Chapter 11
Vertical and Horizontal Integration Systems in Industry 4.0

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11.1 Introduction

Industry 4.0 has been achieving new heights and has high growth expectations, as the current information technology infrastructure enables the industry to adopt it quickly and efficiently. The challenge will be to find human talent with the capacity to develop analytical algorithms that lead to the development of self-learning intelligence, taking advantage of the current infrastructure. In addition, the future of this technology is conditioned to the creation of appropriate scientific areas; without this there would be an obstacle to the adoption and proliferation of this emerging technology.

The technological advances that are currently used in manufacturing are based on Industry 4.0. However, the entire present production process will be transformed in this new technological era. For instance, independent manufacturing cells will be unified as a fully integrated production flow, "intelligent" machines and products shall have the possibility to communicate with each other, and some decisions will

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be made autonomously. A new man- machine relationship will replace the classic relationships among suppliers, companies, and customers.

In a market that economic opening is a decisive guideline that induces greater demand competitiveness, causing all companies to work in a continuous improvement scheme and high productivity in their processes and in the administration of them, including new management system and business models, it is necessary to apply new techniques that allow the value generation that gives stability in the market. Technological advance in production systems requires corporations to be agile in their operational processes, as well as efficient information management, to create an organizational synergy that provides competitive advantages within the production system and throughout its value chain. This has caused divergences in the management and operations of companies that work under technology criteria in Industry 4.0, of which they don't, this difference reveals the fast transformation and achievements obtained by the corporations that have transformed their processes to the new system.

Systems integration is the first step toward Industry 4.0 vision and achieving its goals [1]. The systems are analyzed as a whole, it considers the productive flow, and in this sense, structural changes are proposed in the organization and management of physical objects, as well as the establishment of connections with information systems [2, 3]; vertical flow refers to how a company develops and executes its activities and includes basic elements such as the organizational structure, its human factor, the relationships of its departments, its technological level, and its administration; in a complementary way, the horizontal flow includes external relations and establishes networks of integration with suppliers, clients, information systems and administration, and technological systems among others [4–6].

This study consists in the creation and structuring of the evaluation tool with the criteria obtained in the first phase and is completed with reliability analysis and validity studies. The evaluation tool will result in the current level of vertical and horizontal integration of the company; this will allow to identify gaps and opportunities to develop the other prominent technologies considered in Industry 4.0 [7].

11.2 Background

The research was carried out through the qualitative content analysis, in which scientific articles, theses, and conference reports were collected and analyzed, obtained from various specialized journals related to the Industry 4.0 technological advances and to the business management. In this first phase, decisive criteria were obtained to propose a systematic evaluation methodology. In addition, knowledge and technological gaps were detected, as well as opportunity areas. The complete study can be consulted in a publication dedicated exclusively to this review [8]. The most important results are presented as follows:

Nine prominent technologies were identified as the backbone of Industry 4.0 [9, 10], including elements of industrial organization and management of information and production processes. These blocks were the focus of the research, so that it obtained the panoramic view of its application in the industrial sector, as well as its importance.

The articles were assigned to the categories. However, the articles revealed interconnections with the other categories, so that the systematic review, in addition to identifying the category with greater weight, revealed the requirements for the successful category application in the industrial sector and its interdependence with the other categories.

Finally, the analysis revealed that the category with the higher growth has been horizontal and vertical integration of systems; this is due to the fact that it represents the industrial base, in terms of administration and establishment of relations with other companies. This review not only shows the nine categories and their applications but also revealed criteria for the value chain management in terms of planning. In addition, the essential characteristics that a company must have to be able to perform in the 4.0 environment include sociotechnical environments as well as physical object virtualization through intelligent systems.

Vertical Integration

The performance of the company lies in the level of synergy it possesses, for it must be considered the crucial elements involved in the creation, development, and product manufacturing as well as its management [11, 12]; the mapping of vertical integration or internal integration is to evaluate the system in order to identify critical areas that must be assisted in a different way, for the vertical integration study have included two components, these are shown separately for the revision purpose, but in the analysis will be merged, because they contain similar elements.

Sociotechnical System

The sociotechnical system is so important, as this system depends on the success of the operations of a company; therefore, this importance is transcendent for its analysis within the vertical structure; the purpose of this system is to provide support to the company so that their activities marked in the plan are executed properly; the sociotechnical system must contain the three elements that are technological system, organizational system, and human operating system [2, 13, 14].

Value Creation Modules

The value creation modules are similar to the sociotechnical system; however, they differ in that the value creation module adds two more elements to complete the activities, causing this module to be analyzed thoroughly and in a particular way in each area. The value creation module's objective is similar to that of the sociotechnical system, which is to provide support to the company operations so that they are executed correctly. Nevertheless, it does not require only the presence of the three elements included in the system described above, and add to the product and processes involved, so that along with the sociotechnical system company operations are executed with high levels of synchronization [14].

Human operating system: it gives due importance to human capital as a critical element of change and is directly involved with the progress of the company [15–20].

Organizational system: in essence, the operations sequence between the hierarchical company levels, responsibility delegation, etc. [21–24].

Technological system: includes all the elements available in technology to carry out the production process activities [4, 25, 26].

Product: can be a product or a service; it is fundamentally the company's reason for being and is included as the result of the three previous systems, without neglecting the particular specifications for each detail and activity within the processes [11, 27].

Processes: these are the activities that give life to the product, so they are considered in the modules of value creation as the means to achieve the objective, in this case would be the product or service; it is a systematic analysis that evaluates the process as functional, to discard activities that do not add value [28–32].

Horizontal Integration

The relationship complexity between strategic goals and the operational part from the different levels of the manufacturing systems inhibits the realization of an intelligent manufacturing system; the Stevens model execution is useful to identify aspects of a manufacturing system that can be targeted for strategic planning, applying standardized techniques and using an agility scenario as an operational goal [12, 33].

Any improvement in the industry is based on the analysis of the current situation and the study of the environment, where they are aimed and which strategies should be considered. For this, it is essential to develop a conceptual model of integration, which describes the control activities in the administration of the manufacturing operations and the level of the company, with a representation of the physical system and an explicit interface for the analysis of the optimal control [34].

Stevens Model

This model is intended for the visualization of the company's performance in the overall scheme of its supply chain operations; with this approach, the level of integration that owns the organization as well as its level of technological absorption is defined; this point is crucial for the opportunity determination that can be found in the company, to be proposed as elements of change.

These change elements will be studied both in the internal organization and throughout company supply chain to place it in one of the four integration levels proposed by Stevens [35] and in this way to visualize schematically the integration that it possesses according to the departments that manage to relate to the operations synergy.

A business model describes the logic of an organization's value chain in terms of how it creates and captures customer value and can be represented concisely by an interrelated set of elements that address the customer, value proposition, organizational architecture, and economic dimensions [3]; the starting point is that all organizations have a business model, which can be explicitly articulated, or not; business models are required for the growth of the organization.

11.3 Methodology

The methodology has been divided into two phases for the instrument construction; one is the design of the instrument, and the second refers to the instrument validity and reliability tests, proposed by Hernández-Sampieri [36].

Instrument Design

To construct the measuring instrument, the process which is divided into 12 phases was followed. Figure 11.1 shows the phases of the construction process of a measuring instrument.

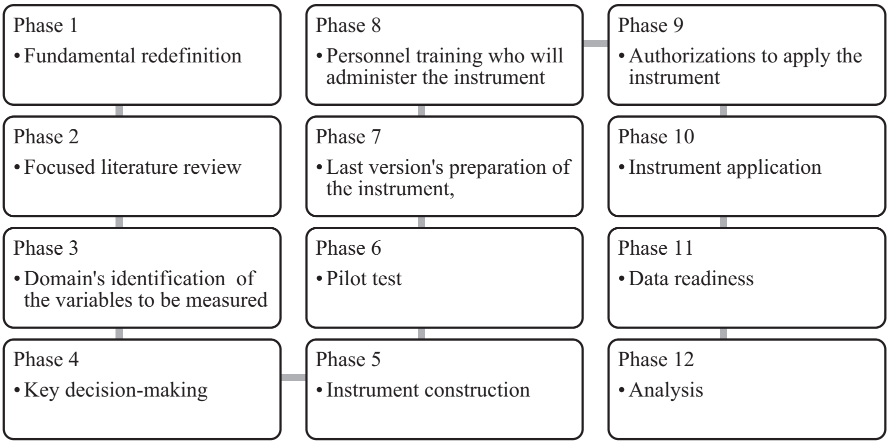

Fig. 11.1 Phases of instrument construction process [36]

Measuring Instrument Requirements

Validity, reliability, and objectivity are elements that should not be treated separately. If any of the three are not met or not analyzed, the instrument is not useful for conducting a study. Table 11.1 shows the measuring instrument requirements, the objectives, and the measuring techniques.

11.4 Information Discussion and Analysis

The analysis of the information obtained consists in the development of the instrument design phases and measuring instrument requirements, as explained below.

Instrument Design

The instrument design was performed exclusively with the monitoring of defined phases.

Phase 1 Fundamental Redefinition The research variables were defined; the proposal will have a goal to be applied in Mexico, on a website, with values on a scale, which reflects the perception of the organization, operations, and clients of the company in the case study.

Phase 2 Focused Literature Review Was performed by reviewing the detailed literature; the findings of this review can be found in Saucedo-Martínez [8].

Phase 3 Domain's Identification of the Variables to Be Measured It precisely identified the components, dimensions, and factors that integrate the variable, based on horizontal and vertical integration systems.

Table 11.1 Measuring instrument requirements [36]

Requirement	Objective	Measuring technique
Validity	It refers to the degree to which an instrument actually measures the variable it intends to measure	Content validity Criterion validity Construct validity Expert validity
Reliability	It refers to the degree to which repeated feedback to the same individual or object produces equal results	Cronbach's alpha
Objectivity	It refers to the degree to which it is permeable or not to the influence of biases and trends of the researcher or researchers who administer, qualify, and interpret	Standardization

Phase 4 Key Decision-Making It was decided to design a new instrument, to be applied in Mexico, applied by a web page, based on a scale questionnaire.

Phase 5 Instrument Construction In this phase the categories and the items were designed.

Phase 6 Pilot Test This test was done with group experts in the academic and research area, such that deficiencies must be detected in the instrument.

Phase 7 Last Version's Preparation of the Instrument Feedback was obtained from the items developed for the instrument, until reaching the final version; Fig. 11.2 shows the survey questionnaire elements.

Phase 8 Personnel Training Who will Administer the Instrument This was done by means of a spreadsheet, to manage the data and to organize them, as well as the codification.

Phase 9 Authorizations to Apply the Instrument The authorization for application was made under confidentiality criteria, and not as a case study, if not to evaluate the requirements of the instrument; this is developed in the second section of the methodology.

Phase 10 Instrument Application Participants to evaluate the instrument are experts in the industrial and service sectors, as well as technology, belonging to important companies in the northern region of Mexico with managerial positions.

Phase 11 Data Readiness The data coding was performed to carry out the analysis of the same.

Phase 12 Analysis The analysis of the information gave rise to the study of the instrument, in which objectivity and reliability can be determined.

Measuring Instrument Requirements Validity

The validity of a measuring instrument is evaluated on the basis of all types of evidence.

The more evidence of content validity, criterion validity, and construct validity has a measuring instrument, the latter will come closer to representing the variables it intends to measure.

$$\text{Total validity} = \text{content validity} + \text{criterion validity} + \text{construct validity}$$

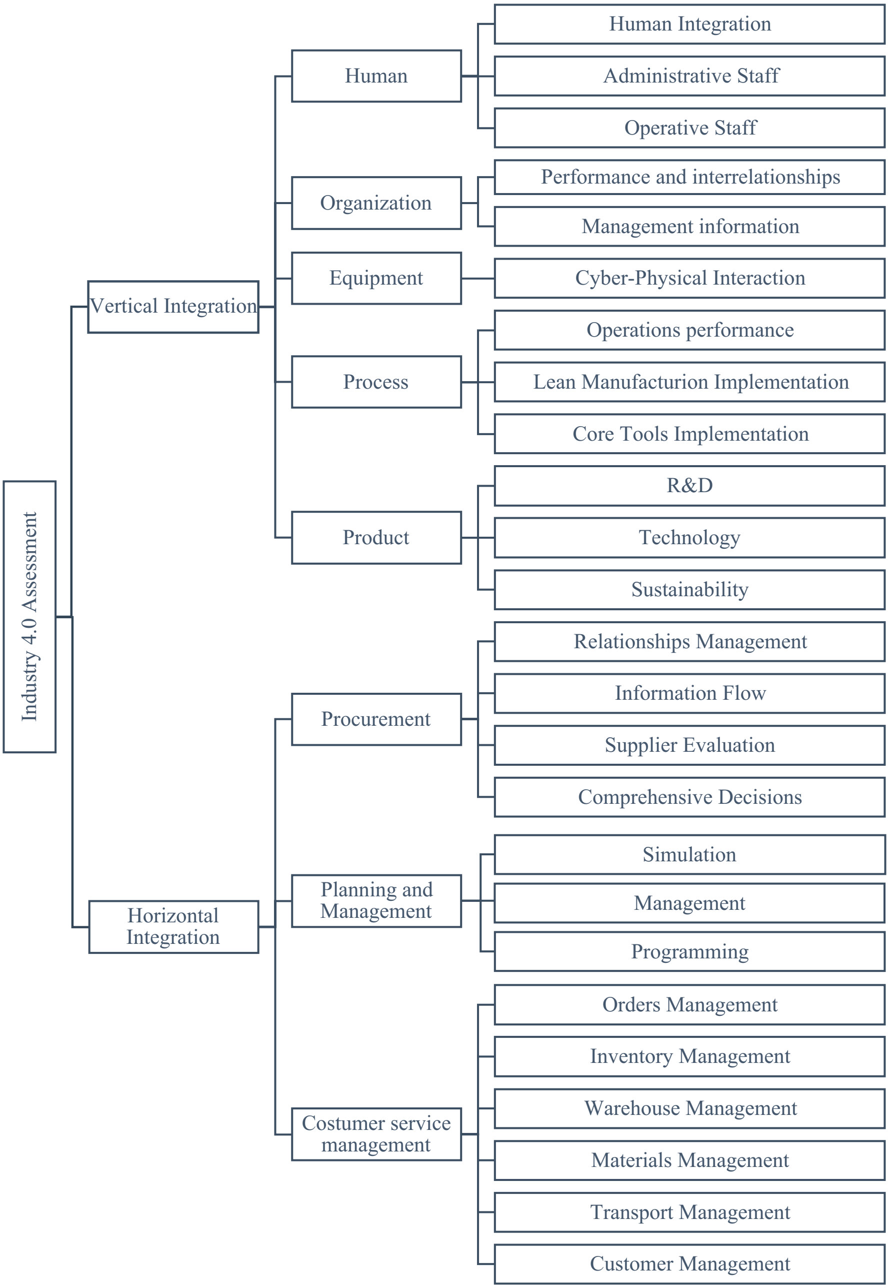

Fig. 11.2 Survey questionnaire elements

Content Validity This validation was carried out in a systematic way, according to the literature review, in which concepts were investigated, until the terms with the highest level of comprehension were defined.

Criterion Validity To perform the criterion validation, tests and comparisons were made with the following tools:

https://www.industrie40-readiness.de from Germany
https://i40-self-assessment.pwc.de from Germany
https://hada.industriaconectada40.gob.es from Spain

Construct Validity This validation can represent the most important and is based on a theoretical basis of correlation of concepts, so that it is expressed as links of the items developed with the rest of the methodology.

Expert Validity This validation was done with experts in the field who reinforced the tool with their points of view, in order to improve the instrument.

Reliability

The instrument reliability was determined by Cronbach's alpha variable. For this purpose, the answers obtained in the application to experts were used; analyzing the data in a spreadsheet was obtained to obtain a value of 99.2%.

Cronbach's alpha used equation

$$\alpha = \frac{k}{k-1}\left|1 - \frac{\sum S_i^2}{S_t^2}\right| \tag{11.1}$$

Objectivity

Standardization Objectivity was obtained through standardization in the instrument application (same instructions and conditions for all participants) and in the evaluation of the results, as well as employing trained and experienced personnel in the instrument.

11.5 Conclusions and Future Work

This revolution is considered holistic from the point of view that includes all the technologies, tools, skills, and knowledge available, to provide systems autonomy and increase level efficiency, customer service, and sustainability.

The inclusion of companies in the new way of operating requires the dissemination of information that allows the understanding and practice of the new modality of carrying out productive activities.

Technologies and the Internet play a preponderant role in the new era; their adoption in companies is imperative.

Companies must have a preparation prior to their application to operate in industry schemes 4.0, to ensure their development in the new system.

The instrument development for evaluating the current system, with validation, reliability, and objectivity tests, contributes to the detection of business gaps and opportunities to improve the industrial environment.

In the future, it is intended to apply to the productive sector, case studies that generate global reports, and analysis that allow investment and growth in technology and process improvement.

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