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Digital manufacturing systems: a framework to improve social sustainability of a production site

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Abstract

The topic of digital manufacturing is increasingly emerging in industry. One of the main scope of data digitalization is achieving more efficient factories. Different techniques and tools under the Industry 4.0 paradigm were already discussed in literature. These are aimed mostly at boosting company efficiency in terms of costs and environmental footprint. However, from a sustainability point of view, the social theme must be equally considered. While energy flows or costs can be already monitored in a production plant, this is not valid for data related to human effort. Monitoring systems aimed at supervising factory social sustainability were not already discussed in literature. The aim of this paper is to propose a method to acquire social related data in a production plant. The method is supported by a smart architecture within the concept of IoT factory. Such architecture permits to monitor the parameters that could influence social sustainability in a production site. After a discussion on production plants facilities and features, the parameters that need to be considered to guarantee socially sustainable manufacturing processes are identified. A set of sensors controls these data taken from different sources, including operator vital signs. Operations as well as humans are monitored. Data acquired by sensors are collected by a central server. A decision maker can interpret the data and improve the production system from a social point of view, implementing corrective actions. Data can be exploited not only for social assessments but even for other analyses on the production system. Guaranteeing social sustainability could boost the factory productivity.
A case study is included in the paper: smart sensors are implemented in a production line to understand the operations efficiency in terms of social sustainability.

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1. Introduction

Today sustainability is a crucial topic that industries should deal with. Indeed, developing sustainable industrial processes, products or services is essential to guarantee a respectable growth of society, compliant to new standards and guidelines [1], considering that industries have the largest impact on resources consumption in comparison with residential, commercial and transport sectors [2]. Therefore, industries must develop efficient strategies to design and improve their production systems, overcoming the last sustainability standards (e.g., ISO 26000 [3]). However, a crucial aspect in the modern digital manufacturing era is to guarantee also human growth and wellbeing, considering also social aspects while developing new production systems, together with more traditional environmental aspects. Human aspects of sustainability are already integrated in the human-centered design (HCD) approach that aims at improving workers' capability, health and safety. These issues are particularly thorny since they have a relevant impact on the industrial management system in general, which must provide healthy and safe working conditions. Considering that workers are the actors during the machineries use, the sustainable design of any production system has to include also workers and

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human-related issues. In this sense, the social driver could positively contribute to guarantee workers' health and the overall socio-economic development. In this context, it is possible to talk about "design for social".

This paper proposes a set of guidelines to let designers face social sustainability aspects during the design and development of new production systems. It starts from the clarification of the main topics of digital manufacturing, under the new paradigm of Industry 4.0, in association with social issues, to define a proper "design for social" methodology. The method embeds a social issue matrix that analyzes possible solutions to solve the main human-related criticalities. To support the methodology a smart manufacturing framework introduced in order to digitalize social data taken directly from the shop floor. Finally, an industrial case study is proposed; it describes the design phase of a woodworking machining system exploiting the human-centred guidelines provided.

2. State of the art

In order to promote sustainable development, manufacturing companies are recently asked to overcome a purely economic vision, paying more and more attention to the environmental impact of their products and processes as well social issues and workers' wellbeing [4]. Indeed, realizing a sustainable process means facing all the three dimensions of sustainability at the same time (i.e., planet, profit, and people). In this context, traditional aspects such as cost reduction, productivity increase, resources efficiency, and high quality are no longer sufficient. They have to be integrated with new social items: e.g., working environment conditions, workers' satisfaction, workers' safety, physical and ergonomics [5][6].

Furthermore, it is worth to consider that nowadays industries are shifting to the new manufacturing era of Industry 4.0, dealing with the digitalization of data and the creation of knowledge to be used by intelligent production systems [7]. New cloud-based services (i.e., collaborative manufacturing, cloud computing, virtual manufacturing, etc.) are available for the industrial sector thanks to the advances in sensor and communication technologies [8]. This new paradigm represents a real opportunity towards a value-oriented sustainable manufacturing [9]. It shifts the manufacturing system to an upper level of data management (e.g., predictive maintenance, big data management), which creates a closer relation with humans. Hao and Helo investigate the potential of smart personal wearable devices in improving human–machine interactions in manufacturing industries [10]. As reported in a recent study by the Boston Consulting group [11], the industry 4.0 requires new skills to workers and creates new working modalities, offering new job opportunities while eliminating some job families.

As a consequence, the analysis of human factors and ergonomics is crucial to ensure a sustainable working performance, as demonstrated by [12][13][14][15]. Furthermore, the evaluation of social impact can validly be used to identify the most critical points which affect productivity and efficiency in the life cycle assessment [16], since the interaction between humans and machinery systems frequently represents the bottleneck of the production line and is a potential manifold of hazards. A human-centered approach can promote the analysis of possible uprising of those hazards and understanding of how the production parameters are affected by workers' performance and vice versa. Furthermore, "design for social" can also support process decision-making, to find the best working place and the optimal conditions to eliminate the potential hazards, to maintain the production system, and to control the impacts of the manufacturing process even outside the company boundaries [17]

Since the 1980s, it is known that the workforce performance was related to productivity, so several studies and methods have been proposed to deal with ergonomic aspects in workplaces [18] [19] and solve problems related to physical workload [20], promoting a workstation redesign and creating concrete benefits in terms of process costs [21]. Cognitive parameters are more difficult to measure, but they are complementary to the physical ones and mainly related to the human-machine interaction. In this field, engineers have to limit the human errors and optimize the mental workload [22]. Studies do not propose a prevention method to avoid working capability losses or improving performance efficiency merging physical, cognitive and environmental aspects. Furthermore, there is a lack of efficient methods to carry out a fast evaluation of social sustainability for manufacturing system, to be used during design phases to pearly optimize the workplace design considering also social aspects.

3. Methodology for "design to social"

In order to support the design of sustainable production systems including also social aspects, a human-centred method able to merge human factors and technical issues has been developed. It aims to improve the workers' conditions at the shop floor, which is directly related to the improvement of global system productivity. In particular, the method helps identifying inefficiencies in terms of space or resources, to be applied during the design of a new plant or to improve the efficiency of an existing one. The method is composed by 4 steps, and each of them uses data and knowledge acquired from the previous one, as shown in Fig.1:

1. *Layout assessment:* it allows optimizing the plant layout according to the specific company processes. It consists in the analysis of physical space occupied by any process entity and of the actual process workflow, by using production flow data. After that, a detailed analysis of the workflow is carried out to identify the current wastes in terms of space and activities (e.g., unused space, disorganized areas, space destined to auxiliary activities). Considering the available resources and production capacity (i.e., energy flows, required materials, cycle times) a new system arrangement is proposed. Finally, a complete and clear vision of the actual process in terms of spatial, resources and productive constraints is created. Such step can be carried out when a new layout is defined or when a re-layout is possible. It is recommended every time when a significant change at organizational and productive level is possible.