlessly cause changes in the extant business model.

Researchers are thus encouraged to conduct more studies about PSS implementation in the mining industry, applying and extending smart mining PSS to other industrial sectors, gathering data from mining companies that apply PSS, identifying the impacts of their PSS application and comparing them with other industries.

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