# 4.0 Transition Methodology for Sustainable Supply Chain Management

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**Abstract.** Customers express more and more willingness to consume sustainable products. This is often considered as a requirement by companies and therefore in their whole supply chains. To ensure an overall improvement of the supply chain environmental performance, the transition to 4.0 must encompass all the stakeholders involved. With a view that facilitates the determination of the required transformations of companies on the sustainability criteria, this article sets out to identify a strategy for optimizing the sustainability of the supply chain considering each stakeholder's resources. Based on deductive research, we propose: 1) a methodology for defining a relevant strategy for 4.0 transition of a supply chain, 2) a qualitative model for assessing the maturity of companies and their entire supply chain, with a focus on the fields of the sustainability, characterizing the 4.0 transformation, 3) a decision-making tool, taking into consideration each stakeholder's deviation from clients' requirements, with a view to identifying and prioritizing the development strategy to be followed for a transition to a 4.0 supply chain.

**Keywords:** 4.0 transformation, sustainable supply chain, maturity model.

## 1 Introduction

The great challenge for today's supply chains is to develop strategies to continuously adapt to the new market demand that becomes "smarter", more transparent, more flexible and more agile at all levels [1; 2; 3]. Supply chains must therefore combine the advantages of artisanal models, producing customized products, and industrial models based on mass production. In addition to technological and digital parameters, a Sustainable Supply Chain (SSC) should respond to social, societal and environmental dimensions improvement [4; 5].

In conclusion there are multiple and sometimes contradictory objectives: to reduce costs and lead times, to increase the ability to innovate, to offer customized products and services, to meet increased customer demands and sustainability performance criteria. Also, there are many barriers to improving the sustainability of a supply chain.

These barriers include a lack of a skilled workforce that understands Industry 4.0, ineffective legislation and controls, ineffective performance evaluation models, and short-term corporate goals [5].

In recent years, new organizational concepts have been developed at a steady pace to respond, in part, to these challenges: the ambidextrous enterprise (capable of simultaneously developing innovative and routine projects) [6]; the Lean enterprise (which hunts down waste to reduce costs, increase responsiveness and the level of performance) [7]; the agile enterprise based on decentralized decision-making and organizational learning [8]; the sustainable enterprise that respects the environment [9]. More recently, the concept of enterprise 4.0 [10] builds on the previous concepts by taking advantage of the digital modernization of industrial tools (internet of things, big data, artificial intelligence, cyber-physical systems) [11; 12; 13]. Changing market has forced these organizations to revisit their supply chain activities in order to include sustainability effectively [4]. The circular economy associates the supply and demand of supply chain industries to improve resource efficiency [14; 15].

However, most supply chain companies do not know how to make this transition to 4.0. We support the idea that they must be able to carry out a factual diagnosis of the different aspects of the 4.0 transformation of their activities. They also do not know how to set achievable objectives that define a 4.0 transformation strategy. In-deed, it can be difficult for a single company, especially small and medium-sized enterprises (SMEs) whose human and financial resources are limited, to identify the approach to follow and define a new strategy, while being aware of the risks involved [16]. Therefore, it is necessary to support companies, to give them a method and tools to diagnose their level of 4.0 maturity, to define their objectives and priorities in their 4.0 transformation, and more particularly their vision of their sustainable supply chain.

Nowadays, there is no organizational transformation method to help companies to define a strategy for their supply chain transformation towards 4.0. The diagnostics currently used are essentially based on interviews with "auditors", without any structuring methodology or factual results. Based on the state of the art detailed in §2, we realized that there is no model to guide 4.0 structural transformation of companies and their supply chains. This observation led us to the hypothesis that in order to make a supply chain progress as a whole, it is necessary for each company in this supply chain to be able to project itself through realistic stages by setting achievable objectives with regard to its capacities to evolve towards 4.0.

By conducting hypothetico-deductive research, the objective of this article is to propose a method and tools for the companies to succeed in their transition towards the 4.0 Sustainable Supply Chain. To do so, we need to be able to evaluate the level of performance of a company in relation to an overall objective of the supply chain of which it is a part, and to be able to help it benchmark itself.

The article is structured as follows: (1) we present a state of the art in order to identify the current problematic for the 4.0 transformation to a sustainable supply chain; (2) we list the main fields concerned by this transformation; (3) we propose a tool and an assessment methodology to help the companies in the supply chain to assess themselves and to define priorities in their strategy towards the 4.0 transitions, in line with their supply, while focusing on the sustainability.

# 2 Literature Review

## 2.1 Strategic Fields of Transition 4.0

Much research has focused on the technological aspects of Enterprise 4.0 [17] and their implications in the supply chain [12;18; 3]. The technological aspects mainly concern the concept of the "smart factory", i.e. the creation of an intelligent and learning environment in a company's production system [19; 2]. Driven by the Internet, the real and virtual world of the company is being transformed into the "Internet of Things" to be faster, more efficient and more flexible in terms of production, using "smart big data". Production is connected with the most modern information and communication systems to create a smart, digitally connected supply chain with production largely organized by itself, while building on Lean concepts [20]. This also implies the implementation of cyber-physical systems, having interconnection between products, machines, ecosystem and even consumers, and this at every stage of the product's life from its design to its end of life [11; 21].

The level of maturity refers to the state of an organization in relation to the deployment of its processes and its objectives [22]. We have identified four fields that best represent our global vision of the Supply Chain and the major issues that must be integrated in order to initiate a transformation towards 4.0 industry [23]:

- Product and process design field
- Production, logistics, and maintenance field
- Strategic organization field
- Sustainability field.

## 2.2 Maturity evaluation models

Different maturity models exist in the literature: purely technological oriented [24], quality oriented organizational processes [25], software oriented CMMI (Capability Maturity Model Integration) developed by (Software Engineering Institute, in 2001, and specific for sustainability management based on ISO 14000.

In the last years other specific maturity models were developed for the 4.0 transformation. In the same line as CMMI, [26] proposes a "4.0 Readiness Model" with six levels of maturity named "outsider", "beginner" for newcomers "intermediate", "experienced" for learners, "expert", "top performer" for leaders. This model considers six dimensions: Strategy and organization, smart factory, smart operations, smart products, data-driven services, employees. More recently [21] proposed a model to evaluate a maturity index on 5 levels: Standard, Big Data, Smart Data, Dark Factory, Industrial Ecosystem. They consider five sectors of the company: Business Management, Development, Manufacturing, Supply chain and Service. [27; 28] identified individual logistics subsystems (Purchase logistics, Production logistics, Distribution logistics, Aftersales logistics) and three main dimensions (Management, Flow of material, Flow of information) according to which the maturity level of a company should be tested. They considered five maturity levels: Ignoring, Defining, Adopting, Managing, Integrated.

In a recent paper [23] proposed a maturity model allowing the evaluation of supply chain companies. They defined five levels of technological maturity and six levels of

organizational maturity of the current situation for the diagnostic model: "1. Basic" and "2. Partial" for newcomers who are starting to question themselves, "3. Managed" and "4. Mastered" for learning companies [2], which have already started a transformation to 4.0, "5. Optimized" and "6. Innovative" for leaders who represent the showcase of the enterprise 4.0. These levels can be likened to "outsider" and "basic", "disciplined" and "adjusted", "optimized expert" and "innovative expert". The latter have already succeeded in achieving the requirements on all aspects of 4.0 transformation, and they are engaged in a continuous innovation process.

On the basis of the four fields identified in §2.1, we propose a methodology and a detailed diagnostic model, with specific development sustainability field. A concrete application of this methodology which is based on a case study will also be presented.

## 3 Methodology & tool

### 3.1 Methodology for SSC 4.0 Transition

The objective of the methodology (Figure 1) is to help supply chain managers to succeed in their 4.0 transformation plan. The proposed methodology is based on the PDCA (Plan - Do - Check - Act) methodology. It offers a frame of reference and is applicable to the entire company in order to improve and even innovate by minimizing risks. The idea is that after one or more cycles of the PDCA, the level expected in the 4.0 transformation is reached.

This methodology integrates in the phases “Do” and “Check” a qualitative assessment of the maturity level. The assessment is obtained for each field of the 4.0 transformation. A gap analysis allows to identify the jobs impacted and the skills to be developed. In “Act” phase an action plan is proposed, especially for recruitments and trainings.

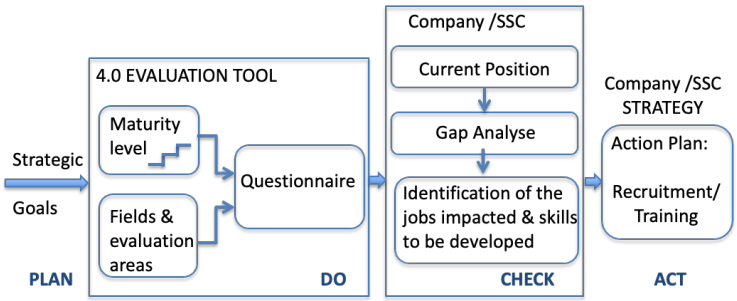


**Fig. 1.** Methodology to define a 4.0 transformation strategy for SSC.

The purposes of these different steps with regard to the 4.0 transition are detailed in Table 1:

**Table 1.** Detailed steps of the methodology.

| | |
|---|---|
| **PLAN:** Define the supply chain manager's priority objectives in line with the company's strategy.<br><br>This phase allows to frame the project, to identify all the requirements and expectations for the future development of the company and the supply chain. | **DO:** Use the 4.0 diagnostic tool :<br>- definition of a maturity scale and its level of control<br>- identifying the fields to be taken into account for the assessment<br>- the realization of a multiple-choice questionnaire for the companies |
| **ACT:** Define a prioritized action plan (long, medium and short term) for the entire supply chain as well as for each of its links in relation to the 4.0 strategy:<br>-employees training<br>-new employee recruitment | **CHECK:** Following the answers to the questionnaire, position the company on each field of the transformation 4.0 :<br>-identification and analysis of gaps between the current situation and the target situation<br>-identification of the job & skills to be developed |

The rest of our article focus on the Do and Check steps in order to propose a 4.0 diagnostic tool that will allow us to identify and analyze the gaps in relation to the maturity objectives of the sustainability field linked to 4.0 transformation.

### 3.2 4.0 Diagnostic Tool for SSC

In [23] we have developed a global model bringing together all the areas of 4.0 transformation previously presented. This model allows us to select the improvement areas and strategies to be adopted so that the supply chain can meet the requirements of the client and the needs of the end customer.

In this paper we focus on “Sustainability field”. Table 3 shows the axis of this field, and the questions concerning it.

| **Sustenability Field** | |
|---|---|
| **Axis** | **Questions** |
| Cyber Security | How do you integrate cyber security in your company? |
| Entreprise and its ecosystem interactions | How the company integrates its ecosystem? |
| Environnemental Impact | What actions has your company put in place to limit the environmental impact? |
| Energy Efficiency Management | How is the energy efficiency of your company managed? |
| Energy Supply | How do you achieve your energy supplies? Who are your suppliers? |
| Circular Economy | What type of waste do you produce? In what quantity? How do you manage your waste? |


**Fig. 2.** Diagnostic process for the Sustainability Field.

Once the responses are done, we should evaluate the current situation concerning each axe. We distinguish two different levels concerning the maturity:

- Level of organizational maturity: one choice between six level proposed by the tool: basic, partial, managed, mastered, optimized, innovative.

- Level of Technological maturity: one choice between the five levels proposed by the tool. For example: for "Energy Supply" axis we propose: 0. Purchase of fossil fuels, 1. Purchase of nuclear energy,2. Purchase of green energy, 3. Green energy production and 4. Green energy resale.

Concerning the target strategy, we distinguish: the target concerning the technological maturity level, and the priority level according to strategy and available resources.

The gap between current situation and the target strategy is calculated by the tool as shown Figure 3 presenting the focus on the sustainability field.

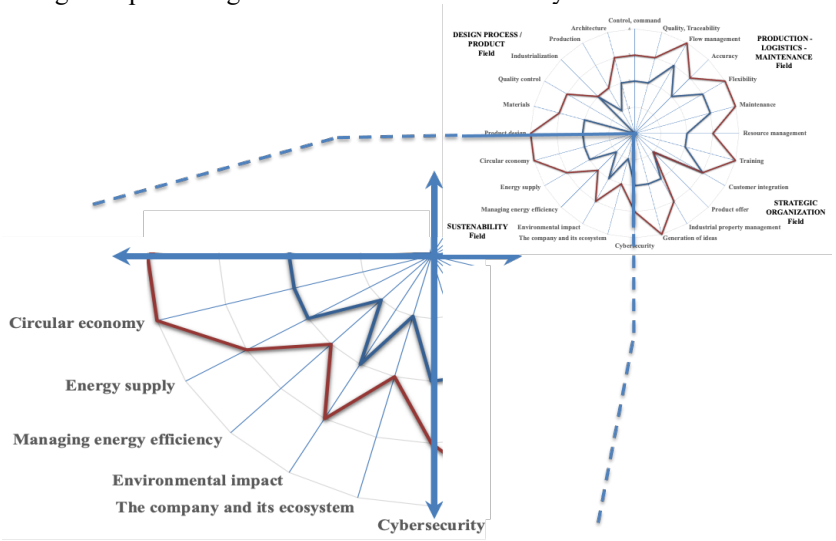


**Fig. 3.** Diagnostic tool result for sustainability field.

This representation allows us to quickly see the initial situation (inner curve - blue) and the target situation (outer curve - red).

The gaps between the initial situation and the target situation allow supply chain managers to identify the axis to be improved in each field, and to associate action plans concerning recruiting and training. In this sense, the tool proposes also a list of skills corresponding to each axis.

## 4 Conclusions & Perspectives

Companies must adapt their organization to meet the new requirements related to Industry 4.0, in a context of sustainable development. Following the literature review we found that there is no organizational transformation method to help companies to define a strategy for their supply chain transformation towards 4.0.

This article aims to propose a methodology and a tool to define the 4.0 transformation strategy for sustainable supply chains. This managerial contribution helps each company, in a personalized way, to design and pilot a strategy of transformation towards 4.0, by prioritizing the axis of development including the essential axis of the

sustainable supply chain. Companies will be able to gain in resilience, agility and efficiency, while being sustainable and respectful of people and their environment. They will also be able to integrate more easily into 4.0 supply chains.

These contributions also make it possible to compare companies by sector of activity and typology, to define possible standards and to implicitly develop a "benchlearning" approach.

The tool allows the aggregation of all the evaluations and automatically generates diagrams allowing the company to have a direct visualization of its positioning with respect to the supply chain objectives. It can then build a strategy based on the company's indicators in relation to the supply chain objectives.

During the implementation of the methodology and the tool presented, the main difficulties encountered were the following:

- identifying a contact with sufficient insight and knowledge of the company's processes to complete the entire questionnaire;
- the confidentiality of the data related to the evaluation of the current situation and the levels targeted according to the company's strategy with the prioritization of the axis.

In perspectives, we plan to propose a specific model of risk management, allowing decision-making in the selection of a transition strategy, starting from the characterization of the model of influence of risks on the project of transformation to the 4.0 supply chain.

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