POST-PRINT Version

A methodology to assess the skills for an Industry 4.0 factory

Federica Acerbi, Silvia Assiani, Marco Taisch

Department of Management Engineering, Politecnico di Milano,
via Lambruschini 4/b, 20156 Milan, Italy
federica.acerbi@polimi.it – *corresponding author –;*
silvia.assiani@polimi.it; marco.taisch@polimi.it

Abstract. The rapid change that is affecting the society together with the rising of new technologies are impacting the manufacturing sector as well. Moreover, this change has also an impact on the skills that operators and managers should master. Companies, on their own, must be always updated in order to keep high their competitive advantage. For these reasons, we carried out this study which aims at searching for a new methodology to assess the current level of companies' workforce in terms of skills needed for taking advantage from the Industry 4.0 paradigm. Starting from an analysis of skills assessment methods, we created *DREAMY4Skills*, a skills 4.0 assessment model focused on the specific job profile within a company operating in the manufacturing sector. This model is based on a maturity model which enables to make companies be aware of their current status in terms of skills and thus it helps companies in implementing a transformation path to pursue a continuous improvement strategy. This work has two purposes, on one side we would like to have a model useful in practical terms to enable the skills 4.0 assessment held by the workforce, on the other side there is the scientific purpose which is to create another small brick in the literature.

Keywords: Industry 4.0, Skills, Assessment Model, Maturity Model.

1 Introduction

Nowadays, we are living in a world where everything is transforming. The rising of new technologies is re-shaping the entire society and even humankind. Along with the Fourth Industrial Revolution, the Industry 4.0 (I4.0) concept has risen and this has been transforming the traditional manufacturing sector by enabling more efficient and flexible production systems. The rising of I4.0 enabling technologies [1] is bringing many advantages but some challenges must be considered [2].

The requests of competencies are changing rapidly, and, since the relevance of human capital is commonly recognized as *"competitive weapon"* [3], today in order to be competitive both new hard skills and soft skills are needed [4]. Companies must develop clear plans for expenditures, but they should also take into account that the increase in productivity and the consequent expected revenue growth will shorten the payback time to a few years. So, in order to really take advantage of this revolution firms must balance investments in human capital and in technologies.

Considering both the relevance of human capital and the change of the necessary skills to be competitive in the manufacturing sector, leveraging on different studies on skills 4.0, as [5], the paper [4] identified a wide spectrum of both hard and soft skills necessary to operate in an I4.0 factory. Moreover, a clustering of them in new or evolved job profiles was developed. From that work, a skills 4.0 assessment model was built in this paper. In fact, companies are interested in understanding their current status in order to act in the proper way to undertake an improvement path. As stated by Watts Humphrey [6] "*If you don't know where you are, a map won't help*". In this study, skills assessment methods were analysed together with maturity models to identify the best way to measure the level of workforce skills and thus, enabling companies to act accordingly to their current status. According to us, those models already developed by academics and consulting companies were not fully completed or were not focused on skills for the I4.0. Thus, we decided to develop *DREAMY4Skills*, a skills 4.0 assessment model focused on the specific job profiles characterising a current manufacturing company.

This paper will be divided into 5 sections: 1) introduction, 2) description of the methodology of the study that is based on a literature review, two focus groups and a pilot assessment; 3) a literature review on skills assessment models, and maturity models; 4) the description and development of the *DREAMY4Skills* model; 5) limitations and conclusions.

2 Methodology

In this section, we define the main steps that we undertook in order to perform the studies and develop *DREAMY4Skills.*

Considering the worldwide necessity to align the workforce skills with the investments in new technologies, we perform a detailed analysis on skills assessment models in order to identify a new way to enable companies operating in the manufacturing sector to have a picture on their workforce current status. For this

purpose, a systematic literature review was performed. In order to collect material regarding the methods most used to evaluate workforce, we searched about both hard and soft skills on the main scientific database by using the following keywords "*soft skills*", "*hard skills*", "*assessment models*", and "*assessment methods*". Among all the papers emerged from the research and looking at their references, we selected the most relevant ones in order to understand how our evaluation could have been performed.

Once we understood which instruments are present in the literature, we decided to analyse which tools are put in place by some consulting companies.

The skills assessment models analysed were not completely effective for our purpose since none of them was explicitly developed to assess skills 4.0. Furthermore, maturity models have been found suitable to assess manufacturing companies' processes within I4.0 context. For these reasons, we performed a deeper analysis of maturity models in order to evaluate whether it was suitable for people as well. The keywords used for this part of the analysis were: "*maturity model*", *"capability maturity models", "People capability maturity model"* and then the terms above were combined with "*Industry 4.0*". To the results obtained from this research, we added a model suggested by academic experts [7], focused on the assessment of the readiness of companies' processes in terms of processes 4.0.

Then, in order to validate and to verify the feasibility and usability of our study, we organized two focus groups: one with academic experts and one with industrial experts.

Finally, we submitted our model to an Italian firm to do a pilot assessment. The results are shown in chapter 4.3.

3   Literature review

3.1   Skills assessment models

In the academic world, many skills assessment models are described and studied. They focused on soft skills or hard skills few of them covered both the thematics.

Considering hard skills, the majority of the models are those developed in the clinical field like [8]–[10]. The majority of them assesses whether a task is performed or not by using yes/no checklists, others do not report how the assessment is performed. Moreover, these studies did not drill down explaining which are the technical skills that the workforce should have, and there is no distinction between different job profiles.

As regards soft skills, the majority of those analysed presents a self-assessment model through a questionnaire with answers based on the Likert scale [11], [12], that biased the results. Finally, the assessment of a mix of technical skills and soft skills, but still in the clinical field, is studied by [13].

There is a lack of studies about skills assessment models in the industrial field and

Consulting companies' tools were investigated too in order to have a more practical view of the topic. They were mainly focused on specific and restrict subjects not regarding the I4.0 paradigm, as for example [14]–[17], but the methodology was interesting because they proposed a multi-source assessment in order to reduce at minimum the subjectivity.

In spite of this, some attempts to assess both soft and hard skills were conducted. An example is "*Toolbox Workforce management 4.0*" [18] where an assessment of skills in an I4.0 context is proposed. The main limitation found was the fact that it considers a generic set of skills that is not differentiated according to the different job profiles. An interesting point instead is that, it is based on a maturity model and for this reason, we decided to further investigate the potentialities that these types of models can have to complete our work.

3.2 Maturity models

A wide literature about maturity models has been written starting from the latest '70 until today. Even if they are applied with many different purposes, the structure is quite common to all of them. The main purposes for which the maturity models usually are utilised are [19]:

— *Descriptive*: the final goal is to describe the current status of an organization and it can be used as a diagnostic tool;
— *Prescriptive*: the final goal is to identify the desired level of maturity for then providing guidelines for the improvement and courses of actions are suggested;
— *Comparative*: the final goal is to perform an internal or external benchmark on the basis of historical data.

The common characteristics shared among the maturity model analysed are:

— the number of levels, that varies from 3 to 6 (the most commons are those composed of 5 levels);
— there is a logical progression among the levels, thus to reach subsequent levels of maturity, all the previous levels must be covered;
— the main goal is always to enable an improvement.

Some models were focused on the process assessment, others were focused on workforce management, and considering also the work done by [18], we thought that the structure of these models, in particular, those with a descriptive purpose, could have been exploited for the skills assessment too. In fact, they allow obtaining a picture of the current status of the entity under analysis. They also support the continuous improvement, by giving specific details, step by step, on the next goal to be achieved. For these reasons, they could be useful to enable companies to design the correct training strategy for each person. Thus, in the end, we took inspiration from [20], that proposed a framework with a detailed description, step by step, on how to create a maturity model.

4 *DREAMY4Skills* methodology

In this section, the focus is on the description of *DREAMY4Skills* and on its development steps including the creation of the questionnaire needed to gather data.

4.1 *DREAMY4Skills*: Skills 4.0 assessment model

DREAMY4Skills, whose development is reported in section 4.2, is a skills 4.0 assessment tool based on maturity models which aims to evaluate the competencies, in terms of both hard and soft skills, owned by managers and operators employed in manufacturing companies embracing I4.0 paradigm. It is composed by five maturity levels, described below, characterizing the competencies level owned by each worker.

(v) **Proficient**: The worker is totally able to manage the emerging technologies and he/she is open to improving his/her capabilities being always updated. He/she is able to use tablets and PC and the software that are commonly installed on them autonomously and in complex situations by supervising the others in case of need.

(iv) **Competent**: The worker is able to manage autonomously the majority of the emerging technologies and he/she is open to improving his/her capabilities trying to be always updated. He/she is able to use tablets and PC quite autonomously and also the software that are commonly installed on them.

(iii) **Practiced**: The worker has few notions about the emerging technologies and he/she is able to use some of them. Usually, he/her is not intentioned to update his/her current status of his/she capabilities unless it is of his/her own interest or it is necessary for his/her career or to keep his/her job occupation. The worker has a working knowledge about tools like PC, tablet and the software that are commonly used.

(ii) **Aware**: The worker has few notions about the emerging technologies even if he/she has never used any of them. Moreover, he/she is not intentioned to update his/her current status of his/her capabilities unless it is of his/her own interest. The worker is aware of the existence of common tools like PC and tablet but he/she does not know how to use them.

(i) **Basic**: The worker is not aware of the majority of the new technologies and he/she has not a behaviour inclined to modify his current status. He/she has no idea about the existence of common tools like PC or tablet neither of their usage.

In order to perform the assessment, ad hoc questionnaires are provided to managers and operators according to the job profile. Thanks to their answers, it is possible to evaluate their competencies level and thus to highlight their strengths and weaknesses. A final report with some indications about the next objectives that should be achieved is provided to the company. This enables the company to define the right training plan.

4.2 *DREAMY4Skills* development

Being inspired by [20], we started by defining the *scope*, essentially for the development of a maturity model since it will be the basis for all the subsequent decisions. The scope is assessing the workforce maturity to embrace Industry 4.0.

In the *design* phase, we defined the general characteristics of the model for the accomplishment of the goal set. These are the following:

— the audience that we address are the companies;
— the method of application is a self-assessment supported by third party analysts;
— the drivers of application are an internal need or a stimulus from an external analyst;

— the respondent of our questionnaire are both managers and workforce; in fact, in order to perform the assessment, we gather data from their answers;

— the application of the model will be based on multiple entities since the questionnaire will be submitted to many people within different process areas. Moreover, the geographical application will be defined on the basis of the company needs and localization of its facilities.

In terms of maturity levels, we defined 5 levels: basic, aware, practiced, competent, proficient as reported above in section 4.1.

In the *populate* phase, we defined what it is necessary to be measured and how the measurement is performed. The definitions of the job profiles under assessment are based on the integration between the identification of the hard skills essential for that process area together with the soft skills that we found to be fundamental in general to embrace properly the I4.0 paradigm and basic knowledge about ICT. This last dimension should be part of the hard skills, but considering their absolute importance in this context we decided to examine it as a stand-alone category. Therefore, the assessment is performed by following these three analysis dimensions.

In order to gather data from the workforce, we created a questionnaire tailored to each job profile. The first section of the questionnaire is dedicated to soft skills, the second one to the ICT literacy and these two parts are submitted to all the job profiles without any differences. The third one is focused on hard skills that are specific for each job profile, therefore this section is developed ad hoc for each job profile according to its characteristics.

To select the structure and formulate the normative answers we were inspired by [7], [17]. We used normative answers, instead of checklists or similar methods, to properly describe a specific level without being subjective, as the model analysed in section 3.1, and increasing the level of standardization. The person answering the questionnaire selects which sentence better describes his/her behaviour, attitude or thoughts.

In the *test* phase, we organized two different focus groups. The first one was held with academic experts the team "Jobs&Skills" of Polimi together with the author of the *DREAMY*. The team "Jobs&Skills" was of fundamental importance in order to validate our questionnaire and the skills defined by us as skills4.0 since their past studies were focused on this topic. The author of *DREAMY*, on the other side, was fundamental for the validation of our model as a whole since she provided suggestions on the possible criticalities of our first version of the model.

A second focus group was organized with industrial exponents in order to verify the formulation of each question and the related normative answers.

Once the model has been created and tested, it was submitted to a sample of companies in order to verify its usability.

### 4.3   *DREAMY4Skills* application

In order to validate our model, we applied it to a real case. We sent the questionnaire to a company and its personnel provided us with the answers. To report the final results,

we used a radar chart. In fact, using a radar chart (see Fig. 1) that shows all the job profiles together, it is possible to better see their differences.

As far as soft skills, all the job profiles are around the third level, the main differences are due to higher knowledge of foreign languages and higher interest in continuous learning showed by managerial roles with respect to the more operative ones.

As regard ICT literacy the results highlight that, as expected, those profiles with lower knowledge are warehouse and production operators being around the third level. These are people who currently do not use PCs and tablets during their working activities. Instead, the profiles reaching the fourth level in ICT literacy are the data scientist followed by the managers. While the best performer is the IT-OT integrator.

Looking at hard skills, the data analysed show that the majority of the job profiles has an evident gap. Also in this case, given that we are talking about new technologies like smart devices, operative profiles have a bigger gap than managerial ones and the best performer is the IT-OT integrator.
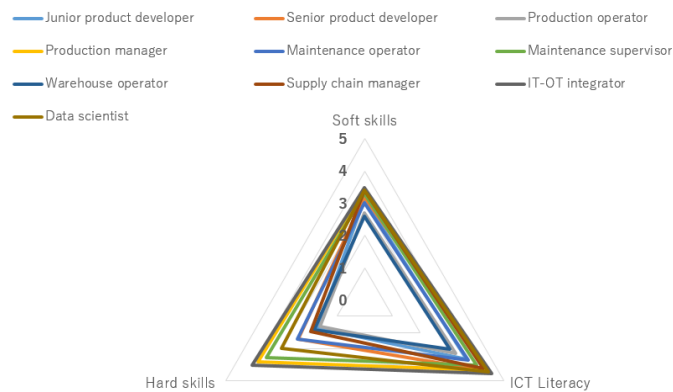
Fig. 1. Radar chart showing the results of the case study

This assessment allowed us to understand the current status of skills owned by the workforce and thus we developed a report to explain to the company the meaning of the scores giving them a detail description about the current level of each profile.

Finally, we suggested them, as forthcoming targets, the improvement needed to reach the upper level by underlining the strengths and weaknesses of each person.

5 Limitations and Conclusions

The model provides a picture of the current status of companies' workforce enabling their continuous improvement.

In order to apply it in an effective way, some communication efforts are required to companies because the assessment must be seen by the workforce as something positive for their professional growth and not as an internal investigation conducted by human resources to evaluate good/bad performances of a person.

Moreover, to guarantee the alignment between the assessment method and the technological advancement, the model should be kept always updated in terms of both job profiles considered and skills included in the analysis.

To conclude, the proposed model has a descriptive purpose, therefore the main follow-up that we envisage is to make it become prescriptive, by providing companies guidelines to achieve their next goal once the current situation has been assessed.

References

[1]   P. Gerbert *et al.*, "Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries," 2015. .

[2]   WMF, "THE 2018 WORLD MANUFACTURING FORUM REPORT Recommendations for the Future of Manufacturing," 2018.

[3]   G. S. Becker, *The Age of Human Capital*. 2002.

[4]   F. Acerbi, S. Assiani, and M. Taisch, "A Research on Hard and Soft Skills Required to Operate in a Manufacturing Company Embracing the Industry 4.0 Paradigm," *Submitted*, 2019.

[5]   M. Pinzone, P. Fantini, S. Perini, S. Garavaglia, M. Taisch, and G. Miragliotta, "Jobs and Skills in Industry 4.0: An Exploratory Research," Springer, Cham, 2017, pp. 282–288.

[6]   W. S. Humphrey, *Managing the software process*. Addison-Wesley, 1989.

[7]   A. De Carolis, "A methodology to guide manufacturing companies towards digitalization," Politecnico di Milano, 2017.

[8]   C. P. M. van der Vleuten and D. B. Swanson, "Assessment of clinical skills with standardized patients: State of the art," *Teach. Learn. Med.*, vol. 2, no. 2, pp. 58–76, Jan. 1990.

[9]   J. A. MARTIN *et al.*, "Objective structured assessment of technical skill (OSATS) for surgical residents," *Br. J. Surg.*, vol. 84, no. 2, pp. 273–278, Feb. 1997.

[10]   L. S. Mandel, B. A. Goff, and G. M. Lentz, "Self-assessment of resident surgical skills: Is it feasible?," *Am. J. Obstet. Gynecol.*, vol. 193, no. 5, pp. 1817–1822, Nov. 2005.

[11]   A. Wilson-Ahlstrom, N. Yohalem, D. DuBois, P. Ji, B. Hillaker, and D. P. Weikart, "From Soft Skills to Hard Data: Measuring Youth Program Outcomes, Second Edition," 2014.

[12]   Oecd, "Take the Test sample Questions from OECD's pisa assessments programme for international student assessment," 2009.

[13]   S. Arora *et al.*, "Self vs expert assessment of technical and non-technical skills in high fidelity simulation," *Am. J. Surg.*, vol. 202, no. 4, pp. 500–506, Oct. 2011.

[14]   C. Consiglio and M. M. Santarpino, "Dalle competenze professionali ai risultati di successo. Un caso organizzativo di applicazione della BFC map."

[15]   Giunti Psychometrics, "Mappatura e valutazione delle competenze." [Online]. Available: http://www.giuntihdu.it/it/servizi/mappatura.

[16] Business Plus, "Mappatura delle Competenze – Un Metodo e un Modello," 2013. [Online]. Available: https://www.bplus.it/mappatura-delle-competenze-un-metodo-e-un-modello/.

[17] R-Group s.r.l., "Il Manuale dei profili professionali di competenza."

[18] N. Galaske, A. Arndt, H. Friedrich, K. D. Bettenhausen, and R. Anderl, "Workforce Management 4.0 - Assessment of Human Factors Readiness Towards Digital Manufacturing," Springer, Cham, 2018, pp. 106–115.

[19] J. Pöppelbuß and M. Röglinger, "What makes a useful maturity model? A framework of general design principles for maturity models and its demonstration in business process management," in *European Conference*, 2011, p. 28.

[20] T. de Bruin, M. Rosemann, R. Freeze, and U. Kulkarni, "Understanding the Main Phases of Developing a Maturity Assessment Model," in *16th Australasian Conference on Information Systems*, 2005, pp. 8–19.