Evaluating the I4.0 transformation readiness of agri-food companies: from factories to 'smart' factories

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Abstract: The fourth industrial revolution, commonly known as Industry 4.0 (I4.0), is the last technological revolution in manufacturing industry. The economic development due to first three revolution was based on mass industrial production, strongly product-driven. I4.0 changes drastically this approach; the new focus is based on "demand-driven" market that requires the fully-integrated systems able to adapt, in real time, the production system to the demand change. Therefore, a new concept of factory is introduced by I4.0, it is based on open and interconnected infrastructure that allows to manage, to optimize and to monitor the whole production process; according to the National Institute for Standard Technologies (NIST), this can be defined a "Smart Factory". If on one hand the smart factory ensures a flexible and adaptive manufacturing, on the other hand many risk are related to the complexity and interdependence of processes involved (e.g. uncertainty of investments, machines reliability, length of the chain of liability, etc.). Therefore, a preliminary evaluation on the risks and the opportunities related to the competitiveness degree that can be achieved, is needed. This paper addresses these issues by proposing a model for identify the "readiness degree" of agri-food companies to the implementation of smart technologies. Consistently whit this purpose, the model evaluates the potential competitiveness degree of the company by adopting smart technologies, under economic, social and sustainable perspectives.

Keywords: Industry 4.0, Smart factory, Competitive degree Evaluation Model, Readiness assessment

1. Introduction

In Europe the agri-food sector plays a strategic role, according to the last annual agri-food trade report (EU, 2016), in 2015 the entire output of the European Union's agricultural sector was valued at €410 billion and the agri-food industry employs about 7.5 % of the overall workers and 3.7 % of total value added in the EU. In last years, EU is the world's biggest exporter of agri-food products, for an overall amount of € 124 billion, evaluated as the average of exports in years 2013-2015 (fig. 1). Therefore, the agri-food sector can be considered the engine of the European growth under social and economic perspective.

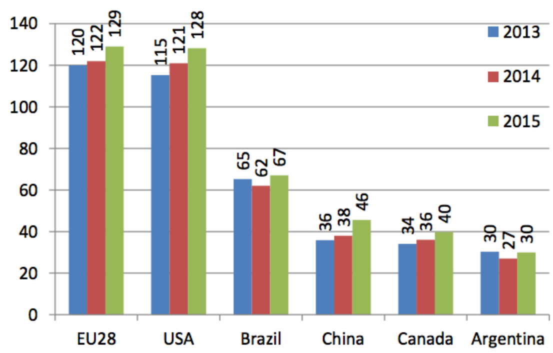

Figure 1. Top world agri-food exporters

The constant pressure on costs, the need for the product traceability, the growing interest paid to the environmental management of the production systems, as well as the greater flexibility of the production are just few of the many aspects to be improved in order to ensuring a high efficiency of the sector (Facchini, et al. 2013). New internet technologies (e.g. internet of things) are now available to monitor, manage and elaborate information concerning spatially decentralized systems interacting each other by cloud computing. A growing interest is paid to potential applications of Internet technologies to manufacturing systems as in the Smart Factories research programs under the Industry 4.0 vision (Digiesi et al. 2013). According to Luque et al. the digital technologies could be the solution to the sector needs, the identification of the key information, the organizations interoperability, as well as the business model integrations would allow to support the continuous decision-making process both at operative and at strategic level. Therefore, the agri-food companies can benefit from the implementation of the paradigms and by technologies proposed by Industry 4.0 (I4) (Luque et al., 2017). I4 can be defined as the development of the manufacturing technologies able to ensure higher levels of interconnectivity, leading to a greater communication between machines and decentralised /local processing of data. By adopting this kind of technology, the 'traditional' agri-food factory can become smart. A smart agri-food factory would be able to satisfy clients request, without changing the lead time, to increase the productivity of existing resources, and to ensure a fast and detailed tracking of the product according to a 'cradle-to-gate' approach. The implementation of I4 devices allows to improve the data management through better communication and data collection for the entire value chain.

If on one hand, the advantages of the I4 paradigms implementation in agri-food sector are unquestionable, on the other hand many companies do not properly evaluate the hazards associated with the implementation of new I4 technologies. The pursuit of the high-tech solutions without assessing the full cost due to their implementation, the introduction of the digitizing processes without addressing underlying inefficiencies, as well as the improper assessment of the possible benefits incurred by adopting innovative devices, are the most common risks for agri-food factories oriented to the implementation of smart production systems. To avoid running afoul of these dangers, companies must gain a detailed understanding of their competitiveness as well as business strategies to be pursuit before investing in I4 solutions. Therefore, a preliminary evaluation about the risks and the opportunities related to the competitiveness degree to be achieved, after smart technologies implementation, can be useful in order to the identify the best developing strategy and for minimizing the risks related to I4 devices implementation.

The purpose of this paper is to develop an analytical model in order to quantify the "readiness degree" of agri-food companies to the implementation of smart technologies. Consistently whit this purpose, the model predicts the potential increasing of the company competitiveness degree, by adopting smart technologies, under different perspectives (economic, social, and sustainable). Moreover, the output of the model could support the company's decision makers, providing a preliminary evaluation, related to the key company's aspects (e.g. quality of the services, efficiency of the production, innovation, etc.), that will be improved by I4 implementation, in both the economic and the organizational terms.

The rest of the paper is structured as follows: a brief review on the readiness models already available in scientific literature is presented in section 2, in section 3 the model methodology's is introduced, results obtained by applying the model in three different companies are in section 4; finally, conclusions of this work are in section 5.

2. Literature Review

The internalisation of the new technologies requires that the available knowledge has to be collected, documented and transferred to explicit knowledge. Therefore ideally, the organizations should recognize the not optimized problems factors and reduce them. From this perspective, a maturity or a readiness model for business model management in I4, would allow companies to achieve an optimized business model leading to improve their strategic goals, responsibility and spirit. In case of I4 innovation, where the changes occur frequently and require organizations to keep up, the structured business models are not still very widespread (Rübel et al., 2018).

The term "readiness" implies a propensity of the system to change. Consistently, the readiness models are developed whit the target to capture the starting-point and evaluate the readiness of the system before engaging in the maturing process. According to Wendler et al. (2012), the term "maturity", identifies a model structured as a collection of elements that describe the characteristics of effective processes at different stages of development. Although this definition, provides a basic understanding of the underlying logic on the maturity model functionality, it does neither clarify the meaning of the "maturity-states" nor of the key elements of the model.
Today, most of the available maturity models generate an awareness of the analysed processes: their state, importance, potentials, requirements, complexity, and so on. Furthermore, they may serve as "starting-point" in order to implement a systematic and well-directed approach for improving the business process, ensuring a certain quality, avoiding errors, and assessing one's own capabilities on a comparable basis.

Every maturity model should consist of two common components to fulfil its purpose: the first component consists of identifying a set of levels required for describing the development of the examined object in a simplified way, the second component allows to identify the capabilities of each criteria to achieve the objectives of the process, according to a multi-dimensional approach (e.g. affected processes, organizational units, problem domains, etc.)

A systematic literature review carried out by Gökalp et al. (2017) on maturity models, considers the model as the framework that supports the organizations in achieving the most important goals, by providing a comprehensive guidance and a strategic road map. The study found that in the last years there is a growing research stream in I4, however there is a research gap due to limited research in the use of the maturity models, and the majority of the models available do not support manufacturing enterprise architecture holistically. Additionally, there are not models developed on a well-defined structure with practices, input and outputs. Therefore, the need for a structured I4 maturity model remains valid.

According to Schumacher et al., the difference between readiness and maturity models depends on the time period to be considered. In particular, the readiness model evaluates the system before the change, while in the case of the maturity model, the evaluation consists to capturing the 'as-it-is' state in progress, in other words in this case the evaluation is performed during the change (Schumacher et al., 2016). The maturity model introduced in 2016 by Schumacher et al., provides the current state of the strategies adopted by different manufactured companies and evaluate the fitness of the I4 strategies, according to nine different point of views: product (digitalization of the product), customer (digitalization of sales/services), operations (decentralization of processes), technology (utilization of mobile devices), strategy (implementation I4 roadmap), leadership (management competences and methods), governance (labour regulations for I4), culture (knowledge sharing), and people (autonomy of employees). The results shown that the model can assist the companies in order to provide a self-assessment on their degree of the I4 implementation.

In 2017 Peesl et al. (2017), presented a Capability maturity models for I4 that allows to evaluate the business processes of the organisation, in order to support the companies in estimating their current competitiveness level. The model dimensions address to five areas: purchasing, production, intralogistics, sales and human resources. The evaluation method is developed according to a 6-step approach. The first step consists to create the awareness for I4 in the company; the scope of the planned I4 project is identified in the second step; in the third phase the target state for each field has to be defined. On the basis of the defined target profiles, concrete measures are planned and evaluated the concrete measures in order to determine the difference between the actual and the target maturity level. In fifth step the defined objectives (target profile) and measures regarding the relevance and the contribution to the company strategy are selected. In this way, the projects requirements for I4 implementation are defined, are connected and implemented (last step). The model has been tested in an Austrian company, and results show that the organizational changes within this field are still a bottom up driven process instead of a management indicated holistic change process.

In order to support companies for identify the proper digitalization transformation roadmap (digital reediness), a Digital REadiness Assessment MaturitY (DREAMY) model is introduced by Carolis et al. The model is adopted for assessing, by means of a scoring method, the 'as-is' scenario of a manufacturing company according five main areas, identified as: Design and Engineering, Production Management, Quality Management, Maintenance Management, and Logistics Management. A questionnaire is developed in order to synthesizing the specific knowledge to be detected and evaluate the digital competitiveness of any companies. Thanks to the information gathered through the adoption of the questionnaire, it is possible to assess the company's digital readiness with a series of maturity indexes. The paper not presents any case study to test and evaluate the model effectiveness (Carolis et al., 2017).Recently, an additional 'Readiness Measurement Model', commissioned by the IMPULS Foundation of the German Engineering Federation (VDMA), has been developed. The model allows to calculate the I4 quantitative score, by means of a self-assessment performed trough an online questionnaire (www.industrie40-readiness.de). On the basis of six key I4 dimensions, the online tool provides the readiness level of the company (from 0-low to 5-top), consistently with the minimum requirements that must be met for the implementation of I4 technologies. The overall I4 score, is estimated according to a 'lowest score' approach, this means that if a company reaches the level 5 (top performer) in three fields and level 1 (outsider) in one field, the overall readiness is equal to level 1. The survey conducted in Germany through the online platform on the readiness levels evaluated for 836 companies (Lichtblau et al., 2015), shown that there are not companies characterized by higher readiness level. Indeed, the average readiness level of the Germany's companies is less than one, both for mechanical engineering industries and for manufacturing industries (fig. 2).

The analysis of manufacturing systems evaluating the integration of I4 strategies under conditions of uncertainty is presented in 2017. The authors introduced a five-stepped evaluation method. First, the evaluation scope is set. Consequently, quantitative and qualitative criteria are identified consistently with the company's targets and the planned implementations of I4 technologies. Overall data, for each criteria, are collected. Finally, a multi-criteria evaluation is carried out in order to identify a probability distribution of the NPV. Uncertain, quantitative criteria, monetary as well as non- monetary evaluation, are modelled via probability distributions according to a Monte-Carlo Simulation (Liebrecht et al, 2017). The calculation process depends by computational performance of the equipment adopted (software and hardware parts) and by the number of simulation iterations.

Table 1. Overall results for Industry 4 readiness in for Germany's companies

Level	Mechanical engineering industries (%)	Manufacturing industries (%)
0. Outsider	38,9	58,2
1. Beginner	37,6	30,9
2. Intermediate	17,9	8,6
3. Experienced	4,6	1,7
4. Expert	1,0	0,6
5. Top performer	0,0	0,0
Average Readiness	**0,9**	**0,6**

To sum up, the literature review conducted shown that are available different models able to ensure, independently by the industrial sector considered, a deep evaluation about the status quo of the company, under technological and organizational perspectives. If on one hand the existing models allow to identify, for each industrial sector, the current readiness degree of the company, on the other hand the existing models do not allow to assess the company's key aspects that could be improved by I4 technologies implementation.

Therefore, the approaches evaluated are not able to provide any information about the expected benefits by adopting smart technologies, under economic, social, and sustainable perspectives. The model introduced in the next section aims to fill this gap by providing, on the basis of the current readiness degree of the companies active in agri-food field, a prediction of the potential increasing of the companies' competitiveness degree by means of the implementation of I4 technologies.

3. Methodology

The readiness model proposed is based on an analytical approach developed with the Matrix Computation Toolbox implemented in Matlab, in the following the main steps of the model application are shown:

1. Qualitative and quantitative statements, according to different dimensions (tab. 2), are provided in input to the model, in order to

estimate the current company competiveness degree (φ_i).

The overall current company competiveness degree (φ_0) is obtained by the weighted average of competitiveness degrees estimated for each of seven dimensions (eq. 1):

$$\varphi_0 = N^{-1} \sum_{i=1}^{N} \varphi_i \omega_i \quad (1)$$

Where N identified the number of dimension considered (seven dimensions are considered in case of agri-food companies) and ω is the weight corresponding to each dimension;

2. Starting from statements corresponding to current business' performance and considering the implementation of I4 technologies, the new performance, for each statement, are predicted by the model. On the statistical basis and considering the performance of the smart agri-food I4 technologies, available on the market, the new performances, for each statement, are predicted and are evaluated in term of competitiveness;
3. In output the model provides the overall companies competiveness degree (φ_0^*) predicted after the implementation of I4 technologies.

   Both φ-values, between 0 and 1, increases with increasing of the competitiveness degree of the company.

A VBA macro is implemented in order to simplify the interaction with the model and easily identified the results of the evaluation.

3.1 Input parameters

The model evaluation is based on seven dimensions, each of them is characterized by four statements based on both qualitative and quantitative values, estimated on a yearly basis, considering the full range of the products manufactured (table 2).

Table 2. Model's dimension and statements

Dimension	Statements
1. Quality	1.1 Low-quality products*,1 [%]
	1.2 Customer satisfaction (evaluated on range from 1-low to 100-high satisfaction) [#]
	1.3 Scraps* [%]
	1.4 Investment on quality process² [%]
2. Innovation	2.1 Investment on R&D sector² [%]
	2.2 Investment on ICT sector² [%]
	2.3 Number of patents [units]
	2.4 Fully automated machines available³ [%]
3. Service - Level	3.1 Time-to-market* [days]
	3.2 Lead time* [hours]
	3.3 Delivery time* [days]
	3.4 Fulfilled order ⁴ [%]
4. Packaging line efficiency	4.1 Productivity rate* [units/hour]
	4.2 Downtime/uptime machine ratio* [#]
	4.3 OEE* [#]
	4.4 Inventory turnover index* [#]
5. Sustainability	5.1 Waste generated⁵ [%]
	5.2 Overall energy consumption [GWh]
	5.3 Overall Carbon footprint⁵ [kgCO₂eq/units]
	5.4 Work accidents [accidents]
6. Flexibility	6.1 Overall setup time [min]
	6.2 Updates (equipment and organizational) in production process [units]
	6.3 Forecast Mean Absolute Percentage Error [%]
	6.4 Average Skills required for day-to-day line activities (evaluated on range from 1-low to 100-high complexity) [#]
7. Economy	7.1 Overall company's turnover [M€]
	7.2 ROI [%]
	7.3 ROS [%]
	7.4 Overall logistic cost ratio² [%]

(*) parameters estimated as average of indicators referred to specific products;
(1) 'low quality' products are considered the products which do not meet the quality standard identified by the company;
(2) percentage evaluated from company's annual turnover;
(3) percentage evaluated from overall number of machines available;
(4) percentage evaluated from actual demand;
(5) percentage evaluated from overall annual production;

The competitiveness degree for each different statement is evaluated with a Level (L) ranging in [0-4] according to threshold values in shown appendix A. Level '0' corresponds to the obsolescent agri-food companies, while the level '4' identifies a smart agri-food factory, characterized by high competitiveness degree.

3.2 Theoretical formulation

The analytical formulation adopted in the model is based on an evaluation matrix (E_V) where each column identifies the level corresponding to the different statements (four statements for each dimension) and each row represents one of the seven dimensions considered in the model (eq.2).

$$E_v = \begin{bmatrix} L_{1,1} & L_{1,2} & L_{1,3} & L_{1,4} \\ L_{2,1} & L_{2,2} & L_{2,3} & L_{2,4} \\ L_{3,1} & L_{3,2} & L_{3,3} & L_{3,4} \\ L_{4,1} & L_{4,2} & L_{4,3} & L_{4,4} \\ L_{5,1} & L_{5,2} & L_{5,3} & L_{5,4} \\ L_{6,1} & L_{6,2} & L_{6,3} & L_{6,4} \\ L_{7,1} & L_{7,2} & L_{7,3} & L_{7,4} \end{bmatrix} \quad (2)$$

One indicator for each dimension (V_i) can be calculated as the sum of the levels obtained by the indicators of the same dimension (eq. 3).

$$V_i = \sum_{j=1}^{4} L_{i,j} \quad (3)$$

The company competiveness degree for each dimension (φ_i) is evaluated by comparing the V_i-value with the value assumed by V_p (eq. 4).

$$\varphi_i = \frac{V_i}{V_p} \quad (4)$$

where V_p identifies the performance of the 'perfect smart factory' obtained by giving the maximum level to all statements ($\forall L_{i,j} = 4$). Therefore, the value of V_p, for each dimension, is equal to 16.

The same formulation can be adopted for identifying the overall company's competiveness degree (eq. 1) before (φ_0) and after the implementation of I4 technologies (φ_0^*). The gap between two competitiveness degree (χ) estimates the predict improvements, due to I4 technologies implementation.

3.3 Output parameters

The improvements due to the implementation of I4 technologies are identified on the basis of the prediction factors ($\mu_{i,j}$) estimated by analysing the performance of the agri-food I4 technologies, available on the market and tested by sector companies for researches purposes (tab. 3).

Table 3. Prediction factors for the implementation of I4 technologies in agri-food smart factory

Statement ID	$\mu_{i,j}$	Reference
1.1	0,5	Manenti, 2015
1.2	1,2	Caylar et al, 2016
1.3	0,1	Bechtold , 2014
1.4	0,8	Bauer at al, 2015
2.1	1,25	Bauer at al, 2015
2.2	1,25	Bauer at al, 2015
2.3	1,5	Bauer at al, 2015
2.4	1,3	Manenti, 2015
3.1	0,75	Manenti, 2015
3.2	0,7	Rüßmann et al, 2015
3.3	0,7	Rüßmann et al, 2015
3.4	1,1	Rüßmann et al, 2015
4.1	1,05	Bauer at al, 2015
4.2	0,5	Manenti, 2015
4.3	1,15	Manenti, 2015
4.4	1,3	Manenti, 2015
5.1	0,2	Manenti, 2015
5.2	0,8	Manenti, 2015
5.3	0,8	Bauer at al, 2015
5.4	0,5	Bauer at al, 2015
6.1	0,2	Rüßmann et al, 2015
6.2	1,1	Rüßmann et al, 2015
6.3	0,15	Bauer at al, 2015
6.4	0,7	Caylar et al, 2016
7.1	1,15	Caylar et al, 2016
7.2	1,4	Blanchet et al, 2014
7.3	1,06	Bauer at al, 2015
7.4	0,8	Blanchet et al, 2014

Therefore, for each dimension is estimated a new indicator (V_i^*) given by equation 3, considering the new evaluation matrix (eq. 5). Where each $L_{i,j}{}^*$ value represents the predict level for each statement (eq. 6)

$$E_v{}^* = \begin{bmatrix} L_{1,1}{}^* & L_{1,2}{}^* & L_{1,3}{}^* & L_{1,4}{}^* \\ L_{2,1}{}^* & L_{2,2}{}^* & L_{2,3}{}^* & L_{2,4}{}^* \\ L_{3,1}{}^* & L_{3,2}{}^* & L_{3,3}{}^* & L_{3,4}{}^* \\ L_{4,1}{}^* & L_{4,2}{}^* & L_{4,3}{}^* & L_{4,4}{}^* \\ L_{5,1}{}^* & L_{5,2}{}^* & L_{5,3}{}^* & L_{5,4}{}^* \\ L_{6,1}{}^* & L_{6,2}{}^* & L_{6,3}{}^* & L_{6,4}{}^* \\ L_{7,1}{}^* & L_{7,2}{}^* & L_{7,3}{}^* & L_{7,4}{}^* \end{bmatrix} \quad (5)$$

$$L_{i,j}{}^* = \mu_{i,j} L_{i,j} (\forall i, j) \quad (6)$$

According to equations 1 and 4, respectively, the overall competitiveness degree (φ_i^*) and the competitiveness degree for each dimension (φ_i^*) are evaluated.

4. Model Application

The model is tested on a sample of 8 agri-food companies characterized by different size, business sector as well as technology availability. For each case a questionnaire of twenty-eight questions is submitted to main company managers. The questionnaire is subdivided in seven sections (one for each dimension), for each section four different essay-questions are provided, according to the statements shown in table 2.

In most cases, three different managers are involved in the model implementation, on the basis of the expertise and of the responsibilities of each manager, a weight for each questionaries' section was attributed to given answers. Three different weights (0.2, 0.6, and 1) are identified according to the skills of the manager interviewed, 1 is the weight assigned to the specific section in case of the manager have a deep awareness of the potential and of the limits regarding the aspects considered in the section. On the contrary, a 0.6 or 0.2 value is adopted in case of medium or low competence, respectively, of the manager about the aspects investigated in the section. In all cases, the weights are identified by the applicant of the model considering the professional profile of the manager interviewed.

The questionnaires collected for each company are analysed by the applicant of the model, one iteration is required for each company's evaluation. The level (L) corresponding to the different statements, according to the threshold values shown in appendix A, is assigned to replies provided by company's' manager/s. In case of more managers of the same company were interviewed, a weighted average of the values corresponding to different levels is considered for identifying the overall level to be associated to each statement. Further evaluations and the prediction factors of the company analysed, are identified starting from the overall section-levels thus established.

In this paper is shown an application of the model in order to evaluate the readiness degree of two different agri-food companies, first (identified as A) is a medium enterprise with less than 100 employees, able to ensure an annual productivity of about 30x10^3 tons of final product. The second is a big company with some 250 employees that in last tree-years has produced about 100x10^3 tons of final product.

The evaluation is conducted by submission of a questionnaire to three different managers (packaging line manager, quality manager, waste manager) and for each company is identified the statements required in input by the readiness model. On the basis of prediction factor is estimated the readiness degrees of two companies (tab. 4 and tab. 5) for the implementation of smart technologies.

Table 4. Readiness degree - company A

	Current (NO I4)						Predict (YES I4)					
	Statement				φ_i	φ_0	Statement				φ_i^*	φ_0^*
1	1	3	2	3	0,563	0,536	3	4	4	3	0,875	0,777
2	1	3	2	1	0,438		2	4	3	3	0,750	
3	3	2	3	4	0,750		3	3	3	4	0,813	
4	2	1	3	0	0,375		2	3	4	1	0,625	
5	3	3	2	3	0,688		4	3	3	4	0,875	
6	3	1	1	1	0,375		4	3	3	3	0,813	
7	3	2	2	2	0,625		3	3	3	2	0,688	

Table 5. Readiness degree - company B

	Current (NO I4)						Predict (YES I4)					
	Statement				φi	φ_0	Statement				φi*	φ_0^*
1	2	3	3	3	0,688	0,643	3	4	4	3	0,875	0,813
2	2	2	3	3	0,625		3	3	4	4	0,875	
3	3	2	3	4	0,750		3	3	3	4	0,813	
4	2	2	3	3	0,625		2	3	4	4	0,813	
5	3	3	2	4	0,750		4	3	3	4	0,875	
6	3	2	3	2	0,625		4	3	3	3	0,813	
7	1	2	2	2	0,438		2	3	3	2	0,625	

It is very interesting note that the current readiness degree is 0.536 for company A and 0.643 for company B, this means that technology B-company is smarter, if compared to the technology of A company. In both cases the overall competitiveness degree (φ_0) is estimated considering the same weights (ω_i) for each dimension.

The predicted readiness degree is evaluated on the basis of the agri-food prediction factors shown in tab.3, the implementation of I4 technologies in company A allows to increase of 45% the overall competitiveness degree of the company (fig. 2). As far as concern the performance of B-company, the benefit due to I4 implementation are evaluated around 25%.

Figure 2 Current (NO Industry 4.0) and Predict (YES Industry 4.0) Overall Competitiveness degree for company A (a) and B (b).

According to model predictions, for both companies, the improvements due to I4 implementation are not negligible, in particular in the first case (A-company) the I4 devices adoption is strongly recommended. Indeed, in this case, the smallest enterprise, even if characterized by more obsolescent technology, would gain more benefits from smart devices implementation.

On the contrary the improvement of the B-company is quite limited, if compared with benefit gained by the other company. This is due to two main reasons: the current technology level of the B-company, for different statements, is already characterized by highest level. In these cases, the I4 implementation would not further benefit; the second reason is related to the different improvement levels ensured by available I4 technologies. In particular, there are devices thats allow to obtained significantly benefits in specific dimension rather than in other (e.g. $\mu_{2,3} > \mu_{2,1} > \mu_{4,1}$), therefore the performance increase is strong dependently by current company competitiveness degree and by corresponding dimension.

5. Conclusion

The research work presented here aim to develop a readiness model and a related tool for assessing the competitiveness degree of the agri-food companies in case of the implementation of I4 technologies.

The model is aims to provide the following benefits: standardization, development, higher quality, more flexibility, continuous benchmarking and improvement, global competition among strong business, creation of appealing jobs, new service and business model in a traditional sector like that of agri-food.

The readiness model is developed by using an analytic approach implemented in the Matlab Matrix Computation Toolbox. The conceptual modelling and qualitative and quantitative methods are adopted in order to predict the competitiveness degree of the smart factory. The model is validated by applying it to two different agri-food companies. The results obtained shown the reliability and the effectiveness of the model in evaluating the competitiveness degree in case of I4 implementation.

The flexibility of the model allows to apply it in many other business sectors. However, solutions regarding possibly occurring problems concerning the application in different industry sectors need to be identified to guarantee the model's success in the future.

Future development activities will be mainly focused in developing a method to identify company-specific target statements, in improving accuracy of the statement as well as in defining the strategic steps to achieve the desired competitiveness levels. Furthermore, it could be assessed, how the application of the readiness model affects the organizations and their business model management. Since a standard covering this specific topic is not yet in use, conclusions about purpose and intention could be analysed.

A further development to improve the readiness model will be the evaluation of the investment, running cost as well as management cost required to transform a factory in a smart-factory. In this way the preliminary competitiveness prediction will be support by rough economic evaluation.

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Appendix A. LEVEL VALUES IDENTIFICATION

Statement ID	Level ($L_{i,j}$)					Unit of measurement
	0	1	2	3	4	
1.1	Higher than 10	]5, 10]	]3, 5]	]1, 3]	Lower than 1%	[%]
1.2	Lower than 70	]70, 80]	]80, 85]	]85, 95]	]95, 100]	[#]
1.3	Higher than 10	]5, 10]	]3, 5]	]1, 3]	Lower than 1	[%]
1.4	Higher than 20	]10, 20]	]7, 10]	]1, 7]	Lower than 1	[%]
2.1	Lower than 1	]1, 3]	]3, 4]	]4, 6]	Higher than 6	[%]
2.2	Lower than 1	]1, 3]	]3, 4]	]4, 6]	Higher than 6	[%]
2.3	Lower than 2	[2, 6[	[6, 8[	[8, 12[	Higher than 12	[units]
2.4	Lower than 20	]20, 40]	]40, 50]	]50, 70]	Higher than 70	[%]
3.1	Higher than 24	]15, 24]	]12, 15]	]8, 12]	Lower than 8	[days]
3.2	Higher than 5	]3, 5]	]2, 3]	]0.5, 2]	Lower than 0.5	[hours]
3.3	Higher than 10	]5, 10]	]3, 5]	]1, 3]	Lower than 1	[days]
3.4	Lower than 70	]70, 80]	]80, 85]	]85, 95]	Higher than 95	[%]
4.1	Lower than 10	]10, 50]	]50, 100]	]100, 750]	Higher than 750	[units/hours]
4.2	Higher than 0.15	]0.1, 0.15]	]0.07, 0.1]	]0.01, 0.07]	Lower than 0.01	[#]
4.3	Lower than 0.8	]0.8, 0.9]	]0.9, 0.92]	]0.92, 0.98]	Higher than 0.98	[#]
4.4	Lower than 2	[2, 10[	[10, 15[	[15, 30[	Higher than 30	[#]
5.1	Higher than 50	]25, 50]	]20, 25]	]10, 20]	Lower than 10	[%]
5.2	Higher than 200	]75, 200]	]50, 75]	]10, 50]	Lower than 10	[GWh]
5.3	Higher than 0.2	]0.07, 0.2]	]0.05, 0.07]	]0.03, 0.05]	Lower than 0.03	[kgCO_2eq/units]
5.4	Higher than 125	]80, 125]	]60, 80]	]20, 60]	Lower than 20	[accidents]
6.1	Higher than 120	]45, 120]	]30, 45]	]10, 30]	Lower than 10	[min]
6.2	Lower than 5	[5, 10]	]10, 15]	]15, 20]	Higher than 20	[units]
6.3	No forecasting system	Higher than 15	]10, 15]	]1, 10]	Lower than 1	[%]
6.4	Higher than 60	]40, 60]	]30, 40]	]10, 30]	Lower than 10	[#]
7.1	Lower than 1	]1, 25]	]25, 50]	]50, 500]	Higher than 500	[M€]
7.2	Lower than 0	]0, 3]	]3, 5]	]5, 10]	Higher than 10	[%]
7.3	Lower than 0	]0, 3]	]3, 5]	]5, 10]	Higher than 10	[%]
7.4	Higher than 20	]10, 20]	]7, 10]	]1, 7]	Lower than 1	[%]