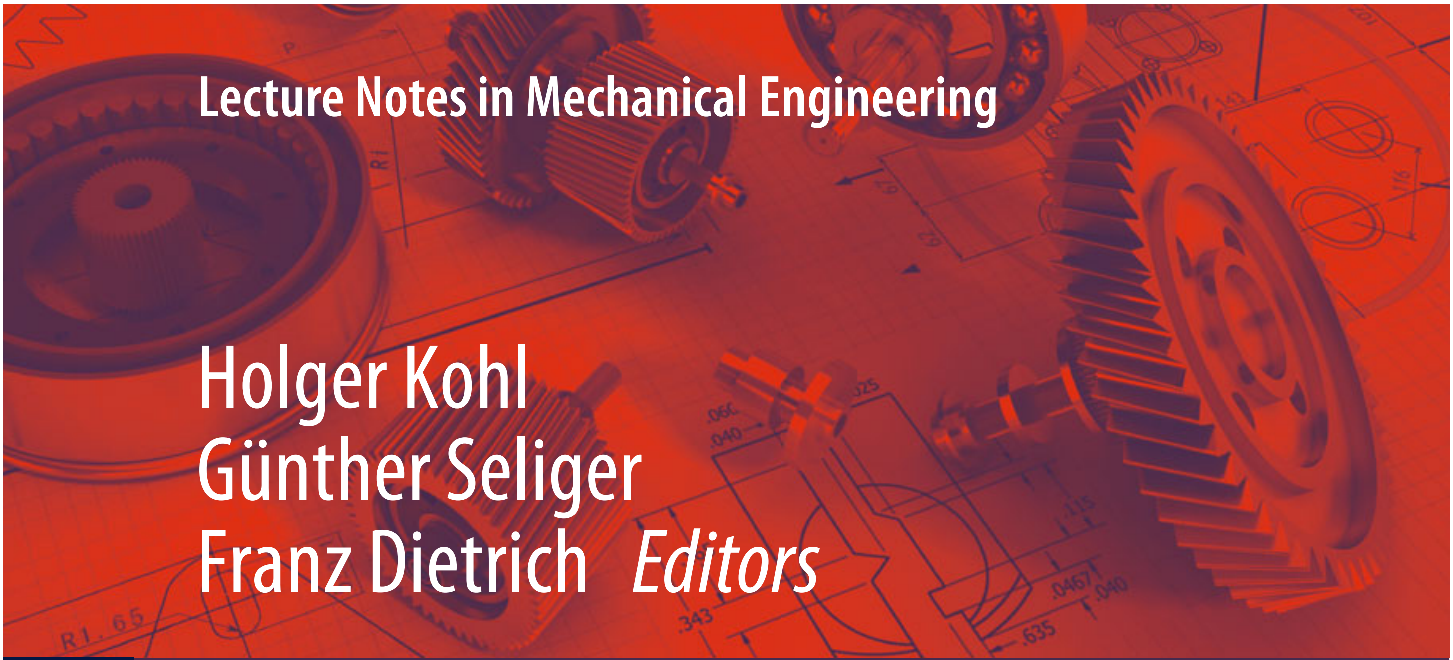

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Evaluation of Competencies for a Sustainable Industrial Environment

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Abstract. The organisation of worker activities in manufacturing shops have been differently conceived depending on political, societal, environmental and economic circumstances affecting industrial development. From Taylorism and Fordism through Lean Manufacturing to the innovative Cell Production system, the level and quality of abilities and competencies of workers have increasingly become the kernel of factory management models. Sustainability has increasingly become a crucial factor for product success. The design and manufacture of industrial products are conceived in circular loops within the 6R framework. The digitalisation of information has allowed significant advancements. Qualified and skilled operators have accompanied and led these evolutions, and their abilities and creativity have grown relevant, despite the continuous increase in automation.

This work investigates the contribution of craftsmanship abilities in the industrial environment. For this purpose, the Craftsmanship Index has been proposed to assign a quantitative value to the craftsmanship skills contributing to the manufacturing activities. A customised questionnaire to be administered to workers is used to calculate this index, which is helpful to analyse worker abilities and the way they are learned and developed, being part of effective management and decision-making tools. A case study in the Japanese manufacturing environment expands on previous results achieved in Italy.

The Craftsmanship Index allowed us to give a quantitative relevance to the level of abilities of operators depending on the analysed department. Some cultural differences have also emerged thanks to the comparison between the Japanese and the Italian culture.

Keywords: Industry 4.0 · Craftsmanship · Cell Production · Lean Manufacturing · Intangible Assets

1 Introduction

Craftsmanship has always contributed to the structure of production processes. From traditional to mass production, modern industry has always aimed to reduce human intervention in production, in order to speed up times and reduce costs, with an increasing use of machines and automation at the expense of labour, to guarantee products with

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certain quality standards. Both Taylorism and Fordism present the idea of employing a workforce that uses machines to do the job: workers do not actively participate in the manufacture of the product, but their actions are limited to the use of machinery. With the introduction of the Toyota Production System and Lean Manufacturing, the man comes back to the centre of the factory: workers are required to be able to use machines, acquire specialist skills and participate in the entire lean factory approach in terms of initiative and flexibility. The skills and competencies required are even more important in the modern Cell Production systems, where the operator knows how to carry out all the tasks related to a product [1, 2]. In addition to today's economic crisis, the increase in competitiveness by emerging economies combined with environmental and social considerations have undermined the paradigms of mass production and scientific standardization, re-evaluating the possibility of an economic scenario in which craftsmanship returns to be the protagonist of growth and innovation. The revolution of Industry 4.0 is radically transforming workers' job and competencie profiles. It is therefore be necessary to implement appropriate training strategies and to organise work in a way that fosters learning, enabling lifelong learning and workplace-based Continuing Professional Development [3].

Production systems have shifted from mass production to mass customisation: personalised, customised products that present different characteristics for different customers. Mass Customisation (MC) has emerged as a practice that combines the best of the craft era with the best of the mass production era [4]. Many companies have been able to mix scientific knowledge and tradition, learning to communicate the skills of master craftsmen through new communication channels. It is just about using the potential of craftsmanship to create value added to a product [5]. Craftsmanship implies the production and delivery of high-quality products or services performed by highly qualified and competent operators. It can be combined with the most modern technologies, still being a synonymous with innovation and customization. But skilled workers also increase sustainability: environmental, with "clean" production cycles combined with longer life cycles; economic, social and institutional, generating new jobs and improving manufacturing quality [6]. Fyhn and Søraa use a slightly different model where the economic aspect is replaced with "cultural sustainability". Also, this adheres to the definition: "capable of being maintained or continued", as it has to do with the craft's ability to sustain a knowledge-tradition and practice into the future in terms of having sustainable communities of practice bringing forward a certain level of skills in building. They do so by changing and adapting these skills to match a transforming reality [7].

In a context in which craftsmanship confers characteristics of uniqueness, added value and sustainability to the product and the process, it is necessary to determine an approach that goes beyond the limits that companies are facing today in this sense, and that takes into account how this intangible asset quantitatively and qualitatively affects the business system [8]. Intangible resources have steadily increased over the years, reaching very high percentages (over 40% of total assets in high-tech sectors) in industrialized economies. This rise of the intangible economy could play an important role in explaining secular stagnation. Over the past 20 years, there has been a steady increase in the importance of intangible investments relative to tangible investments: by

2013, for every £1 investment in tangible assets, the major developed countries spent £1.10 on intangible assets [9].

Intangibles (such as human, structural and relational capital) are difficult and expensive to be measured. The main problem with this kind of measurements is that it is not possible to measure social phenomena with anything close to scientific accuracy [10]. However, some models have been proposed to provide a qualitative evaluation, which is often globally recognized. These models attempt to quantify the company's human, structural and relational capital to convert them into accounting and financial terms. Conversely, other models attempt to quantify these resources more strategically. To date, no models for quantifying intangible assets referring to the level of craftsmanship and skills used in the manufacturing process of an industrial product have been proposed.

In this work, the evaluation of artisanal competencies relevance within the industrial environment is carried by means of a method that has been developed in previous studies [9]. It is based on a specific questionnaire that is administered directly to the workers and on the calculation of the Craftsmanship Index, CI. In particular, the proposed methodology has been customised to be applied to the Japanese manufacturing context. It allowed us to customise the implementation of the proposed methodology to Japan. The proposed approach and the related questionnaire utilised for the evaluation are introduced in Sect. 2. The obtained results are presented and discussed in Sect. 3.

2 Evaluating Craftsmanship in Industrial Environment

This section deals with the methodology (Sect. 2.1), the structure of the questionnaire (Sect. 2.2) and its implementation to the Japanese context (Sect. 2.3).

2.1 Proposed Methodology and Previous Studies

The artisan contribution to an industrial product contributes to providing added value for the customer, in terms of characteristics such as uniqueness, quality, innovation, and sustainability. A focus on employee characteristics such as behaviour or cognitions is relevant not only because it can yield important individual outcomes related to wellbeing, but also because such characteristics benefit organisations. Job crafting is a promising yet relatively unexplored approach [11] that, potentially, employees can use to heighten their job satisfaction and wellbeing [12].

Operators develop skills and competencies thanks to natural characteristics, personal predisposition and vocation, as well as influenced by the surrounding cultural and/or work environment. In the Italian development, skills are the abilities that are innate and competencies are acquired though training activities.

The general methodology proposed by [9, 12] is based on the CI that describes the performance of manufacturing operators based on four factors: (a) craft skills, F_{Cfts}; (b) creativity skills, F_{Cvt}; (c) culture, history and tradition, F_{CHT}; (d) influence of territorial vocation, F_{Tv} (Eq. 1).

$$CI = \frac{\sum_{i=1}^{4} w_i F_i}{\sum_{i=1}^{4} w_i} = \frac{w_1 F_{Cfts} + w_2 F_{Cvt} + w_3 F_{CHT} + w_4 F_{Tv}}{\sum_{i=1}^{4} w_i} \quad (1)$$

Craft skills refer to the acquired competencies, which a worker learns during his working life. An apprenticeship is necessary, while passion is useful but not necessary. Creativity skills are related to the natural skills and predispositions, which every person has that, once linked to the acquired competencies, can lead to better performance. Culture, history and tradition can influence human activities and how people interact with tasks in the work context. Territorial vocation may influence as well, in terms of availability of natural resources and other features. Most of these points, mainly concerning cognitive processes, concur to attribute intangible characteristics to the product and are difficult to be quantified. However, they can be effectively defined qualitatively. The number of owned skills and competencies is significant and represents a competitive factor for certain kinds of manufacturing enterprises: a more skilled and competent worker or employee can be evaluated as a competitive advantage. As a consequence, the proposed index can also be useful to an enterprise to understand how to acquire skills and competencies to foster positive development.

The CI is calculated as a weighted sum of the four factors above, as shown in Eq. 1. Weights w_i vary according to the production context and societal issues being studied. The application of the CI requires a broad and in-depth study of the industrial context and societal issues. Information regarding crucial aspects of the product manufacture, such as production processes, in terms of their phases and operators' skills, as well as the manufacturing context features (points of strength and weakness), the industrial structure and the market. The chosen approach is to consider the production process and the skills required at each phase of it together with the competencies that the operator possesses to perform the operations.

The methodology used to investigate the operators' natural skills and acquired competencies requires designing a questionnaire based on a set of "closed" questions to collect information on the qualitative and quantitative variables being investigated [12, 13]. The measuring method proposed includes tools through which the interviewee identifies the answers closest to an ideal position agreed between the management and the experts of the considered process. This allows to quickly involve a large number of people to gather information, to know opinions, attitudes, and intentions. With careful planning, questionnaires can yield high-quality usable data, achieve good response rates and provide anonymity, the latter encouraging more honest and frank answers, than for example interviews. This can help to reduce bias [13]. Well-constructed questionnaires can contribute to a deeper understanding of job characteristics, craft skills and the context in which they are applied. Therefore, the questionnaire proposed in this paper consists of a self-evaluations by the operators, who express their opinion about how their own skills and competencies are learnt and developed and how they contribute to obtaining the finished product.

2.2 Details About the Questionnaire Structure

The questionnaire has a structure which is functional to the research aim. It is divided into three parts that possess the same structure. The three parts of the questionnaire are described below in detail:

(1) "*Personal Data and details*", consists of the personal details of respondents, including gender, age, and education level. Also, information concerning the work activity, the position, the department, and the interaction of the worker with other departments have been investigated. This part is composed of 2 questions.
(2) "*Mapping Competencies and Skills*", concerns the skills and competencies acquired in the specific work context, their nature, and their development. Generally, skills require specific training to be acquired. However, sometimes they can be acquired by self-learning. This part also investigates how the operator's work is carried out, whether the machinery is used, and what factors have the greatest influence on the quality of the finished product. This part consists of 35 questions.
(3) "*Job Characteristics and Work Context*" refer to the characteristics of the work context and to the generalized work activities, common to several jobs that must be adapted to the particular context. The influence of the socio-cultural context is the focus of this part. This part is composed of 6 questions.

Each question of the questionnaire is organised in sections and levels and has a set of possible choices based on a Likert scale, in order to let the respondents have more chances to choose. The main advantage of using this measurement system is that it is a numerical scale and it's therefore easily convertible in quantitative terms: replacing each judgment with a numerical score, allows us understanding the position of the person on the concept investigated. It collects the opinions of the workers about their job and it gives appropriate weights to them.

Weights are associated with each question. Higher weights have a greater influence on the calculation of the index, therefore they refer to aspects considered more significant for the purpose of calculating the CI. A crucial point is the assessment of the weights that must correspond to the relevance of the considered skills in a certain industrial context. A number of scenarios were examined for their determination, and a proposal has been made based on previous industrial experiences with the necessary participation of the enterprise management in the process.

2.3 Implementation of the Questionnaire to the Japanese Context

The questionnaire was translated into Japanese to be administered to the operators of the Japanese industrial sector of hydraulic pumps. It has been modified according to the Japanese industrial culture and context. The original weights, which were applied in previous case studies, have been redesigned together with the enterprise management. Three departments of the same enterprise were considered.

In total 60 questionnaires, each composed of 43 questions were prepared.

All the 60 respondents returned the questionnaire, with a return rate of 100%. This number can be considered valid to carry out a statistical analysis. All the data were collected and analysed and are presented in a grouped form in Sect. 3.

3 Results and Discussion

The data gathered from the survey have been elaborated to calculate the CI. Several graphical elaborations have been done, to analyse and explain the main result of the present investigation. The application of the proposed method to a specific industry, geographical and cultural context has allowed us to identify some peculiar differences between the Japanese and the Italian cultural contexts that can significantly influence the definition of the CI. As an example, in the Japanese industrial environment, natural skills are not admitted. Instead, experience and devotion are considered necessary and sufficient to achieve and reach the best performance to fulfil the assigned task.

In Fig. 1 the percentage of experienced workers per each considered department and the percentage of production processes able to carry out by workers per each considered department are shown. It is worth underlining that a larger percentage of experienced workers are employed in each department and that their distribution is almost the same in all the examined manufacturing departments. The situation is different if examining the ability of operators in each department. In particular, it is possible to remark that Dept. #2 presents a fragmentation of the activities with workers that are directly able to carry on no more than one-fifth of the operations. On the opposite, in Dept. #3 some operators control the entire manufacturing cycle of products. Dept. # 1 has an intermediate configuration with some operators that can lead more than the 50% of the manufacturing activities.

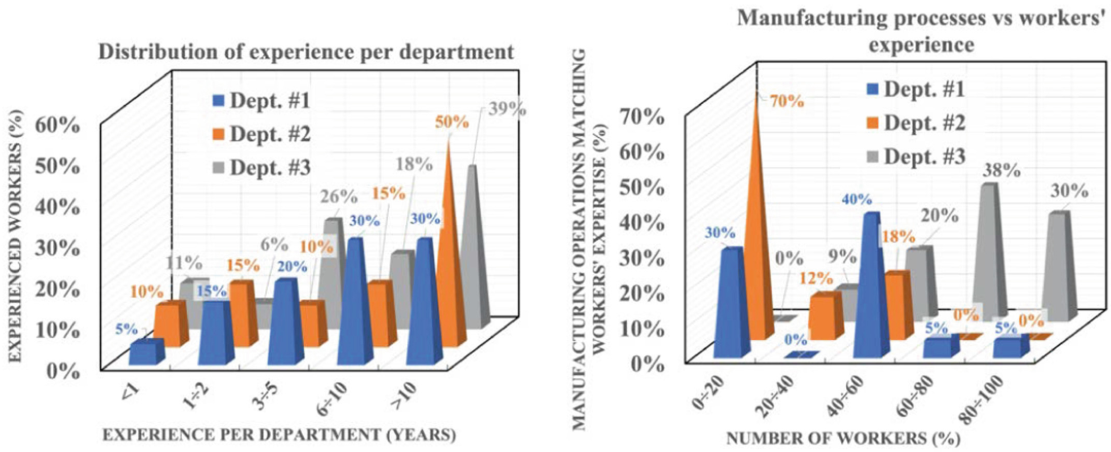

Fig. 1. (left) Percentage of experienced workers per department. (right) Percentage of manufacturing processes matching workers' expertise by department.

Figure 2 shows the calculated normalised CI (left side). Higher values of this index mean that more advanced skills and competencies are needed. The higher value was calculated for the Dept. # 2 and the lower value for the Dept. # 1. Dept. # 2 utilizes CNC tools to machine the process components. Despite being the department with more automation and less manual work, there are many skills and abilities required, such as understanding a technical drawing, developing an NC program and knowing how to use the machinery. A higher value was expected for the other departments, where hand work is more used in terms of time-consuming activities. A possible explanation is the high specialisation and fragmentation of the competencies within the Dept. #2 (see Fig. 2, right side) that helps to make each task simpler and achieve higher productivity. Special attention is needed to assure that all the operators can develop the required skills.

A comparison between workers perceptions about the relevance of the tasks they are responsible for and management expectations has also been considered. The data

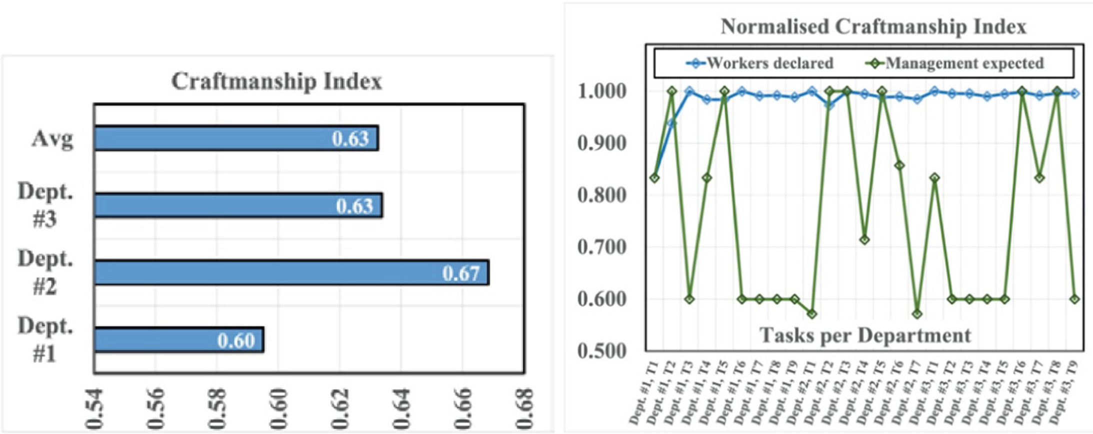

Fig. 2. (left) Calculated normalised CI. (right) Normalised CI per dept. Per task: expected (management) and perceived (workers).

provided by managers concerning all the weights associated with each task describing its relevance within each department are used to calculate an index expectation. A comparison between the expected importance of each task from the management perspective and the declared relevance from the worker perspective is shown in Fig. 2, right side. A discrepancy is clearly visible between the operators' perception of their duties and the manager's expectations. This result highlights the tendency of underestimating what is considered relevant for the workers. It can be helpful to promote a better alignment between operator perception and manager expectation to understand the importance of each task and take the necessary measures to develop the appropriate skills.

4 Conclusion

The aim of this paper is to investigate the artisan contribution to the manufacturing process of a product in the industrial environment. The CI, which has been proposed previously, has been applied and extended within a case study carried on in the Japanese industrial sector of hydraulic pumps to analyse how artisan skills and competencies are learned, developed and applied. A questionnaire has been designed and administered to operators working in the manufacturing departments. It investigates the artisan skills at a strategic level, from their acquisition up to their development over time.

The assignment of weights to the different components of the index is a crucial point of the analysis. There are no objective assignment criteria, the weights must be defined considering appropriate scenarios and agreed with the management and experts.

The CI comparison between workers and managers concerning their understanding of the value of each operative task has been made leading to the awareness that the perceptions of the operators and those ones of the managers are different. In particular, managers often underestimate the value of tasks in comparison with the perception of workers.

The proposed methodology can be applied to different industrial and manufacturing contexts. It can be used to distinguish and classify companies based on the quality and contribution given by the craftsmanship and skills exploited in their production systems.

The CI can allow the estimation of how craft skills are learned and developed. This index can be part of effective management and decision-making tools. The extension to the Japanese industrial environment has allowed identifying some similarities and differences between the Japanese and the Italian industrial contexts and confirmed the general validity of the proposed approach.

All the data, in a grouped form, are available on request.

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