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Reconfigurability for higher Supply Chain Performance

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I. Introduction

Companies must respond to market changes and adapt their production systems, machines, equipment, and software to the effects of climate change, natural disasters, digitization, and cyber cyber-physical systems on the supply chain [1]. Consequently, this leads decision-makers and managers to restructure their supply chains [2], they must be flexible and reconfigurable due to the high susceptibility to variability, and their performance depends on the market [3]. A reconfigurable supply chain is a process that responds to market and industry regulatory changes [4], but their reconfiguration must be done quickly and cost-effectively [3]. Hence, over time companies have accelerated the processes of reconfigurability of their supply chains because of pandemics, technology changes, and global trade instabilities. Reconfigurability occurs to adapt quickly to customer needs, manage internal and external customer relationships efficiently, add or remove rapidly supply network partners, and achieve a responsive manufacturing system [5]. Indeed, a system with a high degree of reconfigurability can increase its production rate and product range with minimal time and cost [6].

Reconfigurability is one of the most influential paradigms for knowing manufacturing requirements. However, the definition of reconfigurability has been changing; it is considered an intermediate paradigm between Dedicated Manufacturing System (DMS) and Flexible Manufacturing System (FMS). Their denominations are modular manufacturing, component-based manufacturing systems, modular product systems, and flexible modular manufacturing.

However, given the changes and uncertainty of the manufacturing environment, reconfigurability is evaluated through the low and high levels at which companies implement many actions to reconfigure their manufacturing. At lower levels, all the changing hardware resources lead to achieving SC reconfigurability. It is mainly accomplished at higher levels by changing software resources and choosing alternative methods or organization structures by flexible people, which can be maximized cost-effectively [7]. Koren et al. (1999) argue that a cost-effective response to market changes requires a manufacturing approach that combines not only Dedicated manufacturing lines and a Flexible manufacturing system but also can react to change quickly and efficiently through a design of systems and machines for a flexible structure that enables systems scalability to market demands, and design manufacturing systems around the part family [4].

Dolgui et al. [8] defined reconfigurable SC (RSC) as "a network designed in a cost-efficient, responsive, sustainable, and resilient manner that is increasingly data-driven, dynamically adaptable, and capable of rapid structural changes in physical-cyber spaces by rearrangement and reallocation-of-its-components-to-quickly-adjust-supply-and-production capacities and functionality in response to sudden changes."

SC reconfigurability is the adjustment of operations to customers' needs in the shortest possible time; this requires systems capable of being rapidly modified, reducing or controlling costs, and reconfigurability efforts. The reconfigurability directly affects the SC functionality to respond quickly to new market circumstances explaining the performance of the supply chain. Reconfigurability enables rapid response to market changes and contributes to reduced SC costs, economies of scale, increased feasibility of product/component change, increased product variety, and reduced lead time [9]. In turn, reconfigurability is analyzed by the SC evaluated from visibility for sensing, learning, coordinating, and integrating [10]. SC reconfigurability needs I4.0 to connect the production areas providing technology to

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readjust productive and functional capacities to the client's demands. [11]

The primary benefit of reconfigurability in SC is the ability to react to changes rapidly and cost-effectively. Changes in SC derivate of reconfigurable applications are increasing the frequency of new product introductions due to shorter product life cycles, changes in parts for existing products to improve product customization, significant fluctuations in the quantity and mix of product demand, changes in government safety, environmental regulations, and process technology, resulted in higher-quality products. [12]

Koren et al. (1999) proposed reconfigurable manufacturing systems, defined as new manufacturing system that differs from the dedicated manufacturing lines and flexible manufacturing systems due to their character of multidimensional paradigm focused on implementing structural flexibility through adopting new technologies to stay competitive. It is an ability that allows the addition, removal, or rearrangement of manufacturing systems and functions. [3]

SC improves its performance if it can be reorganized or changed quickly and cost-effectively. Rapid is the keyword for adjusting and reconfiguring the SC; this includes rapid response to customer requirements, quick outsourcing/in-sourcing activities, and rapid addition or removal of partners from the supply network achieving responsive manufacturing. In addition, SC Quick Configuration permits product configuration and the inclusion of new intelligent technologies and software [5].

Other indicators to measure the reconfigurability level are lead time, reconfiguration time and cost, reliability, and productivity. SC depends directly on the ability to adapt to the market dynamic described by concepts such as agility, flexibility, adaptability, and alignment. [13]

Reconfigurability can be measured through its six ideal characteristics or dimensions; 1. Modularity, 2. Integrability, and 3. Diagnosability (Dimensions focused on the time and effort to reconfigure the SC), 4. Convertibility, 5. Scalability, and 6. Customization (Dimensions oriented to SC cost reduction). [6][14]

A. Reconfigurability dimensions oriented to reduce reconfiguration time and effort.

Modularity differs depending on the perspective from which we consider it. From the design perspective, Modularity is a design approach subdividing a system into smaller parts called modules. It can be created independently to be used in different production systems. From the user perspective, Modularity uses standard units to create product variants. It aims to identify independent, standardized, or interchangeable units to satisfy a variety of functions [15]. Besides, Modularity reduces system complexity, referring to physical and logical aspects, KPI, and the simulation model used to represent the system. It helps in deep knowledge about the system and guides the reconfiguration strategies. A module includes four aspects; 1. The physical aspect of the module, 2. The control aspect, and 3. The simulation aspect, and 4. KPI [16]. Also, Modularity can define as the strategy for constructing processes and products starting from more complex subsystems, which build individually, but with integrated operations enabling the production of different products through different combinations [17]. Modularity is composed of network structure design, responsiveness, and total cycle time [5], and it is measured considering the fundamental degree of coupling of a product independent of where the module boundaries are set [14]

Integrability is the operation's ability to incorporate components or modules to introduce new technologies and procedures into an existing structure through mechanical and informational technologies and tools, to facilitate integration and communication [17]. Other authors suggest that integrability is the ability to add or remove resources. In other words, integrability readily integrates the systems and components, introducing future technology [18]. Also, it is the ability to incorporate existing processes and resources within the supply network to establish a mechanism combining the introduction of new SC processes and resources. Integrability can be composed of Real-time integration, Collaboration, and Transfer pricing [5]. *Diagnosability* is a way to detect and correct failures as soon as possible following three parameters: detectability, predictability, and distinguishability. Diagnosability allows quick identify problems from the beginning reducing supply network effectiveness and efficiency. It is the ability to quickly read the problems, current state, sources of quality, and reliability problems, diagnosing the root cause of output product defects that occurs in large systems [17]. Diagnosability is assessed through Visibility, Data reliability, and resilience. [5]

B. Reconfigurability dimensions oriented to cost reduction.

Scalability maintains cost-effectiveness as the workload grows [14]; it is the capability of manufacturing systems to adapt their throughputs to changing demands with minimal cost, in minimal time, over an extensive capacity range, at given capacity increments [17][14]. Scalability in the SC depends on latency, the ability to achieve performance objectives in an uncertain environment, and data quality; this is assessed through delays in SC performance [6]

Convertibility is the capability of a system to adjust production functionality or changes from one product to another [14]. Convertibility refers to the ability to easily change the functionality of the existing system and machines to match new production and market requirements [17]. Convertibility is the capacity of SC partner firms to adapt to future products from the existing ones fast. It involves the flexibility of process and resource entities within each firm [5]. Convertibility is measured based on the increment of conversion, the routing connections, and the replicated machine [6]. Also, it can be measured by considering Adaptability, Leagility, and Trust [5].

Customization can measure by the product's degree of freedom. It is the degree to which the capability and flexibility of the manufacturing system (hardware and control) match the application or product family [18].

Customization is the system's ability to produce a product with features specific to a particular customer [17]. It can be measured through the value-added time, throughput rate, and the average number of customizable functions [6]. Similarly, customization can be evaluated through new Product development, customer satisfaction, and sustainability [5]. Firms continuously measured the customization level due to the increasing frequency of new product introduction, changes in the components for existing products, fluctuations in product demand and product mix, changes in government regulations (safety and environment), and changes in process technology [14].

C. SC performance and reconfigurability.

SC is a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and information from their origin (suppliers) to customers [19]. SC refers to activities that produce specific or added value for customers [20] and is considered a philosophy because of its impact on the internal and external members of SC performance [21]. Recent literature shows that SC is a relevant part of daily business that constantly evolves and integrates suppliers and customers with internal functions to optimize all SC members' performance [22]. SC is a system that includes material suppliers, production facilities, distribution services, and customers linked together through tracking of material flows and the flow of information feedback. [23]

SC performance can measure at strategic, tactical, and operational levels [23] by considering dimensions such as flexibility, reliability, responsiveness, quality (assurance, detected and corrected), asset management, and information sharing (connection with customer and supplier). These SCP dimensions can drive SC to a high SC performance. Therefore, Companies are restructuring and adapting SC to respond to market demands and build strong customer relationships. But, to achieve that, companies need to accelerate the reconfiguration effectively-cost to rearrange their SC. Different studies suggest that SC improves its performance if reorganized or changed rapidly and cost-effectively their SC to adjust to customer and supplier demands (this refers to the REC implementation). But REC requires a rapid process to reconfigure SC accelerated, implying a faster response to customer requirements, outsourcing/in-sourcing activities, and partners' addition or removal from the supply network achieving responsive manufacturing.

C. Hypotheses development

Although the literature expresses that the set of reconfigurability dimensions contributes to the evaluation of reconfigurability performance, it is still unknown how each reconfigurability dimension contributes to the SC reconfigurability and the improvement of SC performance.

Additionally, the studies do not demonstrate the orientation of the reconfigurability of manufacturing systems. It is unknown if REC is oriented or focused on the time and effort to reconfigure the SC (ROTER: Modularity, Integrability, and Diagnosability); or if REC is cost reduction oriented (ROCR: Convertibility and Customization) [4].

On the other hand, even though many studies have analyzed reconfigurability and each of its dimensions, the contribution of each reconfigurability dimension still needs to be discovered to improve and achieve a high SC performance. Therefore, it is critical to analyze the levels of each reconfigurability dimension that must be reached to increase the SC performance. Consequently, this leads to the following hypotheses.

- H1: Reconfigurability is positively related to SC performance.
- H2: There is a positive and significant relationship between reconfigurability oriented to reducing time and effort (ROTER) and SC performance.
- H3: There is a significant relationship between cost-reduction-oriented reconfigurability (ROCR) and SC performance.
- H4: ROTER and ROCR drive SC performance.
- H5: ROCR dimension improves SC performance, but when companies focus on the ROTER dimension, SC performance increases positively and significantly.

Hence, this research aims to evaluate the effect of each reconfigurability dimension on SC performance and analyze the sectors that show higher manufacturing reconfigurability processes levels. Thus, in the next section, we present the methodology. Section 3 presents the results and discussion of the investigation. In the final section, we show the conclusions and future research.

II. METHODOLOGY

The research technique used for data collection was the survey, using a questionnaire from the fourth round of the international project called HPM (High-Performance Manufacturing). We develop an intensive literature review to support the main concepts (Reconfigurability, Supply chain performance). This questionnaire comprises 16 scales, with more than 160 variables and their respective items. Industry practitioners and academics pre-test all the final questionnaire items to check the content validity. The scales rationality is based on the contributions of researchers such as Koren 2010; Malhotra, Raj & Arora, 2010; Bi, Lang, Shen & Wang 2008; Molina, Rodriguez, Ahuett, Corts, Jimines & Martinez, 2005; Mehrabi, Ulsoy, Koren & Heytler, 2002, Mehrabi, Ulsoy & Koren, 2000; Koren, Jovane, Heisel, Moriwaki, Pritschow, Ulsoy & Van Brussel, 1999, Min, Mentzer & Ladd, 2007; Fullerton and Wempe, 2009.

Responses were rated on a five-point Likert scale (where 1=Strongly Disagree and 5=Strongly Agree). Besides, we operationalize the scale using at least six items. The survey was consolidated into 12 questionnaires referring to 12 functional areas. The analytical unit was the plant. An average of 23 employees per plant responded to the questionnaires. The empirical analysis considers the database of the fourth round of the international HPM project, which includes 309 manufacturing plant responses. The HPM database comprises fourteen countries' machinery, auto supplier, and electronics sectors. [24] (see Table I)

TABLE I
SAMPLE PROFILE

Country	Auto supplier	Electronics	Machinery
Vietnam	7	9	5
Austria	1	1	6
Brazil	6	3	6
China	3	9	16
Spain	6	7	7
Finland	4	6	6
Germany	7	6	10
Israel	0	7	1
Italy	5	7	16
Japan	9	6	5
Korean	12	8	5
Sweden	1	4	2
Taiwan	1	19	10
UK	4	4	5
Number of employees	Percent of distribution		
250<	50%	56%	63%
250-1000	37%	30%	24%
>1000	13%	14%	13%

Finally, only 262 of 309 companies responded to all the items of the scales: Reconfigurability and Supply Chain performance, which are the core of this research. Regarding the number of employees, 63% percent of the machinery Plants had less than 250 employees, 24% had between 250 and 1000, and 13% had more than 1000 employees. 56%. of electronic Firms had less than 250 employees, 30% had between 250 to 1000 employees, and 14% had more than 1000 employees, a total of 56%. The auto supplier sector had 50% of Firms with less than 250 employees, 37% had between 250 to 1000 employees, and only 13% had more than 1000 employees. However, the sample size is enough to test our hypothesis.

The survey was analyzed through content, criterion, and construct validity. Further, we developed an Exploratory Factor Analysis (EFA) because the variables used in this research are theoretically explained in the literature but are still unknown for verification using empirical evidence because of the novelty and the faster this paradigm is changing. Also, it is necessary for more exploratory analysis because the revolution technology and contextual variables are modifying the variables that better contribute to responding to market demand. Thus, to justify construct validity, we tested an EFA using principal component and varimax rotation (due to the correlation between variables being less than 0.70), considering Reconfigurability and Supply Chain performance constructs. As a result of EFA, the Kaiser-Mayer-Olkin measure of sample adequacy was 0.883, the chi-square of 2885.793, the degree of freedom of 210, and the p-value was $p<0.000$. Therefore, the variables are highly correlated, providing a reasonable basis for factor analysis [25]. Furthermore, the extracted communalities were greater than 0.5.

The EFA test reduced the variables into two constructs. The total variance explained by the two constructs was around 63%. We used the alpha of Cronbach, CR, and AVE to demonstrate that the test was correct in expecting a specific collection of items to yield interpretable statements about individual differences [26]. Additionally, we assessed the total variance extracted by one factor to ensure that common method bias is not present. The total variance extracted by one factor evaluated was 31.508%, less than 50%. Hence, there is no problem with common method bias [27]. Thus, the solution is viable; all the standardized regression coefficients were more significant than 0.50, representing an excellent correlation between the item and the factor. This indicates that the dimensions of the factors evaluated are better accounted for by the variables, showing unidimensionality [28].

The reliability of each scale was measured using Cronbach's Alpha, reaching each coefficient with a value greater than 0.8, indicating a high internal consistency [26]. Additionally, we measured Average Variance Extracted (AVE), and the values are well above the recommended value (AVE>=0.50). We also tested the composite Reliability (CR), whose values were above 0.60, which is an acceptable value to indicate scale has internal consistency.

The model considered Supply chain performance (SCP) as the dependent variable and Reconfigurability (REC) as an independent variable. REC was measured through its six dimensions (Convertibility, Customization, Diagnosability, Integrability, Modularity, and Scalability). Supply chain performance was composed of nine variables (Supply Chain Information Sharing by Customer and Supplier, Supply Chain Information Sharing with customers and suppliers, JIT Link with Customers, Information Technology, Shared Meaning, Supplier Lead Time, Flexibility of the Relationship, Product Identification and Traceability, Supply Chain Evaluation, and Performance Assessment). The model evaluation was divided into four single-measured model analyses to test the hypothesis (see Fig. 1). We used Hierarchical regression analysis to identify the percentage of variance explained by each independent variable in a separate mode [24]. This technique is the most appropriate and conservative, as opposed to the covariance-based method, due to the complexity of the model and the available data, showing outstanding robustness when assessing the model.

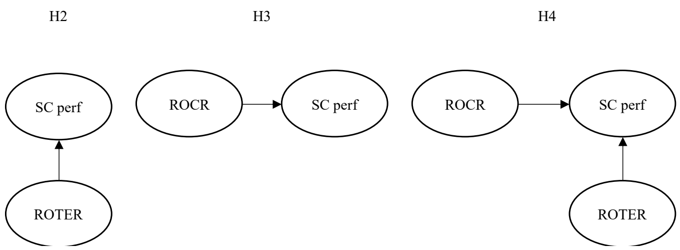

Fig. 1 Hierarchical regression model analysis

The sample requires to measure any regression model is 50+8K, where K is the number of independent variables present in a model. Therefore, the data sample of this research meets the minimum requirements [29]. Due to the existing correlation between the independent variable, the division of variance through the hierarchical regression model is the most appropriate methodology [24]. Hence, we tested the relationship between REC y SCP (H2). Then, we measured the relationship between ROCR and SCP (H3). Third, we insert each dimension in two blocks, the reconfigurability dimension related to time and reconfigurability effort. In a second block, we introduced the cost reduction reconfigurability dimension (H4) (see Fig. 1). To test H5, we introduced in the first block ROCR dimension, and a second block ROTER dimension (see Fig. 2)

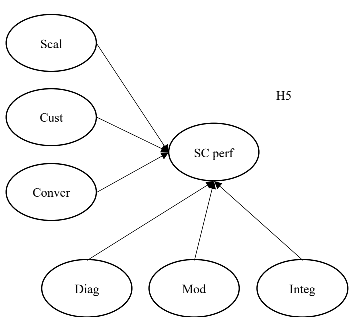

Fig. 2 Hierarchical regression model analysis

III. Results

First, we evaluated the correlation between variables. All values were higher than 0.4, except the correlation between Modularity and Diagnosability (Table II). SC performance has a low degree of association with Modularity and Convertibility dimensions. It is because SC and manufacturing Plants needed changes in tools, parts programs, and fixtures. Although Modularity and diagnosability are complementary, results show that the relationship between these variables could be more robust. Thus, this is because some companies have fault detection systems or equipment that can interchange intra-modularly to avoid delays. On the other hand, convertibility shows high and full levels of relationship with Integrability, Diagnosability, and Scalability, indicating that the evaluated companies can incorporate components or modules to introduce new technologies and processes, developing them effectively and at acceptable costs, which allows the exchange in an accelerated way from one product to another according to the new requirements. Otherwise, the current companies' capacities for diagnosability or identification of problems contribute to the flexibility of manufacturing systems and identify modifications that allow adjusted production levels.

TABLE II
CORRELATION MATRIX

Variables	Modularity	Integrability	Diagnosability	Scalability	Convertibility	Customization	SC performance
Modularity	1						
Integrability	0.618	1					
Diagnosability	0.373	0.548	1				
Scalability	0.474	0.581	0.536	1			
Convertibility	0.417	0.655	0.617	0.628	1		
Customization	0.44	0.552	0.679	0.532	0.582	1	
SC performance	0.324	0.336	0.205	0.238	0.328	0.197	1

Additionally, we evaluated the reconfigurability dimensions oriented to the reconfiguration times and effort reductions (ROTER). Companies were separated by sectors to test ROTER, determining that the companies analyzed have an orientation of the reconfigurability manufacturing systems towards reduction of times and efforts of average reconfiguration (3.23 of 5).

TABLE III
ROTER DIMENSION

SECTOR	Modularity	Integrability	Diagnosability	ROTER
Auto supplier	3.23	3.24	3.43	3.30
Electronic	2.90	3.43	3.54	3.29
Machinery	2.82	3.17	3.42	3.13
Total	2.95	3.28	3.46	3.23

The Auto supplier sector shows the highest levels of reconfigurability aimed at reducing reconfiguration times and efforts, while the Machinery sector shows the lowest levels of this indicator (See Table III). It is important to visualize that companies are more focused on Diagnosability through early detection systems of problems, and to a lesser extent, on the Modularity of their manufacturing.

Also, we analyzed the level of reconfigurability oriented to cost reduction (ROCR). We found that some companies consider two ways of Customization; oriented to control (companies integrating control modules) and flexible due to machines built around part of the family manufactured. Customization control is concerned with using open-architecture technology to integrate control modules. The Electronics sector shows higher efforts to reconfigure its CS based on cost reduction, while the Machinery sector presents the lowest levels of reconfigurability aimed at reducing costs (See Table IV).

TABLE IV
ROCR DIMENSION

SECTOR	Scalability	Convertibility	Customization	ROCR
Auto Suppliers	3.38	3.26	3.55	3.40
Electronic	3.67	3.49	3.63	3.60
Machinery	3.47	3.17	3.53	3.39
Total	3.52	3.31	3.57	3.47

Table III and IV summarizes the implementation level of each REC dimension and SC performance. Again, we can see a low difference between reconfigurability and SC performance levels. Also, the table shows the inclination of the companies and their SC to reconfigure operations based on cost-effectiveness due to investments in technology and equipment that demands reconfiguring the SC based on time and machinery.

For this reason, the levels of Modularity are the lowest compared to the rest of the dimensions, followed by Integrability due to interface problems (software and hardware), technologies, machinery, and current equipment in the companies analyzed. In turn, due to costs, equipment, and level of technological inclusion, companies need the facility to create product variants. In addition, there are problems with the standardization of interfaces, module independence, machine module relationship, number of shared modules, and Intra-modules and Inter-modules interaction.

We evaluated the contribution of each reconfigurability dimension to SC performance. Thus, we group the reconfigurability dimension into two blocks considering the proposed by Koren et al. (1999). The first block is the reconfigurability dimension associated with time reduction and reconfigurability effort, and the second block is the reconfigurability dimension associated with cost reduction. Then, the Hierarchical regression analysis model was used to test the research hypothesis, entering the independent variables into two blocks. Block one includes the independent variables: Modularity, Integrability, and Diagnosability, and Block two, was composed of independent variables; Scalability, Convertibility, and Customization. SC performance was considered the dependent variable.

Multicollinearity was tested through VIF values, concluding that multicollinearity among independent variables is not a problem (VIF less than 5). Furthermore, the Durbin-Watson statistic was 1.902 (value between 1.5-2.5), suggesting the hierarchical regression output is free from the auto-correlation effect [29]. Therefore, we can conclude that the constructs of our theoretical framework possess reliability and convergent validity (see Table V).

TABLE V
MODEL TEST

Factor	**Supply chain performance**			
	Model 1 (H2)	**Model 2 (H3)**	**Model 3 (H4)**	**Model (H5)**
ROTER	0.251**			
ROCR		0.215**		
Customization			0.006**	0.122**
Convertibility			0.177**	-0.47
Scalability			0.254**	0.121**
Modularity				0.136**
Diagnosability				-0.160*
Integrability				0.063**
F	36.070**	25.954**	15.683**	9.679**
R	0.349	0.301	0.329	0.399
R^2	0.122	0.0910	0.108	0.159
Adjusted R^2	0.118	0.870	0.101	0.143
VIF	1	1	1.512	2.167
Durbin-Watson statistic	1.401	1.332	1	1.369
t-statistic	6.606		5.592	5.5359

Table V shows a significant and positive relationship between the variables. The standard deviation and variance were less than 0.6, indicating low variability of the data, meeting the requirements to test the model. The reliability test from Durbin Watson's statistic and VIF values indicated no multicollinearity or autocorrelation problems. The coefficients were significant ($p<0.000$), indicating that multicollinearity was unlikely to be a problem. The beta values contributed significantly to the dependent variable ($p<0.05$), but Modularity is the best predictor for enhancing SC performance.

For H1, we estimated the relationship between reconfigurability and SC performance. R-value was 0.347. The R^2 value was 0.120, and the model was significant F (1, 260): 35.576 ($p<0.000$), β =0.261 ($p<0.000$). Also, we tested H2, measuring the dependence relationship between SC performance and ROTER (model 1). The result was significant, with a moderated relationship level between variables. The R^2 value explains 12.2% of the dependent variable variance, and the model tested was statistically significant F (1, 260): 36.070; ($p<0.000$). Also, we evaluate the relationship between ROCR and SC performance (model

2). The R^2 value was 0.0910, and F (1, 260): 25.954; (p <0.000). ROCR explains 9.10% of the SC performance variance. Hence, we accept H1, H2, and H3, concluding that SC performance and reconfigurability (ROTER and RORC) have a positive and significant relationship.

To evaluate models 4 and 5, we use a hierarchical multiple regression. First, we enter Customization, Scalability, and Convertibility as predictor variables. The results showed a statistically significant model (F (2, 259) = 15.683; p < .000)). The R-square value explains 11% of the dependent variable variance. Second, we added Modularity, Diagnosability, and Integrability as explanatory factors of SCP.

The R^2 value explains 15.9% of the Dependent variable variance. When we included this second block of REC variables in the model, we found an increment of R^2 value, this meaning an additional 5.1% of the Dependent variable variance (F (3, 256) = 9.679; p <0.001; R^2 Change = 0.051; p <0.001). All the predictor variables in this model are statistically significant except convertibility. Modularity reported a higher Beta value (β = 0.136, p < .001) than Customization (β = 0.122, p < .001).

Hence, we accept H4 and H5 because the two blocks of REC (ROTER and RORC) improve SC performance. In addition, when we introduce each ROTER and ROCR dimension in blocks, the variance explained by SC performance increases; this result is consistent with the literature and empirical evidence that expresses that nowadays, companies prefer to orient their reconfigurable processes to reduce cost and then start an initiative to reconfigure their manufacturing process-oriented in lead time and reconfigurable effort. [4]

IV. Conclusion

Companies are accelerating the process of SC reconfigurability due to market turbulence and the need to adapt faster to market demands. Nonetheless, Companies prioritize which reconfigurable dimensions are the less costly at the time, increasing the efficient processes. Therefore, companies could focus on implementing and improving SC considering the reconfigurability dimension in blocks, considering the current Plant technologies, layout, capacity of Plant investment, and operative resources[29][30].

Empirical evidence supports the hypothesis that some companies are improving SC reconfigurability focused on the reconfigurability dimensions that, in the short term, reduce manufacturing costs and respond quickly to market demands. Also, the companies are promoting those reconfigurability dimensions that seek to diminish reconfiguration times and efforts. Many reasons lead companies to prioritize which reconfigurability dimension is necessary to improve quickly.

SC reconfigurability increases risk and complexity in companies. On the other hand, implementing a reconfigurable supply chain can require investments in technology and training so that the implementation costs would be higher. [31] These are the high costs necessary to improve or change machinery and equipment, adjust interfaces, invest in new technologies and equipment that are integrated, and accelerate manufacturing reconfigurability of processes following market demands.

Statistical results support the literature review of this research; Companies' investment in the reconfigurability dimension in the way that dimension improves SC performance. But we demonstrated that companies prefer to invest in a reconfigurability dimension that more quickly solves or contributes to changing their operation process and manufacturing adaptability and agility to respond to market demands while allowing you to be competitive.

Also, the results show that companies have taken few actions to promote the manufacturer's Modularity due to the economic implications associated with the structure, equipment, machinery, product families, and interfaces. Companies need to improve the degree of coupling, cohesion, and number of modules, especially for modular product architectures. Besides, Integrability shows medium levels of implementation because not all companies can incorporate components or modules to introduce new technologies and procedures into an existing structure through a set of mechanical and informational tools facilitating integration and communication.

For decision-makers, it is necessary to prioritize the progressive improvement of the Modularity capacity along SC. It will continuously improve the rest of the reconfigurability dimensions if the Diagnosability levels are promoted with new technologies for the timely detection and correction of SC problems. However, we can only achieve the changes in stages. Therefore, it is necessary to modify machine-by-machine or line-by-line production until accomplished a reconfiguration and intelligently controls the production structure. Also, there needs to be more research analyzing empirical evidence to explore and test the effect of REC on SC performance.

Hence, a Confirmatory Factor Analysis (CFA) is necessary for future studies to verify the factor structure of a set of observed variables considered in this research. In addition, in future research, we must analyze which machinery and technologies are a priority to reconfigure SC and which short-term actions need to be accelerated to boost the responsiveness capacity of companies.

Besides, not only have to focus on the analysis of the manufacturing part, but it is also necessary to move reconfigurability from a 3.0 to a 5.0, evaluating the strategic and technological issues, equipment, and paradigms that improve reconfigurability. It is needed to analyze how technology contributes to the improvement of reconfigurability through the I4.0 inclusion along SC, the responsiveness generated from reconfigurability, and evaluate the changes in operational and financial performance derived from the reconfigurability processes mediated by the technology and the strategic actions of the company.

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