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Special Issue

Contemporary Advances in Industry 4.0 Technologies and Theories for Manufacturing Sustainability

Edited by

Dr. Hamed Gholami, Prof. Dr. Safian Sharif and Prof. Dr. Georges Abdul-Nour

MDPI

https://doi.org/10.3390/su142416804

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Application of the COHRV Conceptual Framework to Enhance Sustainable Manufacturing

Georgina Elizabeth Riosvelasco-Monroy, Iván Juan Carlos Pérez-Olguín *, Luis Asunción Pérez-Domínguez, Luis Carlos Méndez-González and Salvador Noriega-Morales

Institute of Engineering and Technology, Department of Industrial and Manufacturing Engineering, Universidad Autónoma de Ciudad Juarez, Chihuahua 32315, Mexico
* Correspondence: ivan.perez@uacj.mx

Abstract: For the implementation of Industry 4.0 (I4.0), companies need the commitment of several departments, knowledge and technology within data management, cyber physical systems, and Internet of Things, among other pillars of I4.0. This industrial revolution (I4.0) offers opportunities for the development of competitive advantages, new market positions within a supply chain, new product design and processes, and manufacturing sustainability. Regardless of such benefits, for small and mid-size enterprises (SMEs) it represents a challenge, because they lack specific capabilities, qualified human resources, and technological and/or financial support. The challenges for SMEs from industrial sectors can be dealt with by means of strategic joint ventures, known as horizontal collaboration. Seen as the new vertical collaboration, horizontal collaboration offers a way for enterprises to combine their strengths in order to gain competitive advantages and develop new market opportunities. This paper presents the Resources and Value Horizontal Collaboration Model, "COHRV", for its acronym in Spanish, structured as a guide to merge enterprises' strengths such as knowledge transfer, qualified human resources, technology, and more. The COHRV model was designed as a disruptive business model, presenting a new perspective for horizontal collaboration projects between SMEs. To show the effective applicability of the COHRV model, data obtained from nine SMEs in a previous case study were used. The objective was to observe how the COHRV model works as a framework to create new strategies for SMEs, to work on a sustainable manufacturing venture.

Keywords: manufacturing sustainability; Industry 4.0; horizontal collaboration; manufacturing SMEs

Citation: Riosvelasco-Monroy, G.E.; Pérez-Olguín, I.J.C.; Pérez-Domínguez, L.A.; Méndez-González, L.C.; Noriega-Morales, S. Application of the COHRV Conceptual Framework to Enhance Sustainable Manufacturing. *Sustainability* **2022**, *14*, 16804. https://doi.org/10.3390/su142416804

Academic Editors: Hamed Gholami, Safian Sharif and Georges Abdul-Nour

Received: 30 October 2022
Accepted: 12 December 2022
Published: 14 December 2022

1. Introduction

Since its origin in Germany in 2011, the Fourth Industrial Revolution, also known as Industry 4.0, has gained a lot of interest in both academic and professional fields. Industry 4.0 is an industrial revolution that enhances the alliance between cyber-physical sources within the value chain in manufacturing [1]. Researchers have been facing challenges, developing beneficial business models to integrate business and manufacturing processes for an efficient, flexible, and sustainable value chain [2]. Industry 4.0 requires enterprises to compromise different departments, knowledge, and technology within data management, cyber physical systems, and the Internet of Things, among other elements of I4.0 [3,4]. Specifically, I4.0 enhances interoperability, real-time capability, security of information, and the virtualization of certain processes [5]. It also offers opportunities for enterprises to gain competitive advantages, new market positions within a supply chain, new product design and processes and achieve manufacturing sustainability. Nevertheless, current Industry 4.0 research presents challenges for implementing this manufacturing paradigm. For SMEs, this is especially difficult, as they tend to have limited financial and technological resources and knowledge [6], a lack of strategy for coordinated actions between units, low talent and capabilities, sustainability in production from the economic and ecological perspective, and

horizontal integration through value chain and investment issues, among other common weaknesses [5].

This paper has two main contributions listed as follows: (1) an effective horizontal collaboration business model for SMEs to create strategies considering horizontal collaboration and sustainable manufacturing pillars; (2) a proposed business model that is generic and applicable to any enterprise from similar supply chains. The authors present a horizontal collaboration business model, the COHRV model (for its acronym in Spanish -Resource and Value Horizontal Collaboration), for influencing SMEs to coordinate and develop horizontal collaboration projects. The objective of this paper is to apply the COHRV model so that SMEs can implement Industry 4.0 and gain manufacturing sustainability within their own value chain.

Globalization and product life cycle have been urging enterprises to incorporate strategies for sustainable activities. Defining manufacturing sustainability as an Industry 4.0 advantage through materials, energy, and human resources efficiency [5], gives enterprises a new perspective for manufacturing processes, through reducing, reusing, redesigning, and other R's processes to enhance environmental measures, and employee and community welfare [7,8]. Sustainability is seen as a term that aims for production efficiency, balancing environmental, social, and economic areas within the industrial systems and the entire product life cycle [5,8,9]. In addition, incorporating and adopting green activities, reducing material waste, using less energy or fewer resources, and ensuring human resources safety, among other measures, generates manufacturing sustainability [5,7,10]. Sustainability innovation means that enterprises have to integrate idea generation within certain areas, such as research and development, commercialization, and the business model, considering production levels such as products, processes, and systems [7,8]. Enterprises must update or modify their business models to incorporate and transform their production processes in a more sustainable manufacturing environment, integrating both vertical and horizontal themes [11].

2. Literature Review

2.1. Horizontal Collaboration

Horizontal collaboration has been identified as the new vertical integration within a supply chain, providing an interrelation of enterprises from the same supply chain link, such as competing businesses [12–14]. Horizontal collaboration is defined as a strategy that eases process and product development by adding value to the supply chain, where enterprises work together to reduce costs, improve customer service, and share knowledge and resources, among other factors [15–17]. Enterprises that integrate within a joint venture using horizontal collaboration, tend to restructure the competitive environment by sharing available resources, technology, and knowledge, typically under a mutual agreement [18,19].

For a horizontal collaboration to be developed, enterprises must take into account three aspects [20,21]:

1. Motivation—analyze each selected supplier, customer, warehouse, among other parties;
2. Activities—plan and share information in a systematic and continuous way to keep updated data, trust and communication;
3. Results—clarify performance metrics from intangible and tangible assets aligned to the horizontal collaboration project.

2.2. Resource and Value Horizontal Collaboration–COHRV Model

Horizontal collaboration is a strategic term meaning two or more enterprises seeking to gain a position within their supply chain and market. Enterprises interact, create, and develop a joint project to gain competitive advantage, new product innovation, or knowledge transfer, among other benefits. SMEs thrive by working together in new ventures, creating long-term alliances, and value creation. Horizontal collaboration fosters a sustainable manufacturing environment, which can benefit SMEs by creating a business model that adapts to and enhances a viable financial joint venture. In a previous study, we

designed and created a disruptive business model for SMEs to develop and plan strategies for implementing joint projects, to maintain or gain new market share and new product development, among other benefits [22]. The COHRV model was developed and validated through a multi-criteria decision-making proposed methodology, based on a series of techniques including:

1. Literature review and analysis of horizontal collaboration pillars;
2. Criterion weight, to reduce ambiguity from the expert panels' evaluation;
3. Analytical hierarchical process, to rank a series of tangible and intangible factors;
4. Hesitant fuzzy linguistic sets, to change the expert panels' evaluation into a linguistic expression;
5. Combinative distance-based assessment, to determine the hierarchical alternatives by using two distance measures.

The methodology proposed and verified by [22], resulted in the top 30 horizontal collaboration factors, which were then grouped into three business model components: content (*what* components), governance (*who* components), and structure (*how* components), as shown in Table 1. For more details about the validation, refer to [22].

Table 1. Top 30 horizontal collaboration factors [22].

Content	Governance	Structure
Firm performance	Confidentiality	Process performance
Production flexibility	Business strategy	Quality
Trust	Absorption capacity	Communication
Operational performance	Trust	Costs
Goal alignment	Leadership	Market strategy
Research and development	Goal alignment	
Process performance	Business model identification	
Commercialization phase	Quality	
Value creation	Commitment	
Focus strategy on limited resources	Process performance	
Negotiation performance	Problem solving and support	
Performance metrics	Cooperation	
Waste reduction		

The COHRV model is seen as a horizontal collaboration framework for enterprises to create and develop joint projects, such as a strategy for sustainable manufacturing innovation. For more information about the design and validation of the COHRV model, read [22]. Figure 1 shows the complete framework, containing three groups that aid entrepreneurs to define the *what*, *who,* and *how* business areas will interact within the project development. The COHRV model is designed as a visual framework that encompasses the following horizontal collaboration pillars:

1. Knowledge transfer is the peripheral structure, which occurs from beginning to end within the joint venture;
2. Organizational structure visualizes the enterprises that will work together in the established project;
3. Value proposition is determined by the companies, and it depends on the proposed project;
4. Incentive is analyzed and declared when the value proposition is identified, so that the enterprises know what they will receive from the joint venture, and how they will protect;
5. Content presents the *what* components of a joint venture. Enterprises must define the shared resources and processes, the research and development area, or the marketing, distribution, and logistics of the new product or service;

6. Governance presents the *who* components. Enterprises that work within the alliance must create a multidisciplinary team, which must be trained and have certain knowledge to work within the strategy;
7. Structure shows the *how* components of a joint venture, taking into account items that link to the horizontal collaboration.

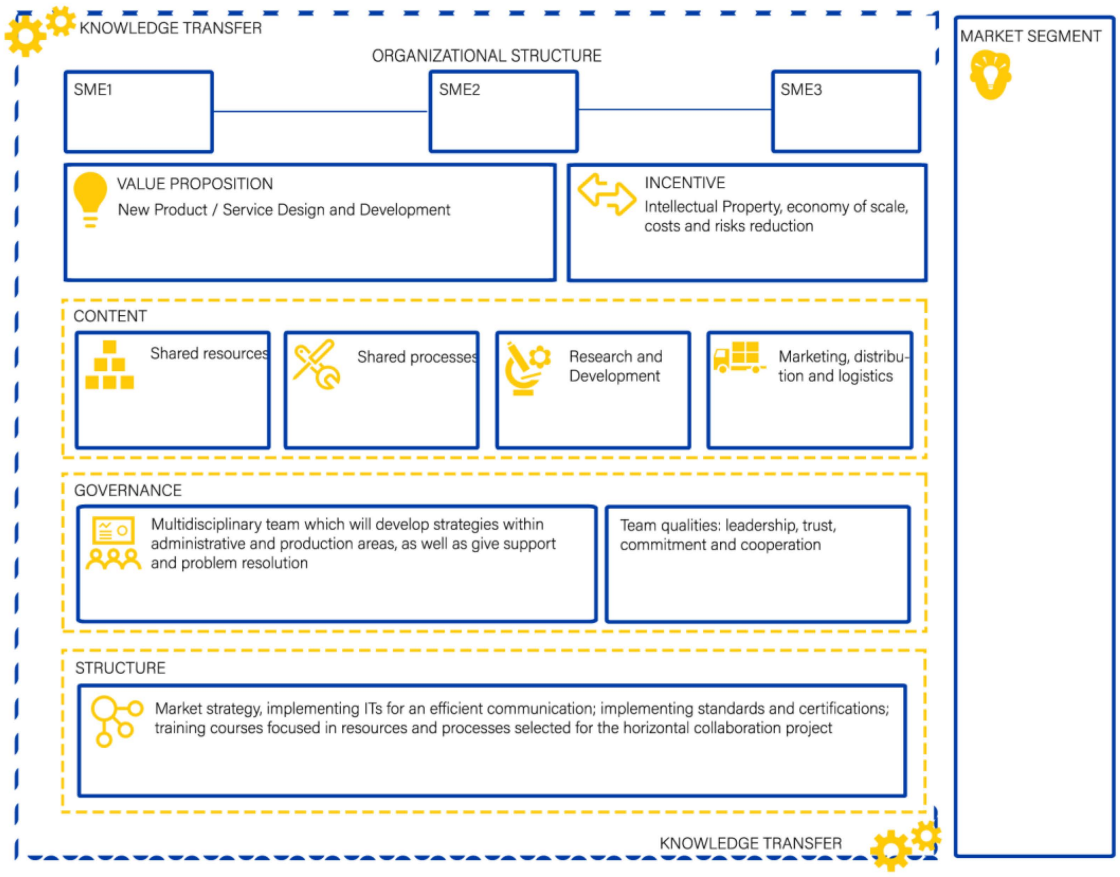

Figure 1. COHRV model [22].

3. Materials and Methods

From the horizontal collaboration point of view, enterprises must create joint ventures for financially viable projects by interconnecting production areas, distributors, and knowledge. For SMEs to gain sustainable manufacturing, they must innovate their business model or create new strategies that integrate certain factors within economic, social, and environmental areas. The COHRV model was designed as a disruptive business model, presenting a new perspective for horizontal collaboration projects between SMEs. To show the effectiveness of the COHRV model, data obtained from nine SMEs in a previous case study were used. The objective was to observe how the COHRV model works as a framework to create new strategies for SMEs to work on a sustainable manufacturing venture. In [9], three sustainable manufacturing pillars and their respective factors are presented, as shown in Table 2.

Table 2. Sustainable manufacturing pillars [9].

Economic Factors	Social Factors	Environmental Factors
Hardware cost	Stakeholder participation	Energy consumption
Applied technology complexity	Employment issues	Holding environmental standards
Software cost	Personnel safety	Environmental planning
Mean time between failure	Personnel training	Inside toxic emissions
Risk level of the system	Acceptance by personnel	Raw material consumption
Research and development cost	Development of management and engineering expertise	Waste cleaning cost
Customer satisfaction	Personnel health	Waste type
Product variety	Personnel wage	Toxic emissions to air, soil, and water
Creativity	Government regulations	Resource availability
Product development stage	Holding related to social standards	Environmental management systems
Competitive enhancement		
Current reliability level		
Reliability improvement plan		
Access difficulty		
Quality of product/service		
Time efficiency		
Mean time of repair		
Manufacturing system type		
Detailed production scheduling		
System design		
Repairability		
Failures type severity		
Technical feasibility		
Flexibility		
Return on investment		
Demand urgency		
Spare machine availability		
Spare parts availability		
Tear and wear rate		
Lead time		
Lost production cost		
Personnel training cost		

Analyzing Table 1, it presents similar factors that the COHRV model takes into account, such as costs, flexibility, production processes, personnel training, and knowledge, among others. Nevertheless, the disruptive business model applies these factors within a framework for enterprises to structure and develop new strategies for joint ventures. The COHRV model at this point demonstrates that its design has taken into account sustainable manufacturing pillars that can facilitate enterprises to gain market share and production and process development, towards more sustainable economic, social, and environmental areas.

Case Study: Cluster MACH

This case study presents the applicability of the COHRV model in nine SMEs that are key partners of Cluster MACH. The nine SMEs were looking to obtain a horizontal collaboration framework to develop a strategy for sustainable manufacturing.

In 2017, thirteen entrepreneurs from Ciudad Juarez, Chihuahua, Mexico, seeking academic and government synergy, created Cluster MACH (for its acronym in Spanish-*Manufactura Avanzada de Chihuahua*—Advance Manufacturing from Chihuahua). The companies used machine tools, soldering, technology integration, and special surfaces to produce parts and manufacture support tools for multinational plants located in Ciudad Juarez. From then on, Cluster MACH has defined a series of objectives in terms of achieving

growth, development, and a competitive position within the industry supply chain, besides the creation of barriers for newcomers [23]. Table 3 shows the thirteen enterprises as key partners of Cluster MACH.

Table 3. Cluster MACHs key partners, market share, and capacity [23].

Key Partners	Market Share	Technology Capacity
ICP Group (2009)	Multinational companies	Research and development for new products. Flexible capacity taking into account I4.0
FEM Automatizacion Industrial (2009)	No data	Invests in research processes, acquisition of new machinery, and human resources training.
AMD Automation (2000)	Local and multinational companies	Invests in migrating toward I4.0 toward a more efficient and flexible production process.
Repinel Electronic Solutions and Automation Systems (1988)	Local and multinational companies	Industry 4.0 is part of their core business. They have work in a joint venture with the Edinn company to produce a software named OEE (Overall Equipment Effectiveness).
FASI Tecnologias (1989)	Multinational companies	As new technologies and innovations have emerged in the market, they tend to update their production processes aided by their flexible capacity.
TAMUSE Systems (2003)	Local and multinational companies	Creative environment that tends to research and develop projects within I4.0, toward new market share in nanotechnology, agriculture, and medical industries.
PIMA Industries (1999)	Multinational companies	Innovating in new market shares in medical, aerospace, and construction industries. Have produced their own ERP software, SIMA, to control and monitor each project in real time.
DMI Corp (1998)	Multinational companies	Use of I4.0 pillars in production process, always innovating to maintain a competitive advantage.
IMSSA (1998)	Local and multinational companies	Has a designated area for IoT research and development. They work with 3D printing to increase I4.0 processes, IIoT.
PPESA (2011)	Local and multinational companies	Customized production as the key factor to deliver products with high value.
Aidmaster Engineering (2009)	Local and multinational companies	Production based on standard procedures that sustain competitive levels, validating each project with their own methodology.
DIMEYCO (1999)	Multinational companies	Enterprise's core asset is human resource training.
IAI Automation (2011)	Multinational companies and MACHs partners	Human resources knowledge is the basis for production process designs.

The case study had a 69.23% of response rate, received from the following Cluster MACH key partners: Aidmaster Engineering, DIMEYCO, DMI Corp, IAI Automation, IMSSA, PIMA Industries, PPESA, REPINEL Electronic Solutions and Automation Systems, and TAMUSE Systems. Out of these nine enterprises, 11.11% are micro enterprises; 77.77% are small enterprises, and 11.11% are mid-size enterprises. In a previous study, the authors [23] proposed a horizontal collaboration and knowledge management matrix, that

was adapted from the Miltenburg matrix [23]. As shown in Table 4, the matrix shows competitive priorities and their specific dimensions and descriptions, based on factor analysis. For more details about the study, refer to [23].

Table 4. Competitive priority dimensions and description [23].

Competitive Priority	Dimensions	Description
Human resources	Knowledge management (D1)	Knowledge management formal planning.
		Use of manuals within the production system.
		Use of tacit knowledge for problem resolution.
		Use of tools such as data mining for obtaining knowledge.
	Process technologies (D2)	Human resources trained in Industry 4.0.
		Company owner with knowledge in different areas.
		Human resources trained in lean manufacturing.
		Training human resources in available technologies inside the company.
Innovation	IP management (D3)	Ensuring protection in products implementing IP strategies.
		IP formal strategies.
	New product development (D4)	The company has a designated design or research department.
		Entry into new niche market.
		Tier level within supply chain.
		Type of investment: owner's own capital or loans for machinery investment.
Organizational structure	Customer service (D5)	Standardized products offered by the company.
		Customers' level of communication.
	Supply chain position (D6)	Product percentage sent to the international market.
		Previous experience of company owner.
		Supplier's level nationally.
	External agents (D7)	Interrelation with governmental departments, public research centers, and technology parks.

The objective was to identify the level of integration from the key partners toward Industry 4.0 pillars, focused on knowledge transfer. Cluster MACHs key partners were evaluated within this competitive priority based on a factorial analysis. Table 5 outlines the scores and each enterprise rating, in order to distinguish which company has certain attributes that can contribute to a horizontal collaboration business model toward sustainable manufacturing. Taking the Cluster MACH score as the market base calculated by the enterprises' average, for which each company score was evaluated as below or above average. Being above average means that the enterprise has certain resources, depending on the dimension, to offer within the horizontal collaboration strategy. Being below average

means that the enterprise lacks certain resources and therefore, it is searching for a way to innovate or grow. For more information about the case study developed in Cluster MACHs key partners, read [23].

Table 5. Competitive Priority score results [23].

Key Partners	Human Resources		Innovation		Organizational Structure		
Dimensions	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**
AIDMASTER	**5.8**	**8.3**	**6.6**	**5.8**	**10.0**	**8.8**	3.3
DIMEYCO	**5.8**	5.0	3.3	**7.5**	3.3	4.4	3.3
DMI	**7.5**	**6.6**	**6.6**	**5.8**	6.6	**5.5**	3.3
IAI	4.1	5.8	3.3	4.1	3.3	4.4	3.3
IMSSA	**8.3**	5.8	**5.0**	**6.6**	**10.0**	**6.6**	**10.0**
PIMA	**7.5**	**7.5**	**5.0**	**5.8**	6.6	**6.6**	3.3
PPESA	**6.6**	**6.6**	3.3	5.0	**10.0**	**5.5**	3.3
REPINEL	**6.6**	**8.3**	**6.6**	**6.6**	**10.0**	3.3	**6.6**
TAMUSE	**8.3**	**8.3**	**5.0**	**5.8**	6.6	4.4	**6.6**
Cluster MACH	**5.0**	**6.0**	**3.3**	**5.0**	**6.7**	**4.4**	**3.3**

Table 5 clearly shows the relative strengths and weaknesses of the companies guided by Cluster MACHs average score. The resulted matrix proposed actions to encourage horizontal collaboration between the Cluster MACHs key partners including:

1. Design and carry out knowledge transfer from trained and experienced personnel in intellectual property manners and applications. This action would allow other key partners to protect both their intangible and tangible assets.
2. Design a joint supply chain to standardize toward an economy of scale, delivery time, and logistics within suppliers.
3. Design a joint supply chain to identify common customers and create new distribution channels and logistics to deliver finish goods.
4. Create a unique R&D department for each enterprise to collaborate and transfer knowledge for new product design, process production, and market share.

The aforementioned analysis is useful for the development of the strategic initiatives presented in the following section.

4. Results

This section presents a detailed view of the COHRV model usability for enhancing sustainability manufacturing between SMEs. As [10,11,24] mention, sustainable manufacturing is achieved through a series of activities focused on influencing production processes as factors of economic, environmental, and social performance. The information gathered from the Cluster MACH [23] was analyzed using a knowledge management and horizontal collaboration matrix, as detailed in the Section 3. As mentioned above, the authors proposed four actions to the Cluster MACHs key partners, so they could immerse in joint ventures, taking advantage of already being part of an industrial cluster.

The following subsections present the four actions proposed, carrying out the COHRV model as the framework to visualize each enterprise opportunity area and the new business model from which the strategies are developed.

4.1. Strategic Initiatives for Horizontal Collaboration

4.1.1. Design and Carry out Knowledge Transfer from Trained and Experienced Personnel in Intellectual Property Matters and Applications

One proposed action is for Cluster MACHs key partners to develop a culture of intellectual property (IP) protection for tangible and intangible assets. To apply the COHRV model as a conceptual framework, three companies were chosen for this joint venture,

as shown in Figure 2. The companies were chosen based on their score for innovation dimensions, as shown in Table 4. Aidmaster Engineering, REPINEL Electronic Solutions and Automation Systems had a score of 6.6 in D3, 5.8, and 6.6 in D4, respectively. DIMEYCO was chosen because it presents the lowest score of 3.3 in D3, but a 7.5 in D4. This mix of companies balances knowledge and experience in different areas.

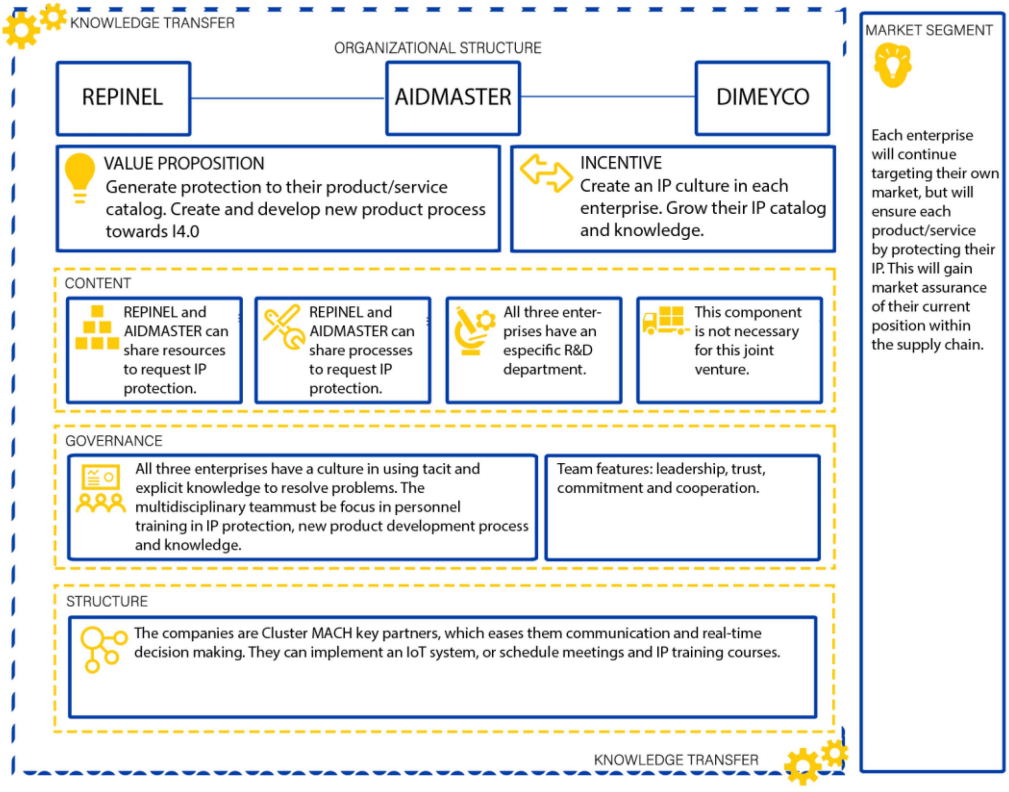

Figure 2. COHRV model applied for IP protection.

The COHRV model gives a new business model conceptualization. The complexities of the cluster are clear without losing detail and while providing a precise holistic picture. As can be observed, those companies integrate knowledge and experience focusing on IP protection, as is established in the value proposition block. The content block in Figure 2 shows the activities for horizontal collaboration regarding IP protection. Governance pinpoints the characteristics of the multidisciplinary team involved in IP protection, and the strategic measures that can enhance the partner's business competitiveness. Sharing the measures developed with the rest of the cluster's key partners strengthens the cluster IP systems and builds barriers to newcomers because of the IP protection culture, which finally enhances their business competitiveness. This strategy enhances social factors within sustainable manufacturing, by staff development and training in IP tasks and projects, thus reducing costs and avoiding application errors.

4.1.2. Design of a Joint Supply Chain to Standardize toward an Economy of Scale, Delivery Time, and Logistics within Common Suppliers

Profitability is an important factor for sustainable manufacturing [24]. Cluster MACH key partners can benefit from economies of scale, time delivery, and logistics by working on a horizontal collaboration project from common suppliers. This can in turn reduce the process through an eco-efficient procedure, being productive, socially beneficial, and financially practical [7,10]. For this proposed action, the COHRV model used three enterprises that interconnected their experience, knowledge, and use of I4.0 components, taking into account their line of business. The three enterprises used were: (1) TAMUSE Systems, with expertise in metal mechanics, automation, transformation, and software development; (2)

REPINEL Electronic Solutions and Automation Systems, with expertise in metal mechanics, automation, and software development; (3) PIMA Industries, with expertise in automation, as shown in Figure 3. From the competitive priorities in Table 5, the scores are 8.3, 8.3, and 7.5 in D2, respectively.

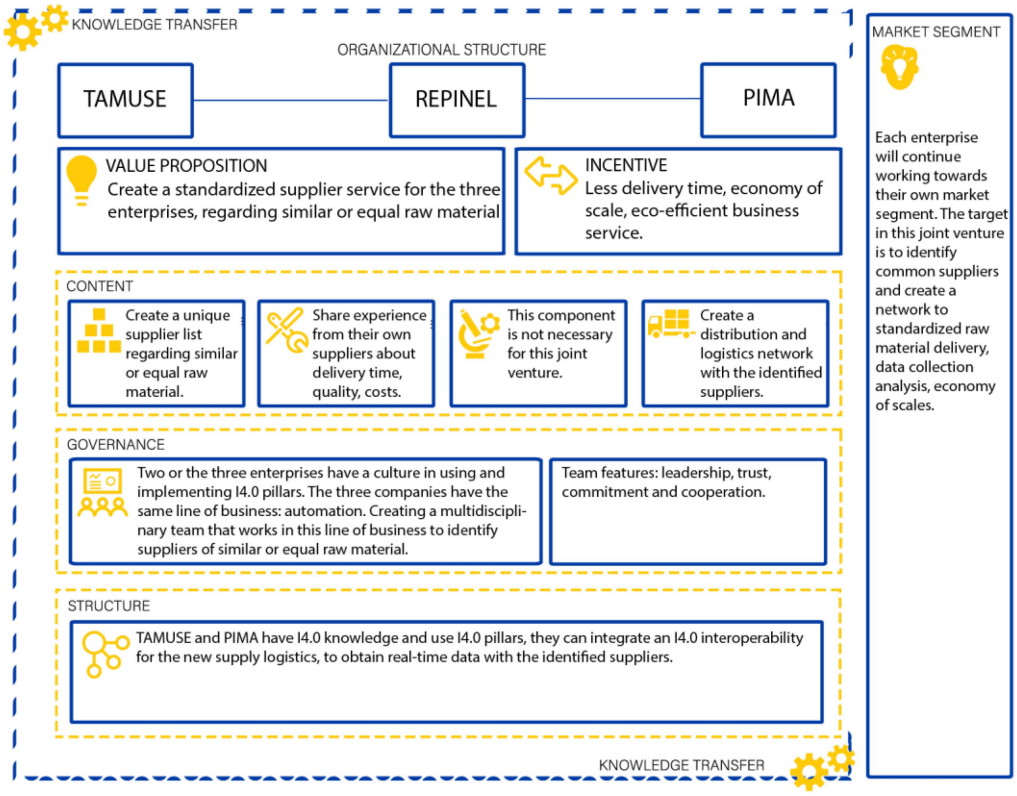

Figure 3. COHRV model applied for supply chain design with common suppliers.

The COHRV model presents a set of activities that can increase benefits and reduce the processes' environmental effects, while being financially viable for the three SMEs [7,8,10]. Since the introduction of just-in-time (JIT) in the 1980s, a highly recommended practice is the improvement and development of suppliers and long-term business relationships [25–27]. The three identified key partners have a great opportunity to design a joint supply chain, given their physical proximity to the multinational companies that they serve. The model indicates the measures needed to capitalize on the business opportunity and ensure sustainability, by reducing costs in lost production, spare parts, and raw material availability, within the economic factors. From the environmental factors, the proposed business model enhances reductions in energy, raw material consumption, and toxic emissions into the air, water, and soil.

4.1.3. Design a Joint Supply Chain to Identify Common Customers and Create New Distribution Channels and Logistics to Deliver Finished Goods

The third proposed action is the implementation of a new goods and services delivery logistics and distribution. The majority of Cluster MACHs key partners are tier level, delivering goods and services to multinational enterprises located in Ciudad Juarez. Sustainable manufacturing measures a reduction in different areas, such as emissions, energy consumption, and resources, among others, which, with this proposed action, can be delivered by the key partners' new strategy. The following horizontal collaboration business model targets a new joint distribution network.

Based on the competitive priority table, two key partners were identified: (1) IMSSA with a score of 10.0 in D5, 6.6 in D6, and 10.0 in D7; (2) PPESA with a score of 10.0 in D5, 5.5 in D6, and 3.3 in D7. Both companies have a similar line of business toward transformation,

and although their products differ from one another, their customers align within multinational enterprises, as shown in Figure 4. Using the COHRV model, these two key partners can participate in a joint venture by creating a new supply chain network toward delivering products and goods to the same customer; enhancing sustainable manufacturing by increasing green processes, such as reducing distribution emissions as a non-contaminating activity; and making financially viable processes by reducing or sharing delivery costs.

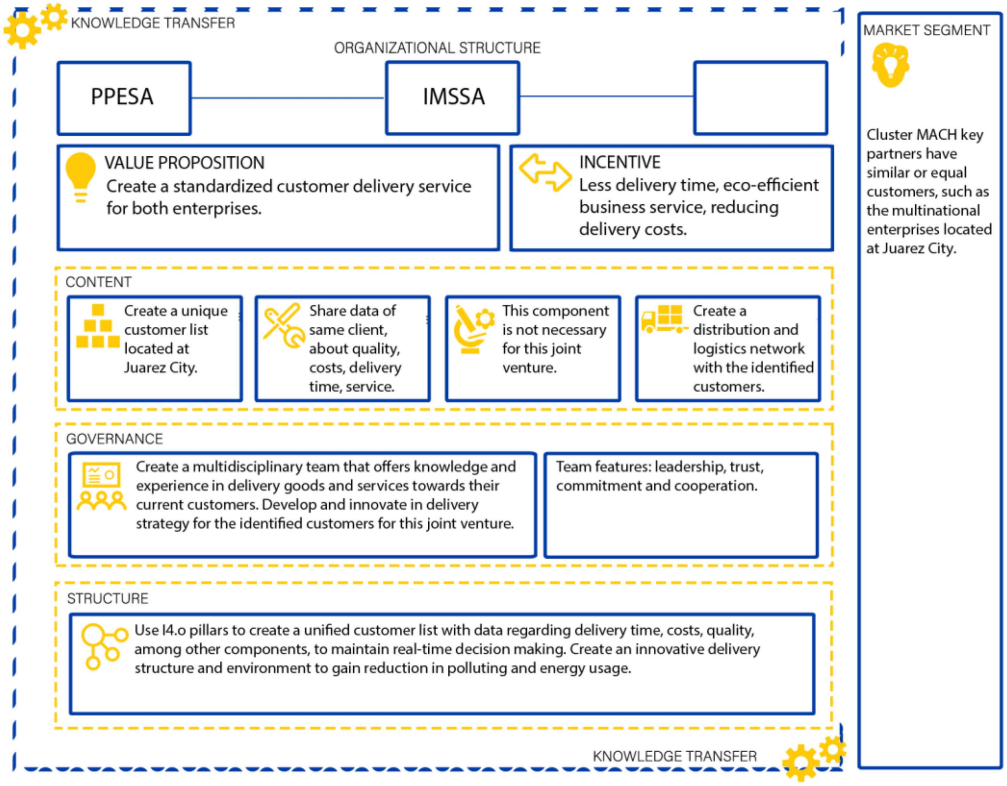

Figure 4. COHRV model applied for supply chain design for the delivery of finished goods.

Sustainable manufacturing creates networks where enterprises can analyze and optimize energy consumption in processes and operations, with a goal of reducing or eliminating waste and pollution, and enhancing employee, customer, and consumer safety [7,10,28]. This horizontal collaboration business model allows the Cluster MACH key partners to implement strategies to reduce pollution, by consolidating the delivery of goods or services to shared customers.

4.1.4. Create a Unique R&D Department so Each Enterprise Collaborates and Transfers Knowledge for New Product Design, Process Production, and Market Share

For the last action, Cluster MACHs key partners present a great opportunity, given that they are already partners of a cluster and thus, already have a neutral space to organize and implement an R&D department. The data obtained from the case study show that the enterprises' level of implementing an R&D environment is based on: (1) processes, (2) development, and (3) innovation and creativity. Table 6 lists the enterprises based on the level of knowledge management and the use of an R&D department.

Table 6. Knowledge management level from Cluster MACH key partners [23].

Key Partner	R&D Department	Knowledge Management Level	Description
TAMUSE REPINEL AIDMASTER DIMEYCO DMI IAI IMSSA PIMA PPESA	Has an R&D department	High-level based in innovation and creativity	Interaction of individuals to create new knowledge through new products or services.
		Medium-level based on development	Increasing the capabilities and competencies of the company's human capital.
	Doesn't have an R&D department	Low-level based on processes	Codification and improvements in processes, procedures, and methodologies.

From this action, the COHRV model shows a horizontal collaboration between nine key partners, the Cluster MACHs key partners as shown in Figure 5. The objective was to create an R&D department that every enterprise can use, where knowledge can be transferred and shared, resulting in reduced processes, energy consumption, and resource sharing, among other sustainable manufacturing factors within the three areas: economic, social, and environmental.

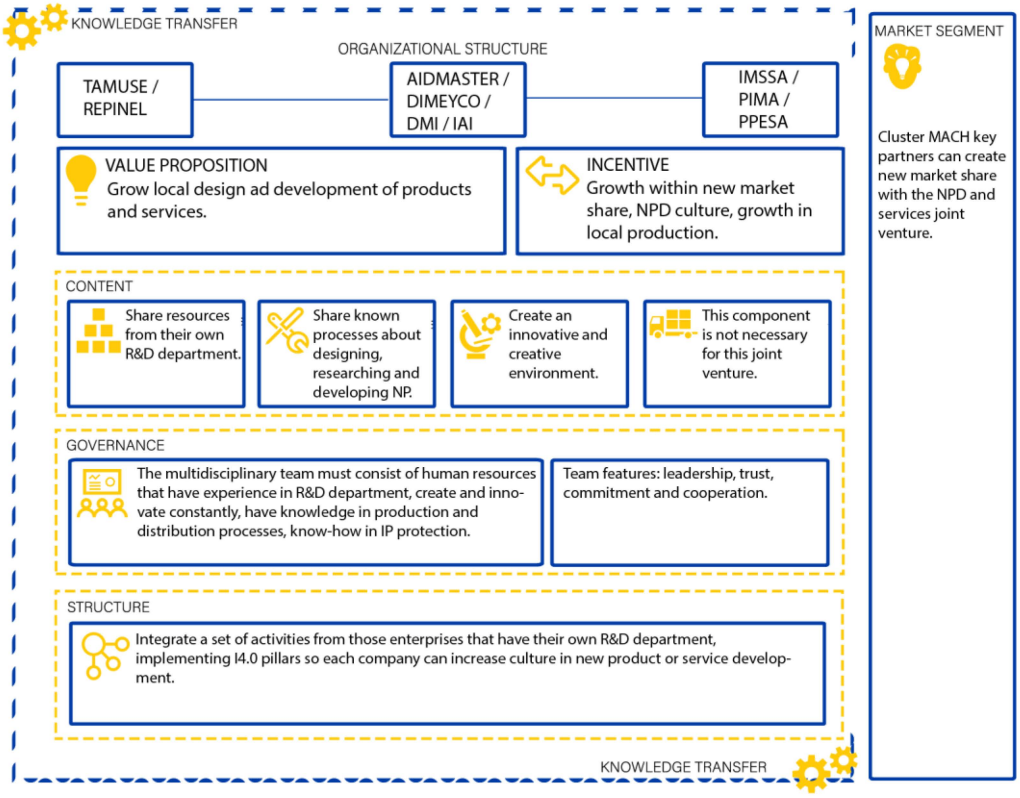

Figure 5. COHRV model applied for R&D department.

The interaction between I4.0 pillars and sustainable manufacturing, creates an innovative and creative environment in enterprises. For SMEs, the implementation of both themes is a little more complicated, due to their lack of financial resources, specific departments, and knowledge in certain technologies and components from each industrial revolution scheme [29]. Nevertheless, companies can work on developing new business models within a horizontal integration to unify their strengths and weaknesses. The COHRV model serves as a new business model framework for joint ventures through which enterprises can integrate their own knowledge, experience, technology, and assets, in order to achieve sustainable manufacturing.

5. Discussion

Enterprises must adapt to the new I4.0 era of digital manufacturing and globalization, where production processes are transformed, with a noticeable direction toward sustainable

manufacturing, to enhance companies' flexibility, speed, and quality, enabling communication and information for real-time decision making [5,30]. In [9], the authors present a structure of sustainable manufacturing pillars, for companies to gain decision-making skills. Nevertheless, I4.0 has challenges that enterprises must overcome to commit and develop a new value chain and business model within their manufacturing industry [6,28]. For SMEs, to achieve sustainable manufacturing within I4.0, vertical or horizontal integration can aid and ease this combination of factors in new joint strategies [29].

Then, this paper presents the Cluster MACH key partners, which have been previously analyzed as to how they managed knowledge, I4.0 pillars, and collaboration from within their own departments and personnel, as well as an industrial cluster [23]. From this article, the authors proposed four actions to the Cluster MACH key partners, so that they can work together and improve their level of knowledge management. The innovative approach was an adaptation of the Miltenburg matrix, to enhance a visual framework for enterprises to position themselves in one of the three knowledge base levels. The study proposed a further work to aid the cluster SMEs as to how they could collaborate and develop each one of the four proposed actions.

Finally, this paper presented the COHRV model [22]. This model is presented as a disruptive business framework as a result of a series of multi-criteria decision-making proposed methodologies. The COHRV model seeks to unify main horizontal collaboration and sustainable manufacturing components to create a disruptive business model toward a horizontal collaboration perspective. In this paper, the COHRV model has been applied so that enterprises can develop and plan new strategies for joint ventures, toward meeting their needs without compromising their economic, social, or environmental future [7,8], thus gaining sustainable manufacturing. The applicability of the COHRV Model is effective by pinpointing the joint ventures needed to strengthen the cluster, the plans now being deployed are enhancing sustainable manufacturing within the I4.0 pillars, producing acceptable results and benefits.

6. Conclusions and Recommendation

The main objective of this paper was to present the usability and effectiveness of the COHRV model as a disruptive horizontal collaboration business model. A previous case study was used to apply the four proposed actions to nine key partners of Cluster MACH. Each one of the actions were integrated into the COHRV model.

From a theoretical perspective, the COHRV model provides a framework that enhances SMEs opportunities to grow and develop within their supply chain link, thus creating, updating, and challenging product and service processes, distribution, and the use of new technologies. All the while considering the sustainable manufacturing pillars for enterprises to reduce costs, production processes, waste, and pollution, among others. In addition, SMEs can grow a culture of the R's components that sustainable manufacturing pillars drive.

From a practical perspective, the COHRV model is an effective visual framework for enterprises to visualize each of the model components. Each action integrated in the COHRV model brings a conceptual framework for the Cluster MACH key partners to know what, how, and who will contribute and collaborate in each strategic action.

Further analysis can be developed by measuring the results of the three sustainable manufacturing areas: economic, social, and environmental, with their respective factors to each of the four proposed COHRV models. For more analysis of the COHRV model, the disruptive business model may be applied in actions between enterprises, to investigate the incorporation of sustainable activities within competitive enterprises, not key partners of a cluster, toward green activities broadening the R's actions in manufacturing processes.

Author Contributions: Conceptualization, G.E.R.-M. and I.J.C.P.-O.; methodology, G.E.R.-M., I.J.C.P.-O., L.A.P.-D. and L.C.M.-G.; software, I.J.C.P.-O., L.A.P.-D. and L.C.M.-G.; validation, I.J.C.P.-O., L.A.P.-D. and L.C.M.-G.; formal analysis, G.E.R.-M., I.J.C.P.-O., S.N.-M., L.A.P.-D. and L.C.M.-G.; investigation, G.E.R.-M., I.J.C.P.-O., S.N.-M., L.A.P.-D. and L.C.M.-G.; resources, G.E.R.-M., I.J.C.P.-O.,

L.A.P.-D. and L.C.M.-G.; data curation, G.E.R.-M., I.J.C.P.-O., L.A.P.-D. and L.C.M.-G.; writing—original draft preparation, G.E.R.-M., S.N.-M., L.A.P.-D. and L.C.M.-G.; writing—review and editing, G.E.R.-M., I.J.C.P.-O., S.N.-M., L.A.P.-D. and L.C.M.-G.; visualization, G.E.R.-M., I.J.C.P.-O., L.A.P.-D. and L.C.M.-G.; supervision, G.E.R.-M., I.J.C.P.-O., S.N.-M., L.A.P.-D. and L.C.M.-G.; project administration, G.E.R.-M., I.J.C.P.-O., L.A.P.-D. and L.C.M.-G.; funding acquisition, G.E.R.-M. and I.J.C.P.-O. All authors have read and agreed to the published version of the manuscript.

Funding: This research received funding as part of the main author's scholarship given by the National Council for Science and Technology.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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