Tools for Evaluating Human Factor Aspects in Production and Logistics System

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Abstract. Even though the advancement of technology has a great influence on the production and logistics system (PLS), companies are more dependent on manual human work because of their cognitive ability and flexibility. Inversely, many decision support models in PLS have neglected the characteristics of human workers which could degrade their working conditions. Therefore, this paper would assist the managers in a production and logistics system to evaluate the current workload on their workers. This study would suggest different tools for evaluating the human factor aspects of operations management. Initially, the paper introduces the three aspects of human factors such as physical, mental and psychosocial. Thereafter, tools for evaluating these aspects are presented. The tools are NMQ, NASA TLX, SWAT, and JCQ. Then, this paper summarizes the contribution of tools towards the production and logistics system by classifying it into three segments such as process, system settings, and technology.

Keywords: Human factors, Production and Logistics System, System Settings, Process, Technology

1. Introduction

Production and logistics systems are in a thrust to sustain their operations process with globalization and the challenging market. Thus, researchers are active in developing decision support system that improves the production and logistics system (PLS). Also, operations processes necessitate a huge volume of manual work, such as material handling and assembly even though automation provides a great opportunity. This is because humans are more flexible with their blend of motor and cognitive skills. However, decision support models for production and logistics have neglect the characteristics of human workers, which resulted in unrealistic planning outcomes that could harm the workers employed in the system [1]. Thus, it is important to understand the human worker characteristics when planning and designing a system, the worker's characteristics could be classified under three aspects such as mental, physical, and psychosocial [2]. Analyzing the characteristics of human workers would help operations managers to properly plan and take decisions at the strategic level to improve the design of products, processes, and workstations. Also in recent research papers, they explain the importance of considering human factors in production and logistics system [3]. However, there still exist a gap in literature that shows how to evaluate HF in production and logistics system. Therefore, purpose of this paper is to address different tools that

would assist the managers to evaluate HF aspects in production and logistics system. The paper is being built on integrative review methodology [4], by examining the literature and thereby synthesizing the results into a model elaborating the relationship between the tools and PLS.

The rest of the paper is structured as follows. The next section introduces the three aspects of HF. Section 3 describes the tools for evaluating the workload on operators. Section 4 explains the contribution of tools towards PLS. Finally, the paper winds up with a conclusion.

2. Three aspects of HF

According to IEA council(2000), human factors are defined as " *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*". Therefore, HF could be explained as the relationship between humans and the system. Therefore, there is a great need to understand different aspects of humans, thus they are classified into three aspects, which are explained below,

Mental Aspect: or the Cognitive Aspect is defined as the cognitive ability of humans to make decisions and solve problems based on their attention, learning and forgetting capabilities. For example, assembly workers require excessive cognitive demand due to the high amount of information, system complexities and variants of components required in assembling [5]. It is seen that with the increase in product variation could increase the mental load to the assembly operators [6].

Physical Aspect: The physical wellbeing of humans to perform a task. The increased level of physical fatigue is studied under the physical aspect. Fatigue could be general body fatigue or fatigue to a particular muscle of a worker engaged in manual work. For instance, workers who are engaged in manual material handling experience physical fatigue and discomfort which account for a high risk of developing musculoskeletal disorders (MSDs). Thus, operators are encouraged to take a break in between to reduce the fatigue accumulation on them [7].

Psychosocial Aspect: is defined as the individual's demand at work concerned with his or her ability to control the activities and utilize their skills. It is seen that when workers demand high psychological factor with low control on their work would lead the workers to high stress and ill health [8]. Factors like high autonomy, high control and a high degree of variety could improve employee's motivation [9]. In today's working life these factors contribute to encourage better health at work.

Therefore, to develop a better healthy and working environment, there is a need to consider these aspects of human factors from management point of view when designing and planning new processes in a production and logistics system.

3. Tools for evaluating workload on operators

For evaluating the workload on the operators engaged in manual workload from a system level, questionnaires had proved to be one of the best methods to collect the necessary data from workers [10]. The questionnaire could be self-administered by the

worker, which eliminates the chances of observer bias. Also, Questionnaires would reduce the cost of collecting data, by avoiding the practicality of scheduling and follow up of scrutiny [11]. Moreover, questionnaires are the finest subjective assessment technique that could assist managers to evaluate the workload and its effects on labors with long term perspective.

Thus, the questionnaires were selected based on literature search. Initially, the keywords and syntax for the search of tools were defined based on the three HF aspects. Thereafter, the paper with the most potential and relevant questionnaires under each human factor aspects are extracted out. Finally it showed up to be, NMQ [12] under physical aspect; SWAT and NASA TLX [13] under mental aspect and JCQ [14] under psychosocial aspect were selected. When NMQ, NASA TLX and SWAT evaluates the workload, JCQ is the tools which evaluates the outcomes from the workload.

Nordic Musculoskeletal Questionnaire (NMQ)

NMQ is a standardized questionnaire for the analysis of musculoskeletal symptoms in a worker. They focus mainly on the symptoms that are associated with the work settings [15]. Also, the NMQ serves in decision making in occupational health practices [12]. NMQ consists of 28 questions which could be classified into two types of questionnaires, the general questionnaire and specific questions dealing on the low back, neck, and shoulder. General questions are structured based on "Do musculoskeletal troubles occur in a given population and if so, in what parts of the body are they localized?". The questions are structured based on 9 anatomical regions. The respondent has to reflect on the trouble caused in each anatomical region during the preceding 12 months. Thereafter, a special questionnaire focuses on the regions which are most common to musculoskeletal symptoms. Questions are based on the symptoms and the duration of the past time such as the previous 7 days, the last 12 months and entire life. An analysis is done based on the severity of the symptoms in terms of their effect on the work and during their leisure time and also in terms of duration of the symptoms during the past 1 year [12].

NASA TLX- Task Load Index

NASA TLX is a multidimensional rating procedure that provides an overall workload score based on the weight-average rating on six subscales. They are mental demands, physical demands, temporal demands, own performance, and frustration. In which the first three describe the demand based on the worker such as mental, physical and temporal and the rest three-dimension explains the interaction of the worker with the task such as effort frustration and performance [16]. NASA TLX is a two-step evaluation procedure consisting of weights and ratings. Initially, the weight of each dimension provides data on the diagnostic information about the nature of the workload imposed by the task and each subscale is tallied in a range from 0 to 5. Where 5 corresponds to the most important factor. Thereafter, numerical ratings for each scale reflects on the magnitude of each dimension for a given task. Each scale is presented as a 12

cm line divided into 20 intervals. The overall workload score for each subject is computed by multiplying each rate by its weight given to that dimension by the subject [17].

SWAT- Subjective Workload Assessment Technique

SWAT is a subjective rating technique that uses three levels such as low, high and medium for each of three dimensions of time load, mental effort load and psychological stress load to assess workload [18] The sensitivity of the tool has been shown in a variety of task: Memory task, manual control tasks, display monitoring [13].SWAT uses three distinct steps i.e. scale development, event scoring and calculating. Under the scale development, each operator sort 27 cards in a combination of three levels of each of three dimensions. Thereafter event scoring, in which actual rating of workload for each given task. Finally calculating, the three-dimensional rating is converted into numeric scores between 0 and 100 using the interval scale developed in the first step [18].

Job Content Questionnaire (JCQ)

JCQ is a tool which has been developed to assess the psychosocial characteristic of jobs. JCQ is associated with the domains of demand control, thereby classifying the worker under the following realms, such as active (high demand and high control), passive (low demand and high control), high strain (high demand and low control) and low strain (low demand and high control) [19]. JCQ could be used by the management to analyze the work quality of its workers. It allows the testing of new technologies, worker motivation and job satisfaction [14].JCQ contains 5 subscales. They are decision latitude, psychological demand, social support, physical demand, and job insecurity. These subscales all together have a length of 49 questions. Decision latitude describes skill discretion, decision authority, skill underutilization, workgroup decision authority, formal authority, and union influence. Psychological demands define psychological demands, role ambiguity, concentration, and mental work disruption. Social support describes socioemotional, instrumental and hostility support from supervisors as well as coworkers. Physical demands define general physical loading, isometric load, and aerobic load. Job insecurity describes general job insecurity and skill obsolescence.

4. Contribution of tools towards PLS

To analyze the involvement and usage of tools in production and logistics system from a managerial perspective, PLS at the system level is classified into three segments such as process, system settings, and technology. The process is determined as the combination of different tasks to achieve a goal. For example, the assembly process, order picking process, etc. The system refers to where and how the process should be performed. For instance, workstation layout and configuration in an assembly system; in order picking process, rack layout, order picking system such as parts to picker and picker to parts are the system settings. Technology provides a mainstay for the entire system and also responsible for proper communication between each task under the system. For example, the level of automation in an assembly process and the assistive

technologies in an order picking process. Finally, the contribution of different tools in each segment are discussed below.

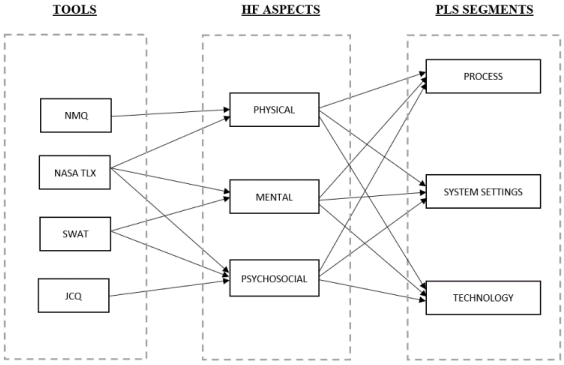

Fig. 1. Contribution of tools towards PLS

Process: HF aspects should be considered as a crucial integral part of the process mapping. While mapping a process, information regarding check points, critical decisions and feedback loop are only considered. However, integrating HF could improve an existing process to attain an enhanced workplace. Thus, there exists a necessity to have a generic view on HF aspects while mapping a process [20]. NASA TLX is the most appropriate tool while mapping a process for improvements concerned with workers. NASA TLX can measure the mental, physical and psychosocial demand. Besides, it is capable of measuring the effort, performance, and frustration, operators could face in a new process.

System Settings: Evaluating HF aspects in System settings could improve the configuration of the system, by improving workplace for operators. Therefore, it is necessary to evaluate the workload of each HF aspect. In an assembly system, configuring the workstation based on the operators could maximize the productivity of workers by reducing their physical fatigue [21]. In an order picking warehouse, there exists different storage assignment methods that could minimize the total travel distance and time [22]. Thus, NMQ could address the physical fatigue in anatomical areas were the musculoskeletal symptoms are common. Also, in an assembly process, the workers have a great need for cognitive demand due to the physical layout of the workstation and also due to the high level of complexities associated with assembling the products. However, these issues could be met with when there exists a low time pressure. On the other side, high time pressure can increase the workload on operators [5]. In this scenario, SWAT and NASA TLX are the most appropriate tool to measure the mental workload on operators. SWAT could evaluate mental effort load, psychosocial stress load and time load, but TLX measures additional dimension i.e. physical demand. Finally, worker's satisfaction is an important factor as it could impact workers' productivity, quality, and health [23]. Thus, it is important to analyze the work quality in a system setting. JCQ is the most optimum tool to analyze the work quality. JCQ mainly measures the ability of workers to take decisions in their settings, the emotional difficulties the workers face

in their work and also evaluate the support operators receive from their superiors and coworkers.

Technology: With the advancement of technologies, it is believed that technologies could improve efficiency, reduces workload and human error but these aptitudes were not satisfied. Automation fails because the role of operators in performing the work is often misjudged. Although automation is able to perform the task, they lack the flexibility of workers [24]. Thanks to the introduction of collaborative robots, which works in close collaboration with operators. However, there is a need to determine the proportion of activities the operator should perform. This could be achieved by analyzing the 3 HF aspects. In a manual assembly, operators and cobots share the work tasks. The main challenges are associated with the right distribution of workload among operators and cobots. Allotting fewer ergonomics tasks to cobots could reduce the physical fatigue of operators [25]. Therefore, NMQ could analyze the musculoskeletal symptoms of an operator during the work and thereby delegates less ergonomic tasks to cobots. Automation could also influence the cognitive demand of operators; automation could change the task from direct involvement to monitoring. However, all operators are not passive with monitoring the task, further reducing their feedback from the system [24]. To analyze the cognitive demand of the operator, tools like SWAT and NASA TLX could be used. Where SWAT could be more adaptable in this situation because of its three-dimensional scale provides a psychological model of workload judgment. Also, Automation creates a work environment in which demand for work is high but the decision latitudes decline, this could affect the physical aspects of the operator ranging from heart disease to depression [24]. JCQ could predict the psychosocial characteristics of the work. JCQ's scale measures the demand for work and the decision latitudes from an operator's perspective.

5. Conclusion

Which is the best tool? The answer to this question is neither one tool could be placed in the first position. Each tool is assessing different aspects of HF. Hence, this paper introduced three aspects of humans such as mental, physical and psychosocial. Thus, NMQ was introduced to assess the physical aspects, NASA TLX and SWAT were introduced to assess the mental aspects and JCQ was introduced to analyze the psychosocial aspects. Thereafter, the contribution of the tools toward the PLS is studied, by classifying PLS into three segments such as Process, System Settings, and Technologies. Finally, this paper would assist the managers to choose the appropriate tool in evaluating PLS. The extension of this paper would suggest conducting an empirical study on evaluating the PLS segments by choosing an appropriate tool.

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