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Design of job rotation schedules managing the exposure to age-related risk factors

Lucia Botti*. Cristina Mora*. Martina Calzavara.**

** Department of Industrial Engineering, University of Bologna, Bologna, Italy (Tel: +39 051 2093320, e-mail: lucia.botti5@unibo.it, cristina.mora@unibo.it)*

*** Department of Management Engineering, University of Padua, Vicenza, Italy (Tel: +39 0444 998756, e-mail: martina.calzavara@unipd.it)*

Abstract: Repetitive work involving manual handling of low loads at high frequency frequently leads to deteriorated posture and movement co-ordination, causing occupational diseases as the most common work-related musculoskeletal disorders (WMSD). Older workers are more predisposed to develop WMSD than younger workers because of their decreased functional capacity. The susceptibility for developing WMSD or injury is related to the difference between the demands of work and the worker's ability to perform a demanded activity.

Current law requires the adoption of risk control measures to eliminate or reduce the exposure of workers to health and safety risk factors. When repetitive handling is unavoidable, job rotation is an effective risk control method to minimize the exposure of workers to the risks of repetitive movements and awkward postures.

This paper presents a mathematical model for the design of activity schedules for aged workers exposed to the risk of repetitive work. The aim is to define the scheduling of the work activities for each worker from a bi-objective perspective. The first objective is to reduce the ergonomic risk of repetitive work by varying the required movements and their intensity during the work shift. The second objective charges the workers with the activities that better fit their skills and abilities. Finally, the proposed model includes the ergonomic risk assessment of each scheduling solution, ensuring an acceptable exposure of the workers to the risk of repetitive work.

Keywords: Job and activity scheduling; Modelling and decision making in complex systems; Intelligent decision support systems in manufacturing.

1. INTRODUCTION

The workforce aging phenomenon and the inverted population pyramid are the cause of important changes to society and industry (Gonzalez & Morer 2016). These changes comprise the inclusion of older workers in industrial processes and the challenge to adapt the work environment accordingly to their needs and capacities. The greater involvement of older workers is one of the main pillar of the Europe 2020 Strategy (European Commission, 2010).

The daily management should consider age related factors in work organization and define individual work tasks, so that everybody, regardless of age, feels empowered and motivated in reaching personal and corporate goals (Čiutienė, R., & Railaitė 2014). As a consequence, the productivity of various age groups is related to the ability of the management to provide proper working conditions and include workers' age management practices.

Older workers are more predisposed to develop work-related musculoskeletal disorders (WMSD) than younger workers because of their decreased abilities and functional capacity (McDonald & Harder, 2004). Furthermore, age is not an independent risk factor for WMSD. Repetitive activities including manual material handling at high frequency involve a significant stress of the upper-limbs, mainly affecting hand and wrist, but even shoulders and low back. Consequently, the workers are exposed to high ergonomic risk, which frequently results in WMSDs, e.g. the most common tendonitis, low back pain and carpal tunnel syndrome. Previous studies have shown that working activities involving repetitive movements of the upper-limbs and frequent manual handling operations increase the boredom of workers while reducing their performance, satisfaction and safety level (Fonseca, Loureiro, & Arezes, 2013). Thus, WMSDs lead to significant loss of productivity due to higher absenteeism and injures rates. Work-related MSDs are the most popular occupational health problem in the European Union (Fonseca, Loureiro, & Arezes, 2013). Such diseases cause more than 30% of the total annual lost-time and are considered one of the most expensive occupational issue (Xu, Ko, Cochran, & Jung, 2012).

Recent researches have investigated the potential age-related changes to consider during the design of workplaces (Boenzi

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et al., 2015; Cardoso, Keates, & Clarkson, 2005; Gonzalez & Morer, 2016; Hitchcock et al., 2001)

This paper introduces a mathematical model for the design of activity schedules for aged workers exposed to the risk of repetitive work. The aim is to reduce the risk of MSDs due to manual handling activities of low loads at high frequency, from a bi-objective perspective. The first goal is to enhance the ergonomic benefits of job rotation by varying the intensity of movements. The second goal is to design job rotation schedules improving the person-job fit, i.e. assigning the workers to the tasks that better fit their skills and capacities. Each scheduling solution ensures acceptable exposure of workers to the risk of repetitive movement, as required by current law and international standards (ISO 11228-3).

The following Section 2 introduces the methods adopted to address the job rotation scheduling problem. Section 3 briefly explains the expected results of the application of the proposed bi-objective mathematical model to a real case study. Finally, conclusions and future developments of this research are in Section 4.

2. METHOD

This Section introduces the person-job fit problem and the adopted assumptions for the mathematical model. The methods and the model in this paper include and improve the previous research by Botti et al. (2014) on the design of job rotation schedules for repetitive tasks in assembly lines. While the previous research was based on a generic working population, this paper focuses on the integration of an aged workforce and the related risk factors during the design of job rotation schedules. In particular, the mathematical model includes the investigation of age-related risk factors, as visual acuity, responsiveness and muscular tone.

2.1 The person-job fit problem

The optimal assignment of the workers to the workstations is accomplished by considering the different competencies and physical characteristics of the working population. Each worker w is characterized by a set of personal skills and ability competencies, besides each workstation s requires different abilities to perform the required task. The person-job fit is defined as the compatibility between individuals and the job or tasks that they perform (Schyns, 2007). The higher the person-job fit, the higher the task performance is. The aim is to assign the workers to the workstation that better fit their skills and competencies to improve the productivity of the whole system.

In the following, 43 items define each workstation and the requirements to perform the demanded tasks. Such items belong to five categories, similarly to the sets defined by Diego-Mas et al. (2009). Table 1 shows the reference items for the considered tasks.

Table 1. Items to define the person-job fit

Category	Item
Movements	Arm abduction, Arm extension, Arm flexion, Elbow flexion, Neck extension, Neck flexion, Neck turning, Neck lateralization, Pinching with the fingers, Trunk extension, Trunk flexion, Trunk rotation.
Functional capacities and senses	Lifting power, Push power, Pull power, Standing, Walking, Sitting, Exerting force while standing, Exerting force in movement, Visual acuity at long distances, Visual acuity at short distances, Hearing, Ability to perform precision work, Flexibility and reaching, Grasping and holding, Bending, Balance, Responsiveness (reaction time), Aerobic capacity, Touch and sensitivity perception.
Competencies and technical skills	Computing capacity, Using assembly tools, Driving forklift truck, Writing, Using keyboard, Using mouse, Previous experiences in the same task.
Relational skills and mental capacities	Reasoning, Responsibility, Taking complex decisions, Initiative/autonomy, Previous contacts with experts.

The first category encompasses each muscular movement, m, of the upper limbs and trunk to perform the required task, while category "Functional capacities and senses" refers to physical capacities and senses, f, as standing and sitting or hearing and touch. The last two sets of items assess the desired technical skills, c , together with the relational requirements, r, demanded by the workstation.

The content of each activity is analyzed according to the scoring system for the workstation assessment in Table 2.

Table 2. Workstation assessment: scores for the items of each category

Movements		Physical skills, competencies and technical skills, relational skills	
Frequency of movements / minute	*Score*	*Skill requirement to perform the task*	*Score*
Very high (>30)	6	Highly required	6
High (15-30)	3	Required with limitations	3
Low (5-15)	2	Very limited	2