SUSTAINABILITY VALUATION MODEL FOR AN EXPORTING COMPANY 4.0.

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Abstract. Industry 4.0 came by digital technology and the promise of increased productivity based on data. The scenario is useful to the stakeholder of the sustainable exporting company because it allows it to create value for the goods it exports. But a model that accepts uncertainty is required to relate the input variables: digital technology and strategy 4.0 with the output variable: sustainability. A problem that is solved under a fuzzy logic approach and the fuzzy inference system which generates the data set to train, control, and validate the adaptive network of the fuzzy inference system (ANFIS). Which, creates the algorithm of the sustainability valuation model (SVM). Thus the general objective is completed, and then the model is used in five exporting companies to supervise, control, and calibrating the result of the output variable, which can be a value between zero and one, where zero means loss sustainability and one reflect high sustainability. Data and knowledge that allows the stakeholder to make strategic decisions about advanced digital skills and competencies in the workplace, which is an innovation in the context of Industry 4.0 that allows a contribution of knowledge to the economic literature and management of the business. The SVM will continue its training process with new exporting ecosystems, face-to-face interviews, and adapt its content to another language.

Keywords. Sustainability, digital technology, Industry 4.0, and fuzzy logic.

MODELO DE VALUACIÓN DE SOSTENIBILIDAD PARA UNA EMPRESA EXPORTADORA 4.0.

Resumen. La Industria 4.0 llegó con la tecnología digital y la promesa de un incremento de la productividad sobre la base de dato. El escenario es útil al *stakeholder* de la empresa exportadora sostenible, porque le permite crear valor a

los bienes que exporta. Pero se requiere un modelo que acepte la incertidumbre para relacionar las variables de entrada: tecnología digital y estrategia 4.0 con la variable de salida: sostenibilidad. Un problema que se resuelve bajo un enfoque de la lógica difusa y el sistema de inferencia difusa el cual genera el conjunto de datos para entrenar, controlar y validar la red adaptativa del sistema de inferencia difusa (ANFIS). Lo que permite construir el algoritmo del modelo de valuación de sostenibilidad (MVS) y así se completa el objetivo general. Luego, el modelo se utiliza en cinco empresas exportadoras con el propósito de supervisar, controlar y calibrar el resultado de la variable de salida, el cual puede ser un valor, entre cero y uno, donde cero significa una baja sostenibilidad y uno refleja una alta sostenibilidad. Dato y conocimiento que le permite al *stakeholder* tomar decisiones estratégicas sobre las habilidades y competencias digitales avanzadas en el puesto de trabajo, lo cual es toda una innovación en el contexto de la Industria 4.0 que permite una contribución de conocimiento a la literatura económica y gestión de empresa. El MVS continuara su proceso de entrenamiento con nuevos ecosistemas exportadores, entrevistas presenciales y adaptar su contenido a otro idioma.

Palabras claves. sostenibilidad, tecnología digital, Industria 4.0 y lógica difusa.

Introduction

Justification

When the fourth industrial revolution or Industry 4.0 arrived, it was accompanied by the complex knowledge of digital technology (DT) widely used by exporting companies to add value to their export goods, while the current knowledge of DT is predominant in the traditional exporting company. In other words, in the universe of the goods exporting company there is a DT gap that the research takes advantage of to propose a sustainability valuation model, which has two input variables: (i) efficient use of digital technology and (ii) use of the strategy proposed by Industry 4.0.

With the two input variables, whose nature is linguistic, the architecture of the fuzzy inference system (FIS) and the adaptive neuro-fuzzy inference system (ANFIS) are built. A system under fuzzy logic that delivers an output variable called "sustainability" of the business. The proposal is defined as the sustainability valuation model (SVM), necessary in these times of uncertainty for the *stakeholder* and very useful in an export ecosystem to make public policy decisions under the context of Industry 4.0.

General Objective

Under the fuzzy logic approach, the general objective is to propose a sustainability valuation model (SVM) for use in an exporting company 4.0. The architecture, which is original and innovative, will be explained in the research methodology section. Under the use of fuzzy logic, FIS and ANFIS have a wide use in applied economics (Trigueros, 2019), engineering systems (Acheson, Dagli, and Kilicay-Ergin, 2013), high-tech manufacturing (Yadegaridehkordi, 2018), agriculture, and ecology (Gay and Vermonden, 2013). That is, an intense use in those branches of knowledge in which man relates to his equals, since it reflects more reliably the behavior of the human brain (Gil Aluja and Kaufmann, 1987).

Industry 4.0

In April 2011, the German government defined the project of "Industry 4.0: with the Internet of Things on the way to the Fourth Industrial Revolution." Since that date, Industry 4.0

has become mainstream in the industrial economy (Blanco, Fontrodona, and Poveda, 2017) and is the basis for the next wave of data-driven productivity increase (University 4 Industry, 2013). The other contribution is the Pyramid 4.0 strategy which has dual causality: (i) vertical causality that occurs from the pyramid base to the top, and (ii) horizontal causality that starts with data capture, data processing, and data use. See figure 1.

The third aspect of Industry 4.0 is the digital technology S-curve (S_{TD}) and the human adaptability S-curve (S_{AH}) (Bocci, 2019), see Figure 2. The S_{TD} curve represents the knowledge of digital technology and the S_{AH} curve represents the use of digital technology adopted by the people working in the company. The distance between the two S-curves represents the digital technology gap. The vertical distance between the S_{TD} curve and the S_{AH} curve represents the low uptake of digital technology in Industry 4.0.
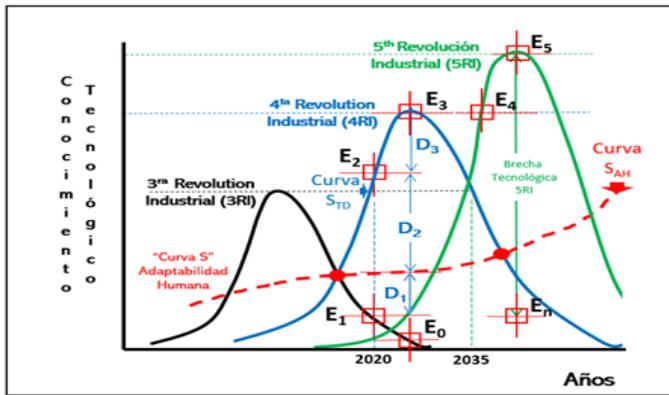

Figure 1. Pyramid 4.0. (cause-effect)
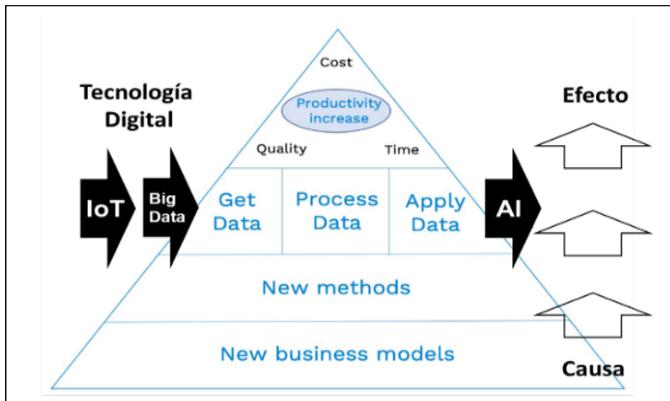*Note:* Source: University 4 Industry, 2013

Figure 2. S_{TD} curve (color green) or S-4IR curve.
Note: Source: Own elaboration, 2020.

Likewise, the S_{TD} curve intersects with the S_{AH} curve which generates a subset of firms below the S_{AH} curve and a subset of firms above the S_{AH} curve. Companies that are located in scenario E1, under the S_{AH} curve, are forced to position themselves above the S_{AH} curve. If they fail to do so, they run the risk of their export products becoming obsolete in the face of the fifth

industrial revolution (5IR). A disadvantage in the face of the arrival of quantum computer technology that will appear in 2030 (Stewart, 2019).

Export 4.0

The splendor of the export of goods began in 1971 when the Bretton Woods Conference agreement ended, a date that initiated the GATT-WTO agreement, the Doha Round and the Information Technology Agreement (ITA). This scenario allowed Industry 4.0 to boost the export economy 4.0 based on the intensive use of digital technology, the consequence of which is the promotion of digital industrial production and digital craftsmanship, which emulates the first industrial revolution (1IR).

Before the 1IR the production of a good was a handicraft production and the success of the export depended on the knowledge to take the artifact from point A to point B. With the advent of the industrial revolution, industrial production was introduced, the success of which depended on the use of the scientific and technological knowledge of the time. That is to say, during industrial production an artifact that is exported carries a hidden effect: the scientific and technological knowledge of the society of the time.

The Economic Complexity Index (OEC, 2020) shows each country with the knowledge associated with exportable goods. According to the index, developed countries are leaders in exporting goods with complex digital technology knowledge, while developing countries strive to ensure that their products do not have a larger digital technology gap. Based on the above, developing countries need to boost Industry 4.0 to improve the sustainability of exporting companies.

Sustainability

The exporting company 4.0 has the responsibility to adopt sustainable development that meets the needs of the present without compromising the ability of future generations to meet their own needs (ISO, 2010). It implies a shift from the idea of sustainability, mainly ecological, to a framework that emphasizes the economic and social context of development (Barcellos, 2010). In other words, sustainability and sustainable development can be seen as a way to express the broader expectation of society as a whole (ISO, 2010), which represents a motivation for the exporting company 4.0 to adopt a balance between economic, social, and environmental aspects. It is necessary to become more aware of its responsibilities towards society as a whole with the conviction that this is in its own interest (Olcese, 2005).

On the basis that the traditional company has a *shareholder* approach oriented to shareholders, customers, and collaborators, whose interest is to enhance tangible assets and their expectations in the short term (Barcellos, 2010), the only objective is to maximize profits and answer to shareholders. While the sustainable company has a *stakeholder* approach whose objective is to enhance tangible and intangible assets and its expectations are long-term. In other words, the company is subject to a strategy and internal codes of conduct that respect social and environmental rights. (Barcellos, 2010), conduct that the sustainable company must show in tangible form in its exportable goods.

For this reason, the concept of sustainability represents a new approach to doing business (Barcellos, 2010) and the creation of sustainable value requires companies to address one or more of four drivers: (i) clean technologies, (ii) pollution prevention, (ii) sustainable vision, and (iv) transparent products (Hart and Milstein, 2003). According to the authors, the clean technologies

engine is associated with disruptive technologies, innovation, and the future. Which is a driver used by the research to relate it to the sustainability of goods exporting companies through the use of the Industry 4.0 strategy.

There is a positive association and certainly very little evidence of a negative association between a company's social performance and its financial performance (Margolis and Walsh, 2003). Likewise, there is empirical evidence of a positive relationship between social performance and financial performance (Barcellos, 2010). This is verified by the social and financial performance of the companies that make up the Dow Jones Sustainability World Index. This index is composed of world leaders in sustainability as identified by Sustainable Asset Management (SAM).

Even so, the sustainable company is still looking for formal data before making the decision to adopt the Industry 4.0 strategy, but reality forces to make the best use of the available information, rich or poor (Gil Aluja and Kaufmann, 1987). *Stakeholder* expectations cannot be expected to be met under hard data and traditional statistics. Uncertainty and the dynamics of Industry 4.0 force us to use possibility instead of probability, subjectivity in the absence of the much desired objectivity. In other words, in the absence of measurement, we will examine "valuation", our reasoning and computers (Gil Aluja and Kaufmann, 1987) under fuzzy logic.

Fuzzy logic

In 1965, Lotfy Zadeh applied multivalued logic to set theory at the scientific, academic, and industrial level, which allowed the use of fuzzy logic. It is very useful when it comes to generating new management and decision-making models based on the opinion and subjectivity of experts. Likewise, it allows the valuation of the complex knowledge of digital technologies without the need to submit to the technocracy of hard and certain data, since the system based on fuzzy logic emulates the most software part of the brain, trying to reproduce the highest level capabilities, especially that of approximate reasoning (Del Brío and Sanz, 2010). For this reason, the research makes use of two well-known systems: (i) FIS, and (ii) ANFIS.

The first architecture is the fuzzy inference system (FIS) with the following process: (i) the fuzzification interface that transforms the certain data into fuzzy data by using the linguistic variables and linguistic labels, (ii) definition of the fuzzy rules with the If-Then statements, (iii) the inference engine that delivers a fuzzy output value. Most fuzzy inference systems can be classified into three types: Type 1, Type 2, and Type 3 (Jang, 1993). For the study, it is decided to use Type 3 rule which uses Takagi and Sugeno's fuzzy rules (If-then). The output of each rule is a linear combination of input variables plus a constant term, and the final result is the weighted average of the output of each rule (Jang, 1993) and (iv) defuzzification is to convert each output from a fuzzy term to a number (see Figure 3).

The other architecture is the Adaptive Neural Fuzzy Inference System (ANFIS) presented by Jang (1993). It uses the routine of a fuzzy inference system (FIS) and the basic learning rule of adaptive networks which is based on gradient descent and the chain rule (Jang, 1993). An algorithm inspired by neural network theory to adjust the parameters of the rules of Sugeno-type fuzzy inference systems (Bermudez, et al, 2014), where the output variable is a function of the input variables (see figure 4).
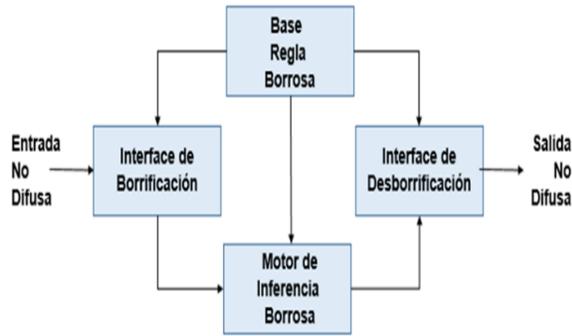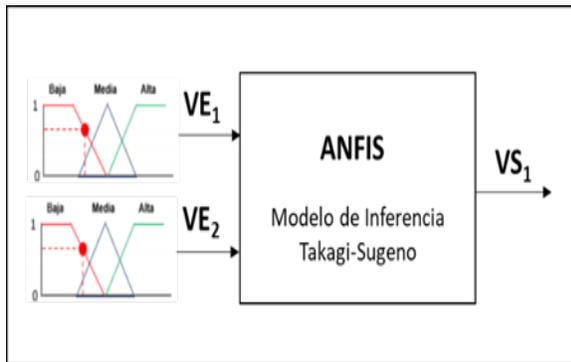
Figure 3. Fuzzy inference system (FIS). 2020

Figure 4. ANFIS architecture. 2020

Where:

$VS_1 = f(VE_1, VE_2)$.

VE1 = input variable = efficiency = efficient use of digital technology [0 1].

VE2 = input variable = strategy 4.0 = use of Industry 4.0 strategy [0 1].

VS1 = output variable = sustainability = numerical value [0, 1].

Although, ANFIS is a soft computing technique (Bermudez, et al, 2014) and one of the neuro fuzzy models of greater impact (Del Brio and Sanz, 2001) allows the construction of expert systems and advanced models through the use of numerical input variables and numerical output variable. In industry it is one of the neuro fuzzy models with the greatest impact (Del Brio and Sanz, 2010) in artificial intelligence together with the FIS, the theory of fuzzy subsets, the triangular fuzzy numbers (TFN), and the Hamming Distance allow the construction of the general objective of the research.

Method

Research design

The research scenario is changing and uncertain and the analytical intention is predictive under a fuzzy logic approach, since a fuzzy methodology is to describe and formalize reality using flexible models that interpret the laws governing human behavior and human relationships (Lazzari, Machado and Perez, 2000). Likewise, the post-positivist paradigm is used to achieve a better understanding of reality in Industry 4.0. A reality that exists but cannot be studied from exact laws and can only be understood incompletely (Ramos, 2015). Even when the reality of the exporting company includes the inadequate use of resources, little scientific and technological knowledge in the design of goods, self-satisfied leaders, and skilled in procrastination of Industry 4.0., an epistemological vein that allows a methodological one under the fuzzy logic.

Research methodology

The appropriate use of a model under the fuzzy logic architecture should include four facets: (i) FLl = Logic Facet, (ii) FLs = Fuzzy subset theory facet, (iii) FLe = Epistemic facet, and (iv) Flr = Relational facet (Zadeh, 2008, p. 2754). The four facets are found in the three activities included in the methodology: (i) construction of the FIS, (ii) construction of the ANFIS, and (iii) application of the SVM (see Figure 5).
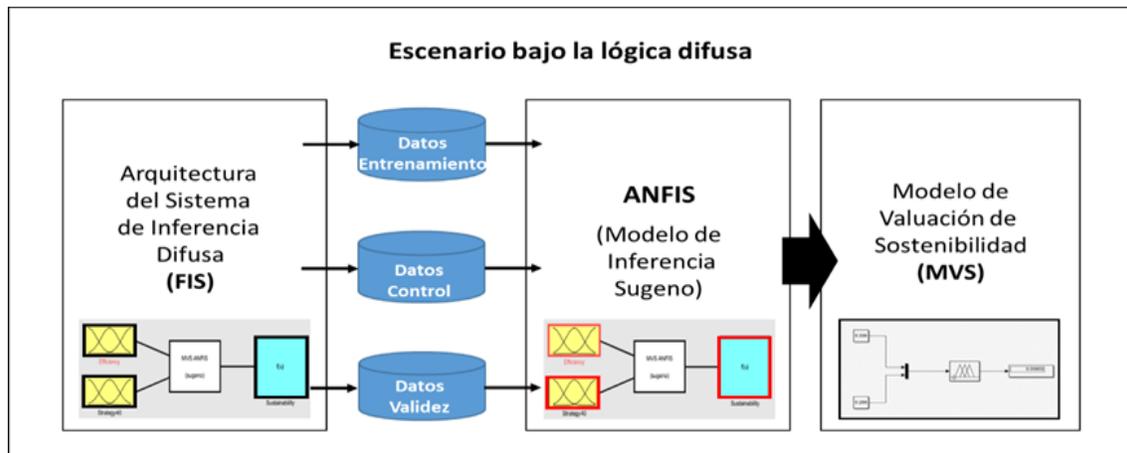

Figure 5. Diagram of the methodology. First the FIS, then ANFIS, and finally the SVM.
Note: Source: Own elaboration. 2020.

Methodology activities are explained:

i. The construction of the fuzzy inference system (FIS) through which the database required by the ANFIS is obtained. Once the FIS is built, 200 random numbers [0 1] are used for the input variable VE_1 and another equal amount for the input variable VE_2, which results in 200 output variable data VS_1.

ii. ANFIS construction. With the data generated by the FIS, the training, control and validity of the ANFIS architecture is executed, and the algorithm of the sustainability valuation model (SVM) is obtained. An architecture based on Sugeno's fuzzy model with a set of nine fuzzy if-then rules, for two inputs (VE_1 and VE_2) and one output variable (VS_1 or sustainability), (see figure 6). The fuzzy rules are represented by:

$$R_k = si \; \mu_{A_i}(x) \; y \; \mu_{B_i}(y) \; where \; f = p_k \, x + \, q_k \, x + r_x$$

Where k is the number of rules (9), A_i (A$_1$, A$_2$ and A$_3$) and B_i (B$_1$, B$_2$ and B$_3$) represent the number of fuzzy membership function of the input variables y p_k, q_k, r_k are the linear parameters of the consequent parts of the nine rules.
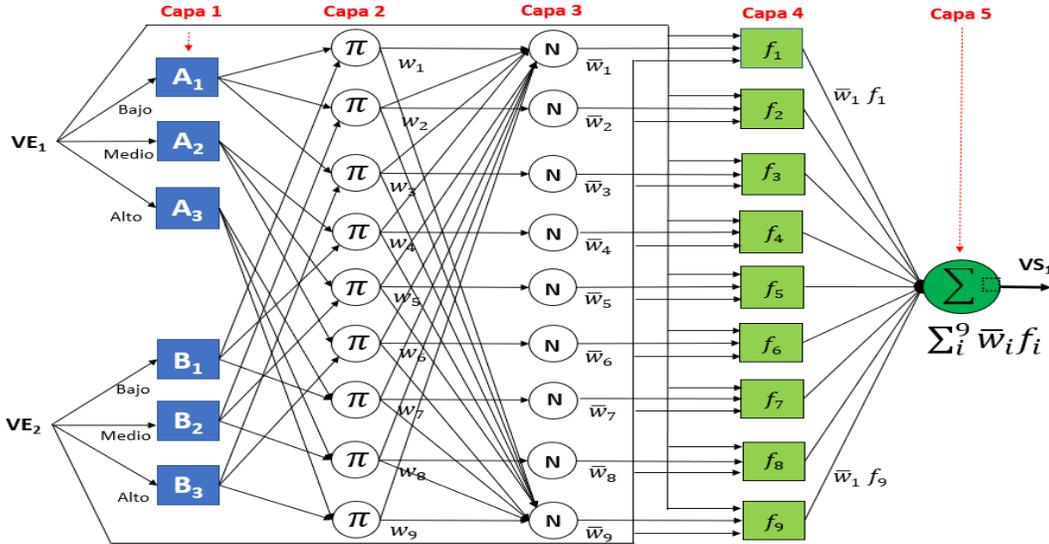

Figure 6. Layers of ANFIS - Sugeno Model. It is developed in five layers
Note: Source: Own elaboration, 2020.

In the first layer, the fuzzification task is executed where each node is an adaptive node dependent on the membership function (see Figure 6). In the research the trapezoidal membership function is used and the output is obtained by the following equation:

$O_i^1 = \mu_{A_i}(x), O_i^1 = \mu_{B_i}(x)$, where: $(i = 1, 2, 3)$. Whose trapezoidal function is:

$$\mu(x) = \begin{cases} 0 & si\ x \leq a_1 \\ \frac{x - a_1}{a_2 - a_1} & si\ a_1 \leq x < a_2 \\ 1 & si\ a_2 \leq x \leq a_3 \\ \frac{-x + a_4}{a_4 - a_3} & si\ a_3 \leq x \leq a_4 \\ 0 & si\ x \geq a_4 \end{cases}$$

In the second layer each node has a fixed node tag π and the output is the product of all incoming signals (see figure 6). Therefore, the output of the second layer is obtained by the following equation:

$O_i^2 = w_i = \mu_{A_i}(x)\ \text{x}\ \mu_{B_i}(x)$, where: $(i = 1, 2, 3, 4, 5, 6, 7, 8, 9)$.

The third layer is considered the normalization layer (N) (see figure 6). Therefore, the output of this layer is calculated by the following equation:

$$O_i^3 = \overline{w}_i = \frac{w_i}{\sum_1^9 w_i}, \text{ where: } w_i \text{ is the normalized firing force.}$$

The fourth layer is considered the defuzzification layer, where each node of this layer is an adaptive node. That is, node represents consequent parts of the fuzzy rule. The linear coefficients of the rule consequents can be trained (see Figure 6). The output of this layer is calculated by the following equation:

$$O_i^4 = \overline{w}_i f_i = \overline{w}_i (p_i x + q_i x + r_i), \text{ where: } (i = 1, 2, 3, 4, 5, 6, 7, 8, 9).$$

The fifth layer is considered the output layer. Here the defuzzification of the consequent parts of the rules is performed by adding the results of all nine rules (see figure 6), which is calculated by the following equation:

$$O_i^5 = \sum_i^9 \overline{w}_i f_i = \frac{\sum_i^9 w_i f_i}{\sum_i^9 w_i}, \text{ where: } (i = 1, 2, 3, 4, 5, 6, 7, 8, 9)$$

iii.   Application of the SVM. The exporting company is selected, the scale of advanced digital skills and competences (HCDA) is applied, the Hamming Distance is calculated, and from the triangular fuzzy numbers the values of VE_1 and VE_2 are obtained. Values that are introduced to Simulink and deliver the VS_1 (Sustainability).

Development of activities
The section explains the development of the three activities of the methodology:
Activity 1. Construction of the fuzzy inference system (FIS). The objective of the activity is to build the FIS (Sugeno), to obtain the data required by the ANFIS. The Matlab development environment version R2020a. and its Fuzzy Logic Toolbox are used, where the following tasks are executed:
   i.   The Fuzzy Logic module of Matlab is accessed and the Takagi-Sugeno FIS is adopted.
   ii.   It is defined: (a) linguistic variable VE_1 = efficiency, with three linguistic labels (low, medium, and high), (b) linguistic variable VE_2 = strategy 4.0, with three linguistic labels (low, medium, and high), and (iii) linguistic variable VS_1 = sustainability, with three linguistic labels. The three variables use the same membership function: (i) low = trapezoidal type function, (ii) medium = triangular type function, and (iii) high: trapezoidal type function.
   iii.   The nine fuzzy rules are defined under the structure: if - Then
   iv.   At the end, the fuzzy inference system (FIS) is obtained to generate the data required in the ANFIS.

Activity 2. ANFIS construction. The objective of this activity is to build the ANFIS and its corresponding algorithm for use in the SVM. The tasks to be executed are:
   i.   Enter Matlab and type <anfisedit> and the Neuro Fuzzy Designer window is displayed and saved with: <File>, < Export>, <Data>, and assign the name SVM. Then the file is reloaded

      using: <File>, < Import>, <Data> and the SVM is chosen. The Neuro Fuzzy Designer SVM window is displayed, ready to load the data files.

ii.   The file with the training set data is loaded. The data are used by the learning algorithm to adjust the network parameters. The objective is to bring the prediction error on this training set to a minimum (Diaz, Etse, Flores, Folino and Will, 2007).

iii.   The file with the control set data is loaded. The data does not participate in the training and only avoids the phenomenon of overtraining (Diaz, et al, 2007).

iv.   The data for the validity set is loaded. (Checking Set). The data does not participate in the training. Its use is to provide a measure of the quality of the network prediction on new data, not available at the time of training.

v.   ANFIS delivers: (i) the six-layer ANFIS structure model, (ii) the VE_1, VE_2, and VS_1 with their linguistic label values (low, medium, high), (ii) the nine fuzzy rules, (iii) the training error, and (iv) ANFIS SVM algorithm that is exported to file and Matlab, for use in Simulink.

Activity 3. Application of the SVM. The objective is to use the algorithm generated by the ANFIS SVM in the Simulink simulator, Matlab version R2020a. Simulink is a graphical environment to be used in the simulation of nonlinear dynamic systems. It is very useful for simulations of a complex system because it allows to explore with relative simplicity different solutions (Del Brío and Sanz, 2001). The following tasks are executed.

i.   Face-to-face or virtual interview to fill in the data of the scale of advanced digital skills and competencies (HCDA), which takes into account the nine technological pillars of Industry 4.0: virtual reality, artificial intelligence, industrial internet, industrial big data, industrial robot, 3D printing, cloud computing, knowledge work automation, and industrial network security (Chen, Liu, Quiang, & Liu, 2016). The other three pillars are included by the researcher: use of GIS, agile projects, and Social Networks (see Table 1). The interview is with each job manager which is classified into two groups: (i) jobs assigned to the efficient use of digital technology under the "efficiency" denomination, and (ii) jobs assigned to the use of Industry 4.0 strategy under the "strategy 4.0" denomination (see table 1). The efficiency group corresponds to jobs in the value chain and the 4.0 strategy group corresponds to jobs that support the value chain.

ii.   The HCDA scale data is processed using Hamming Distance and the certain value of [0 1] is defined for each job. The valuation means the use of digital technology and Industry 4.0 strategy.

iii.   The values of each work center are ordered: (i) the jobs assigned to efficiency (WP1, WP2, WP3, WP4, WP5), with which the triangular fuzzy number (NBT_1) is constructed and the mean of $NBT_1 = VE_1$ is obtained, and (ii) the jobs assigned to strategy 4.0 (WP6, WP7, WP8, WP9, WP10), with which the triangular fuzzy number (NBT_2) is constructed and the mean of $NBT_2 = VE_2$ is obtained.

iv.   The values VE_1 and VE_2 are input to the Simulink and deliver a certain value [0 1] which is the VS_1 = sustainability (S). This is repeated as many times as necessary.

Results

Construction of the FIS

The objective is to build the FIS to obtain the data set required by ANFIS.

i. Enter Matlab, type <fuzzy>, display the Fuzzy Logic Designer window, select <File>, then select <New FIS>, < Sugeno>. Then choose <File>, <Export>, <To File>, type the name of the FIS SVM file and choose <Save>. This saves the file with the FIS architecture (*fis). The FIS SVM file is imported to execute the FIS construction.

ii. In which window the FIS <Input> variables are defined: (a) VE_1 = efficiency with three labels (low, medium, and high), and (b) VE_2 = strategy 4.0 with three labels (low, medium, and high). Both input variables (VE_1 and VE_2) use the same membership function and linguistic labels in the range [0 1].
Low = trapezoidal type function = [a_1 a_2 a_3 a_4] = [0 0 0.1 0.4].
Medium = trapezoidal type function = [a_1 a_2 a_3 a_4] = [0.3 0.5 0.5 0.5 0.7] = [0.3 0.5 0.5 0.7].
High = trapezoidal type function = [a_1 a_2 a_3 a_4] = [0.6 0.9 1 1].

iii. The variable FIS <Output> f(u) = Sustainability = VS_1 is defined. The parameters are values of [0 1], for the three linguistic labels: (i) Low = 0, (ii) Medium = 0.5, and (iii) High = 1. The FIS architecture is concluded (see Figure 7).
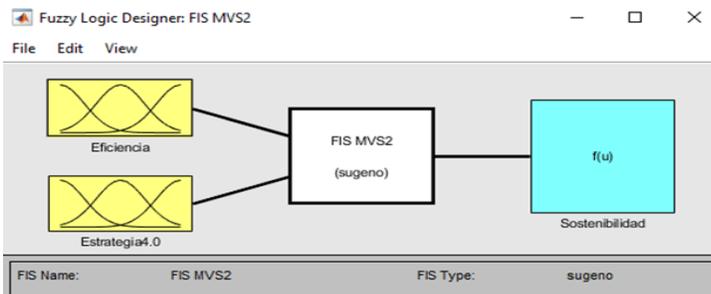

Figure 7. FIS SVM architecture. 2020

Figure 8. FIS SVM Rules. 2020

iv. Then proceed to define the fuzzy rules under the <if - and - Then > structure. In the Fuzzy Logic Disigner FIS SVM window, select < Edit> <Rules> and the Rules Editor FIS SVM

window appears, where, using the < if - and - Then > rule, the nine rules are incorporated (see figure 8).

v. To obtain the FIS construction, select <View> <Rules> and the Rules Viewer FIS SVM window is displayed (see figure 9). Likewise, choose <View> <Surface> and the Surface Viewer FIS SVM is displayed (see figure 10).
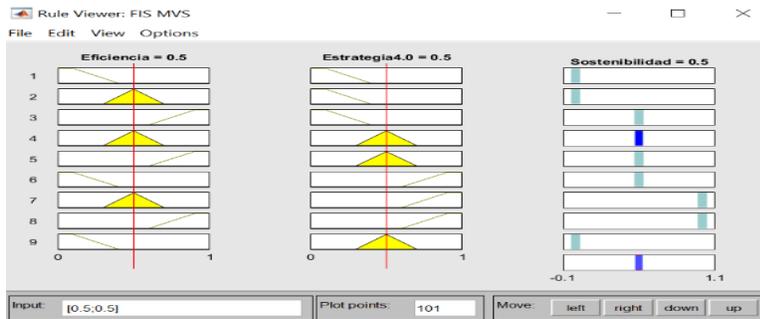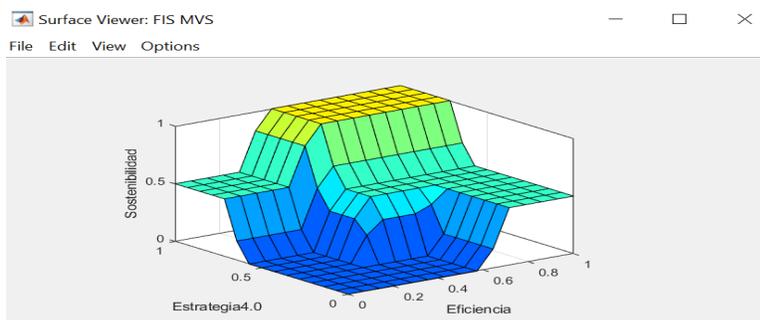

Figure 9. FIS SVM rule. 2020

Figure 10. SVM FIS area. 2020

vi. The Rule Viewer FIS SVM (Figure 8) is used to obtain the 200 VS_1 data. In < Input > the value shown [0.5 0.5] = [VE_1 VE_2] is modified with the random data and filed in an Excel sheet. The Excel file with three columns records: (i) the VE_1 value with 200 values, (ii) the VE_2 value with 200 values, and (iii) the VS_1 column with 200 values (see Appendix I).

vii. The data file is sorted: (i) 60% of the data for the training set, (ii) 30% of the data for the control set, and (iii) 10% of the data for the validity set. Data used in the construction of ANFIS.

ANFIS construction

The objective of the ANFIS construction is to achieve the SVM algorithm, for which the Fuzzy Logic Toolbox module of Matlab, version R2020a, is used.

i. Enter Matlab and type <anfisedit> and the Neuro Fuzzy Designer window is displayed and the file is saved with the name ANFIS SVM. Then the file is reloaded using: <File>, < Import>, <Data>, and ANFIS SVM is chosen.

ii. Check: <Training>, < File>, <Load Data>, and select the file < Entresvm>. Load the data and select < Generate FIS> and in the Add Membership Function window check: INPUT, Number of MFs [3 3], and MF Type select <trapmf> of the trapezoidal type function. In

OUTPUT select: < Constant>, <OK>. Then, in the Train FIS column under < Epochs> write: <10>, <15>, and <20>. Finish the training with 20 epochs, an error of: 0.055 and 110 input data. See figure 11. Finally, choose: <Clear Plot>.

iii. Check: < Testing>, <File>, <Load Data>, and select the <Controlsvm> file. Load the data and select <Generate FIS> and in the Add Membership Function window check: INPUT, Number of MFs [3 3], and MF Type select <trapmf> of the trapezoidal type function. In OUTPUT select: <Constant>, <OK>. Then, in the Train FIS column under < Epochs > write: <10>, <15>, and <20>. Finish the control with 20 epochs, an error of: 0.055 and 60 input data (see Figure 12). Finally, <Clear Plot> is chosen.

iv. Check: < Checking>, <File>, <Load Data>, and select the file <Validitysvm>. Load the data and select < Generate FIS> and in the Add Membership Function window check: INPUT, Number of MFs [3 3] and MF Type select <trapmf> of the trapezoidal type function. In OUTPUT select: <Constant>, <OK>. Then, in the column, Train FIS and under <Epochs > write: <10>, < 15>, and <20>. Finish the validity with 20 epochs, an error of: 0.055 and 30 input data (see figure 13). Finally, <Clear Plot> is chosen.

v. As a result, we obtain the ANFIS system (see figure 14) whose layered architecture is similar to figure 6. We also obtain the list of the nine fuzzy rules (see figure 15) and the new ANFIS fuzzy rule (see figure 16), which includes the SVM algorithm.

vi. The ANFIS architecture delivers an ANFIS SVM Surface Viewer map (see figure 17). It is different from the FIS SVM Surface Viewer (see figure 10) especially in the elimination of the sharp edges typical of ANFIS:

vii. Finally, the ANFIS SVM is exported to the file for use in Simulink. The ANFIS SVM algorithm will be used in the SVM application to simulate the scenarios of the five exporting companies involved.
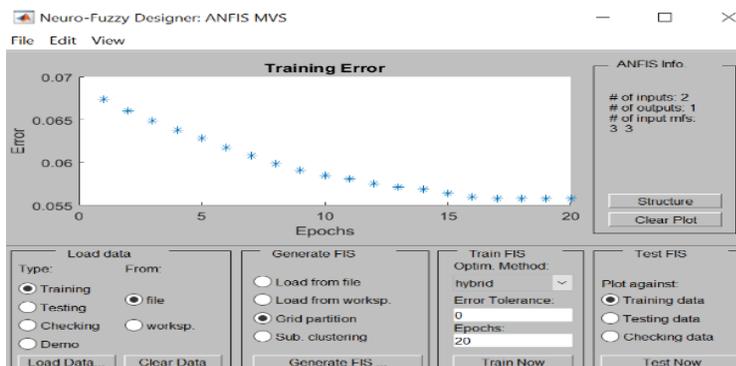
Figure 11. ANFIS SVM-Training error. 2020
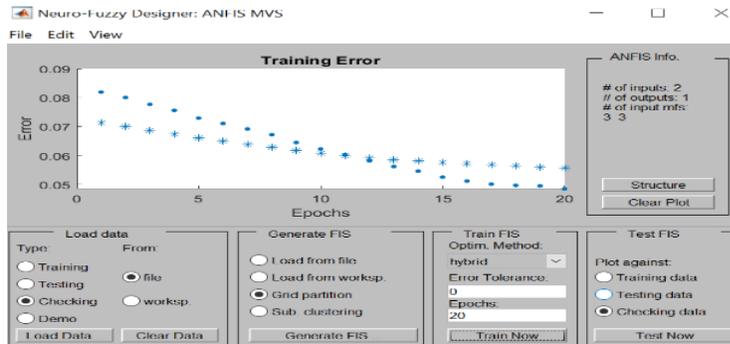
Figure 12. ANFIS SVM-Control error. 2020
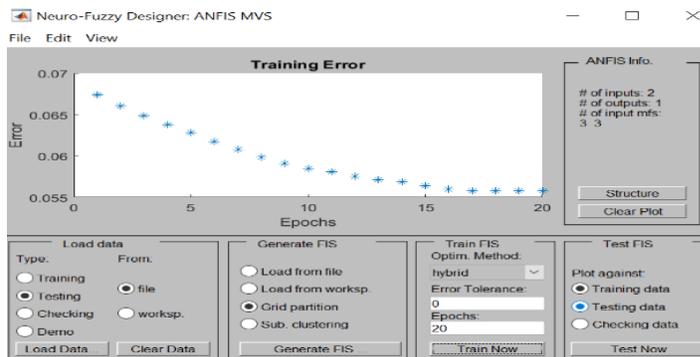
Figure 13. ANFIS SVM-Validity error. 2020
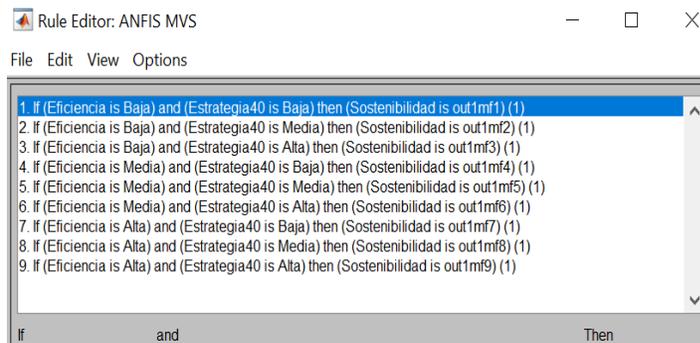
Figure 14. ANFIS-SVM fuzzy rules. 2020
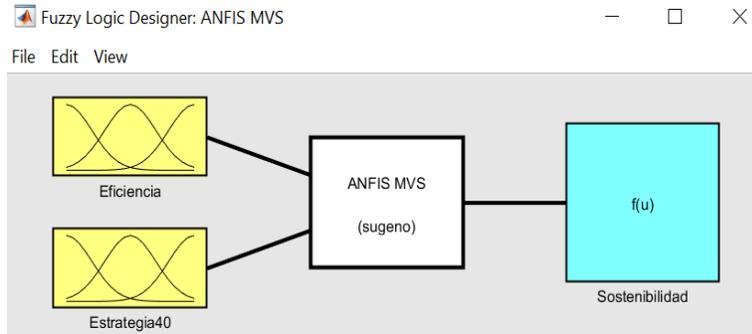
Figure 15. ANFIS-SVM architecture. 2020
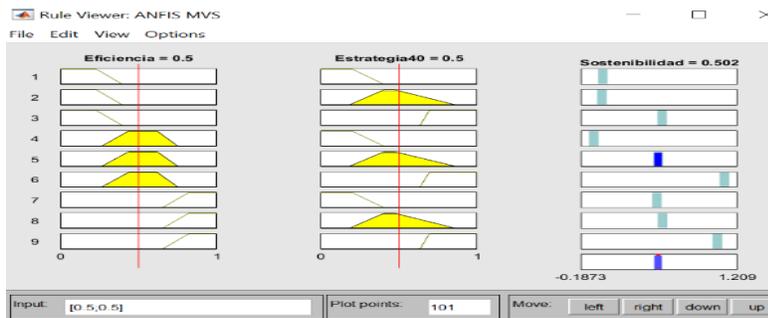
Figure 16. ANFIS SVM rules. 2020
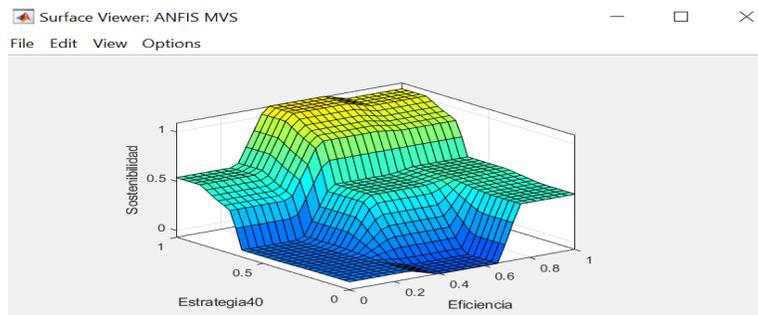
Figure 17. ANFIS SVM surface. 2020

SVM application

The objective is to use the ANFIS SVM algorithm in the Simulink simulator of Matlab version R2020a, for which the following tasks are executed.

i.   The virtual interview is conducted with five exporting companies. An advanced skills and competencies scale (HCDA) is filled out for each exporting company. The assessment is carried out with the person in charge of each work position (WP) and values of [0 1] according to the endecaria scale are used. The researcher has defined the values of the "Ideal Profile" (see Table 1).

Table 1

Format of the scale of advanced digital skills and competences (HCDA)

Vectores I4.0	Habilidades y Competencias Digitales Avanzada (HCDA)	VE₁ Eficiencia					VE₂ Estrategia 4.0					Perfil Ideal
		PT1	PT2	PT3	PT4	PT5	PT6	PT7	PT8	PT9	PT10	
HD	Computaciòn en la Nube	0.8	0.5	0.7	0.6	0.3	0.4	0.8	0.6	0.3	0.4	0.9
	Realidad Virtual	0.7	0.6	0.3	0.4	0.8	0.6	0.6	0.5	0.7	0.5	0.8
	Robot Industrial	0.1	0.5	0.8	0.5	0.7	0.6	0.3	0.4	0.1	0.6	0.9
	Uso de GIS	0.4	0.7	0.6	0.3	0.4	0.8	0.6	0.6	0.4	0.3	0.8
GD	Internet Industrial (IIoT)	0.3	0.3	0.3	0.7	0.3	0.3	0.5	0.5	0.3	0.7	1.0
	Big Data Industrial	0.6	0.8	0.7	0.6	0.3	0.4	0.8	0.6	0.6	0.1	1.0
	Inteligencia Artificial	0.8	0.6	0.6	0.3	0.8	0.8	0.6	0.7	0.8	0.4	1.0
	Impresiòn 3D	0.2	0.7	0.5	0.1	0.6	0.4	0.5	0.1	0.1	0.3	1.0
SD	Proyectos àgiles	0.7	0.6	0.3	0.4	0.8	0.6	0.3	0.4	0.5	0.6	1.0
	Trabajo colaborativo virtual	0.3	0.3	0.5	0.3	0.7	0.6	0.3	0.3	0.8	0.8	1.0
	Seguridad de Red Industrial	0.6	0.7	0.6	0.3	0.4	0.8	0.6	0.6	0.4	0.5	1.0
	Gestiòn de Redes Sociales	0.6	0.5	0.8	0.7	0.8	0.4	0.5	0.8	0.5	0.4	1.0

Note: WP1 = R&D&I, WP2 = Supply, WP = Manufacturing, WP4 = Logistics, WP5 = Marketing, WP6 = Design, WP7 = Services, WP8 = ICT, WP9 = HR, and WP10 = Management. The Ideal Profile values are recommendations of the researcher based on his experience.

In the position WP1 = R&D&I, it is taken into account if there is agile project management, very useful in Industry 4.0.

ii. From the HDCA scale, the data for each work center (WP1, WP2, ... WP10) is used. The data for each work center is processed using the Hamming Distance and a WP value is obtained. For example: for the management position (WP10) we have:

DH Management = 1/12 ((0.9-0.4) + (0.8-0.5) + (0.9-0.6) + (0.8-0.3) + (1-0.7) + (1-0.1) + (1-0.4) + (1-0.3) + (1-0.6) + (1-0.8) + (1-0.5) + (1-0.4).

DH Management = 1/12 (0.5+0.3+0.3+0.3+0.5+0.3+0.9+0.6+0.7+0.4+0.2+0.5+0.6 = 0.48.

iii. The values for each work center are ordered: (i) with the WPs assigned to efficiency (WP1, WP2, WP3, WP4, WP5) the triangular fuzzy number is constructed and the mean is obtained: $NBT_1 = VE_1$, and (ii) with the WPs assigned to strategy 4.0 (WP6, WP7, WP8, WP9, WP10) the triangular fuzzy number is constructed and the mean is obtained: $NBT_2 = VE_2$. The process is repeated for the other four exporting companies.

iv. The values of VE_1 and VE_2, for each exporting company, are entered into Simulink and VS_1 is obtained as a result. In the 2020 scenario (see Figure 18).

v. Another contribution of the SVM is the simulation of VE_1 and VE_2 in Simulink for a future scenario. In Company 1, the value of VE_1 (2020) = 0.35 is changed to VE_1 (2025) = 0.55 and the value of VE_2 (2020) = 0.42 is changed to VE_2 (2025) = 0.45. Where VS_1 (2020) = 0.325 passes VS_1 (2025) = 0.502 = Sustainability. The increase occurs because of the improvement in each job in the efficiency variable and the 4.0 strategy (see figure 19). The simulation continues with Company 2, 3, 4, and 5 (see table 2).
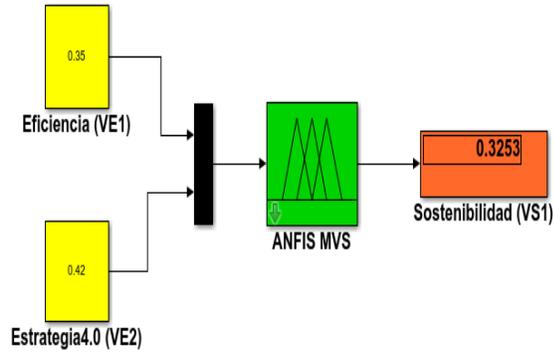
Figure 18. Simulink SVM: scenario year 2020
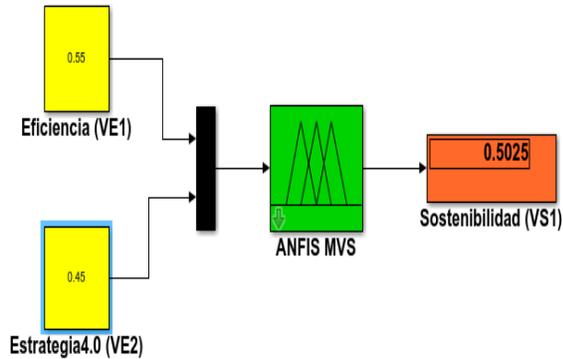
Figure 19. Simulink SVM: scenario year 2025

Table 2
SVM result by exporting company. Scenario year 2020 and 2025.

Empresa Exportadora I4.0	Escenario Año 2020						Escenario Año 2025					Sector Economico de Exportaciòn
	VE₁	VE₂	VS₁				VE₁	VE₂	VS₁			
			Bajo	Medio	Alto				Bajo	Medio	Alto	
Empresa 1	0,35	0,42	**0,325**				0,55	0,45		0,502		Agricultura
Empresa 2	0,18	0,55	**0,002**				0,38	0,65		0,619		Agro-Industria
Empresa 3	0,39	0,42		0,487			0,48	0,66			**0,762**	Medico
Empresa 4	0,41	0,67			**0,824**		0,58	0,75			**0,965**	Electronico
Empresa 5	0.32	0,39	**0,192**				0,41	0,45		0,502		Manufactura

Note: The virtual interview was conducted between May, June, and July 2020. In the 2020 scenario, three companies have low sustainability (red). In the 2025 scenario, the three companies moved to medium sustainability (gray). The decision was to reduce the worst-performing Hamming Distance. In other words, the job manager will have to increase his HCDA, which is a different challenge for each company. But the management of the five companies urges them to improve their HCDA.

Discussion and conclusion

The increase in productivity based on data (University 4 Industry, 2013) and the cyber-physical system to achieve the smart factory (Cheng, et al, 2016) are promises of Industry 4.0 that have yet to be validated. Similarly, the VSM is not the panacea to comprehensively solve the sustainability of an exporting company, it is only a model that helps to understand the current state of the company with respect to the reality of Industry 4.0. A model that cannot interpret all the complex and changing reality, but it does allow the *stakeholder to* align digital strategic thinking, digital strategic direction, and digital strategy in an efficient way. The VSM could even be used in model-based systems engineering (MBSE) for the harmonization of information (Marny and Purohit, 2019) and the initiation of a new business model needed in Industry 4.0.

The model provides appropriate knowledge for the *stakeholder to* drive a sustainability strategy under Industry 4.0. Even more so, when companies have to operate with one eye on the short term and the other focused on the long term (Kotler and Caslione, 2010) in times of uncertainty or turbulence. Based on the above, two groups of exporting companies are defined: (i) those that do not have the slightest interest in Industry 4.0, and (ii) those that have digital technology adapted and proven in their processes. But the technology is underutilized or, in other words, complex knowledge is needed to get the most out of it in order to improve the company's sustainability.

The VSM is useful for the second group of exporting companies, as it allows them to operate at three planning levels: short term, intermediate term (three to five years), and long term (Kotler and Caslione, 2010) with which projects and initiatives can be executed simultaneously in three boxes: (i) short term or present: manage the core business with maximum profitability, (ii) medium term or past: abandon ideas that inhibit innovation, (iii) long term or future: convert innovative ideas into new products and businesses (Govindarajan, 2016). Under these two premises, the SVM allows exporting companies to prolong their long-term sustainability, while optimizing the company's performance and value in the short and medium term (Kotler, Caslione, 2010), since the model delivers certain values of [0 1] which is associated with low, medium, and high business sustainability.

The model uses the benefits of the FIS and ANFIS architecture. Both make use of the same input linguistic variable name, output variable, linguistic labels, universe range [0 1], trapezoidal function type, and fuzzy rules. But their three-dimensional surfaces are different, especially, the ANFIS surface has the smoothest transitions. Even though the training was with 110 data and 20 epochs, the error was 0.055. It is necessary to mention that the Neural Networks, which includes the Fuzzy Logic Toolbox, were not used, since it requires a larger training set (Díaz, et al, 2007).

The truth is that the VSM needs more use for the benefit of its adaptive network. This requires a training process with new export ecosystems, face-to-face interviews, and adapting its protocol to another language, since a critical point of view may require training with a larger number of data and a larger number of epochs. All of which will allow the ANFIS SVM algorithm to develop a better predictive scenario, the box of the future, for a goods exporting company; a scenario of the future that will allow the *stakeholder to* develop product innovation, new business models, new working methods, and higher productivity.

The other aspect to improve is the data capture in the HCDA scale. It is necessary that the interview be face-to-face, in order to achieve a better observation of the reality of the exporting company. Also, the values of the "Ideal Profile" could be improved by making them all value 1. But above all, the most delicate aspect is to synthesize the advanced digital skills and competencies in a few items, when the reality is that in the market there are dozens of disruptive technologies.

However, a synthesis was made based on the operational aspects of DT and the use of brands has been avoided, but it will be necessary to review and adjust the HCDA every five-year period.

Finally, SVM was used in a small number of companies in order to monitor, control, and calibrate the model. It was verified that Simulink is agile in delivering the sustainability value that adjusts to the reality of the company in question. Likewise, the simulator allows to deliver a predictive value of the output variable from data of the input variables, which allows to improve in an efficient and effective way the values in each work place through a better use of the DTs and the 4.0 strategy, an aid to the *stakeholder* that allows him to design a specific strategy to increase the values of the variables, better if use is made of the *Fuzzy-Delphi* and R^+-Expertones.

In conclusion, the overall objective was achieved. Because with the delivery of the SVM, we have validated a model that allows us to measure the sustainability of a company. Even through the simulator, we obtained results that are in line with reality. In other words, the model is useful for the *stakeholder* who has to make decisions regarding Industry 4.0, without the need to be precise. It is expected to be used in order to take care of the sustainability of the exporting company so necessary and useful in society, since the technological gap that drives the fifth industrial revolution (5IR) is a threat aimed at rendering obsolete the products or goods of the 3IR and 4IR. Future research may consider taking advantage of the results of the VSM and generating *fuzzy clustering* in the exporting sectors of a country.

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Annexes

Annex 1
Training, control, and validity set data

Item	VE$_1$	VE$_2$	VS$_1$	Item	VE1	VE2	VS1	Item	VE1	VE2	VS1	Item	VE1	VE2	VS1
1	0.35	0.55	0.30	51	0.96	0.13	0.50	101	0.38	0.64	0.58	151	0.76	0.15	0.50
2	0.27	0.45	0.00	52	0.89	0.35	0.50	102	0.82	0.16	0.50	152	0.18	0.81	0.50
3	0.15	0.33	0.00	53	0.71	0.65	0.70	103	0.22	0.40	0.00	153	0.11	0.91	0.50
4	0.51	0.37	0.38	54	0.75	0.62	0.57	104	0.14	0.46	0.00	154	0.31	0.56	0.07
5	0.75	0.13	0.50	55	0.73	0.67	0.80	105	0.85	0.92	1.00	155	0.05	0.33	0.00
6	0.91	0.17	0.50	56	0.70	0.70	1.00	106	0.56	0.65	0.70	156	0.25	0.47	0.00
7	0.63	0.31	0.16	57	0.78	0.67	0.80	107	0.54	0.84	1.00	157	0.39	0.73	0.96
8	0.41	0.48	0.50	58	0.92	0.96	1.00	108	0.43	0.73	1.00	158	0.26	0.62	0.07
9	0.43	0.77	1.00	59	0.61	0.36	0.35	109	0.58	0.77	1.00	159	0.46	0.32	0.13
10	0.49	0.90	1.00	60	0.35	0.35	0.68	110	0.39	0.61	0.50	160	0.16	0.72	0.60
11	0.18	0.29	0.00	61	0.35	0.81	0.80	111	0.99	0.29	0.50	161	0.27	0.53	0.00
12	1.00	1.00	1.00	62	0.25	0.77	0.50	112	0.79	0.31	0.50	162	0.07	0.13	0.00
13	0.00	0.00	0.00	63	0.46	0.58	0.50	113	0.75	0.69	0.92	163	0.42	0.79	1.00
14	0.10	0.31	0.00	64	0.62	0.39	0.47	114	0.15	0.75	0.50	164	0.33	0.83	0.69
15	0.05	0.05	0.00	65	0.72	0.37	0.50	115	0.36	0.56	0.34	165	0.98	0.81	1.00
16	0.12	0.51	0.00	66	0.82	0.39	0.50	116	0.14	0.45	0.00	166	0.69	0.59	0.50
17	0.25	0.25	0.00	67	0.27	0.69	0.42	117	0.37	0.42	0.38	167	0.49	0.77	1.00
18	0.45	0.45	0.50	68	0.41	0.74	1.00	118	0.56	0.35	0.30	168	0.45	0.48	0.50
19	0.35	0.35	0.18	69	0.65	0.31	0.24	119	0.51	0.31	0.07	169	0.55	0.85	1.00
20	0.50	0.50	0.50	70	0.95	0.27	0.50	120	0.78	0.65	0.73	170	0.35	0.51	0.30
21	0.76	0.28	0.50	71	0.66	0.49	0.50	121	0.95	0.27	0.50	171	0.35	0.68	0.66
22	0.81	0.19	0.50	72	0.76	0.85	1.00	122	0.66	0.49	0.50	172	0.63	0.26	0.11
23	0.91	0.19	0.50	73	0.81	0.89	1.00	123	0.76	0.85	1.00	173	0.71	0.69	0.92
24	0.94	0.37	0.50	74	0.21	0.91	0.50	124	0.81	0.89	1.00	174	0.22	0.69	0.42
25	0.99	0.29	0.50	75	0.38	0.68	0.79	125	0.21	0.91	0.50	175	0.54	0.46	0.50
26	0.79	0.31	0.50	76	0.55	0.33	0.19	126	0.11	0.84	0.50	176	0.61	0.36	0.35
27	0.75	0.69	0.92	77	0.25	0.47	0.00	127	0.36	0.22	0.00	177	0.35	0.56	0.30
28	0.65	0.67	0.80	78	1.00	0.73	1.00	128	0.05	0.33	0.00	178	0.25	0.25	0.00
29	0.32	0.56	0.13	79	1.00	0.33	0.50	129	0.25	0.52	0.00	179	0.70	0.70	1.00
30	0.34	0.45	0.25	80	1.00	0.12	0.50	130	1.00	0.73	1.00	180	0.78	0.67	0.81
31	0.37	0.42	0.38	81	0.66	0.52	0.50	131	1.00	0.33	0.50	181	0.42	0.46	0.60
32	0.56	0.35	0.30	82	0.69	0.59	0.50	132	1.00	0.12	0.50	182	0.85	0.16	0.50
33	0.58	0.21	0.00	83	0.49	0.77	1.00	133	0.66	0.52	0.50	183	0.45	0.71	1.00
34	0.78	0.62	0.57	84	0.45	0.48	0.50	134	0.71	0.42	0.50	184	0.66	0.45	0.50
35	0.11	0.84	0.50	85	0.55	0.85	1.00	135	0.21	0.37	0.00	185	0.15	0.75	0.50
36	0.19	0.96	0.50	86	0.35	0.51	0.30	136	0.41	0.81	1.00	186	0.27	0.53	0.00
37	0.67	0.71	1.00	87	0.81	0.31	0.50	137	0.31	0.91	0.57	187	0.07	0.13	0.00
38	0.81	0.21	0.50	88	0.11	0.47	0.00	138	0.35	0.68	0.66	188	0.42	0.79	1.00
39	0.91	0.31	0.50	89	0.73	0.57	0.50	139	0.63	0.26	0.11	189	0.33	0.83	0.69
40	0.31	0.81	0.65	90	0.50	0.59	0.50	140	0.50	0.58	0.50	190	0.98	0.81	1.00
41	0.41	0.71	1.00	91	0.38	0.81	0.92	141	0.55	0.50	0.50	191	0.18	0.61	0.03
42	0.35	0.68	0.66	92	0.37	0.75	0.88	142	0.15	0.50	0.00	192	0.21	0.69	0.42
43	0.63	0.26	0.11	93	0.71	0.69	0.92	143	0.89	0.15	0.50	193	0.11	0.29	0.00
44	0.45	0.57	0.50	94	0.22	0.69	0.42	144	0.70	0.45	0.50	194	0.38	0.68	0.79
45	0.05	0.45	0.00	95	0.54	0.46	0.50	145	0.29	0.31	0.00	195	0.55	0.33	0.19
46	0.15	0.55	0.00	96	0.59	0.71	1.00	146	1.00	0.45	0.50	196	0.25	0.47	0.00
47	0.89	0.15	0.50	97	0.70	0.79	1.00	147	0.41	0.34	0.25	197	1.00	0.73	1.00
48	0.70	0.45	0.50	98	0.15	0.37	0.00	148	0.65	0.31	0.24	198	1.00	0.33	0.50
49	0.29	0.31	0.00	99	0.14	0.57	0.00	149	0.55	0.27	0.00	199	1.00	0.12	0.50
50	1.00	0.45	0.60	100	0.35	0.00	0.00	150	0.66	0.45	0.50	200	0.66	0.52	0.50

Note: Light blue color: training data; Orange color: control data; Green color: validity data.