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Linking human availability and ergonomics parameters in order-picking systems

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Abstract: Most of the warehouse picking systems are based on manual activities, performed by human operators. Therefore, their performances and costs deeply depend on human availability and productivity, affected by the fatigue of operators and the probability of injuries and their gravity. In this paper, a real case studies analysis concerning the ergonomics of different picking warehouses is proposed, from which two functions that link the human availability and the rest allowance to the ergonomics level have been obtained. Furthermore, two different cost models, estimating the total expected cost considering both human availability and rest allowance, have been developed.

Keywords: Warehouse picking, Human Availability, Injuries, Ergonomics, Cost Models.

1. INTRODUCTION

Nowadays, there are still many production and logistics systems based on human operations, such as order picking warehouses, manual assembly lines, intra-logistics systems and other material handling activities in general. Many researches have studied human factors and ergonomics (HF&E) in order to improve the well-being of workers in several sectors, considering very different aspects. Based on the definition given by the International Ergonomics Association, *"ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance"*. A particular field of HF&E is the Human Reliability (HR) that concerns the reliability of human in industrial context, such as manufacturing, transportation, logistics and others, for example medicine and armed forces. The main theory standing at the base of this branch of research focuses on considering HR as probability to commit errors in the performed process, together with their impact on system performance. Therefore, the existing methods for HR analysis are based on probability risk assessment and cognitive theory of control (Kirwan, 1994; Kirwan and Les, 2003).

In this paper, we have studied the performance of industrial systems, such as production and logistics ones, under a different point of view. Starting from some real practical case studies, concerning different order-picking warehouses, we have linked the performance and, consequently, the cost of the systems to operators availability and productivity, which are affected by the working conditions ergonomics. On one hand, the availability of workers depends on the number and the gravity of injuries, in the same way of machine availability. On the other one, the reduction of productivity is strictly connected to the fatigue of operators, resulting from the increase of required rest allowance. Both these effects are affected by ergonomics conditions.

In the rest of the paper, Section 2 introduces some different case studies and the two functions that have been derived in order to link human availability and productivity to the ergonomics level. Then, in Section 3, we have discussed the cost models useful to estimate the total cost based on these two functions, also proposing a parametrical analysis and their application on the case studies, giving some guidelines to improve the systems from an ergonomics point of view and consequently reducing the total cost. Finally, the conclusions describe the advantages of this study and discuss some possible further researches.

2. ERGONOMICS AND HUMAN AVAILABILITY IN PICKING SYSTEMS

Ergonomics evaluations have become very important in the last years, both for industrial and academic sectors. It has been demonstrated that the future long-term muscular pain, such as musculoskeletal disorders (MSDs), depends on the discomfort felt by the workers (Hamberg-van Reenen, et al., 2008). Generally, MSDs caused by manual tasks represent a large part of all work-related MSDs (Burgess-Limerick, 2007; Euzenat, 2010) and are a central issue for public health (Larco Martinelli, 2010). Moreover, as well demonstrated in Battini et al. (2011), including the ergonomics evaluations in the human operations analysis is a win-win approach due to the strict interaction between productivity and motion efficiency as well as operational safety.

Since warehouse picking mostly deals with human operators and manual activities, a new frontier of research on this field propose the consideration of human factors on order-picking throughput and performance (Neumann and Dul, 2010). In fact, order-picking is typically characterized by repetitive tasks, often involving high load weights and unfavorable body postures, that could lead to musculoskeletal disorders for workers (Grosse et al., 2014; Weisner and Deuse, 2014), which are, moreover, one of the most reported causes of absence from work (52% of all work-related illnesses)

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(Schneider and Irastorza, 2010). However, the integration of ergonomics effects on order picking systems has not received for now enough attention in literature (Grosse et al., 2014). In this sense, one of the first analyses that could be useful to perform is the understanding of the elements that mostly affect the ergonomics level of the order-picking activities. For example, Grosse et al. (2014) highlight how the definition of a maximum acceptable pick height and depth of the storage racks in the storage assignment and the limitation of the weight transportable by each picker in the routing policies could lead to ergonomics improvements and, hence, to long-term benefits, such as costs reduction of the whole system. Also according to Weisner and Deuse (2014), the body posture is influenced by size, weight and type of the packaging and by the configuration of the shelving. They propose the storing of parts according to their picking frequency: items with a low picking frequency and/or a high weight should be positioned in low shelf floors, while items picked more often should stay in a height of 0.85 m up to shoulder height. It derives that human availability is strictly correlated to the ergonomics aspects; hence, it could be interesting the modelling of this parameter in function of the ergonomics assessment. Moreover, several studies can be found regarding the link between ergonomics and human performance, usually expressed through the introduction of the rest allowance concept (Rohmert, 1973; Battini et al., 2013).

2.1 Analyzed warehouse order-picking systems

The reported research starts from the analysis of different case studies, dealing with manual picking picker-to-parts warehouses. In such systems order picking activities are performed by human operators, called pickers. Each picker travels inside the picking area on board of a picking cart. For each row of the order, he/she picks up the required number of item stocked in the shelf and he/she puts them in a pallet. When the pallet is full, the pallet is wrapped manually with a transparent film. All these tasks are hard and the ergonomics level is moderate, also considering the productivity of each picker (in terms of number of handled boxes per hour) and the average weight of the boxes. Furthermore, the considered warehouse contexts refer to different working conditions, in terms of kind of performed activities but also in terms of kind of products stored and handled.

The data about the injuries of such different warehouses have been collected, estimating also the corresponding ergonomics levels using an innovative tool based on motion capture technology, developed by the authors and called Ergo-Log (Fig. 1; Battini et al., 2014). Among the others aspects, a main difference between the studied warehouses concerns the way the operators are employed, which can be of two types. The first kind of warehouse is a normal managed one, in which the operators are directly employed by the company. The other one, instead, considers the presence of stand-by units; since the operators are not direct employees of the company but of a third part, a constant number of resources is assured over time, with a higher efficiency also in case of absences or injuries.

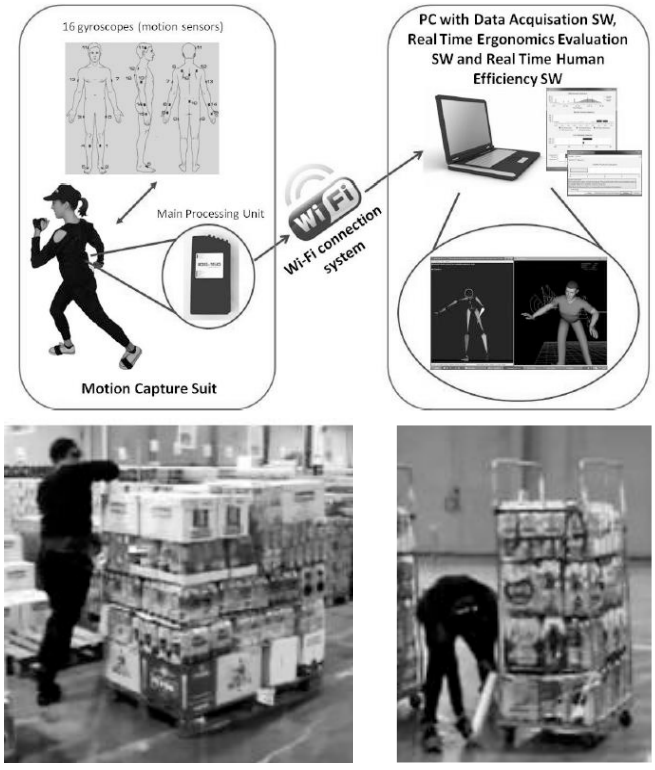

Fig. 1. Example of analysis in picking activity using the Ergo-Log motion caption technology

2.2 Human Availability in function of ergonomics level

Considering a production or logistics system where operators work, the productivity of the system and the corresponding cost depend also on the availability of human resources, especially in case of labour-intensive system. In this case, human availability can be estimated using the number of injuries and the average recovery time, happened in a certain time period. Taking the data regarding the injuries happened in the last years as an input, we can define the real human availability A_h as follows:

$$A_h = 1 - \frac{N_{inj} \cdot \overline{t}_{inj}}{T} \quad (1)$$

where N_{inj} is the number of injuries happened and caused by the work load conditions, $\overline{t}_{inj}$ is the average recovery time and T is the referred period of time, typically 1 or 2 years. These two parameters are strictly correlated to the ergonomics level of the job performed by the operators under analysis; in this study, we firstly introduce a simple mathematical model to link the human availability A_h to the ergonomics level *EL*. Analyzing these two parameters in similar industrial systems with different workload and environmental condition, and performing a regression analysis, we propose a general function defined in (2) and characterized by the behavior depicted in Fig. 2. The human availability A_h has a decreasing trend with the increasing of