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Human Factor Assessment in Assembly Line: an Operative Model

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Nowadays the majority of organizations operating in manufacturing field recognize the importance of including the Human Factor contribution into the industrial process optimization (Hong k. et al., 2007). As far technical measures and work organization procedures have been optimized in order to reduce the defects and upgrade the safety, the Human Factor assessment still represents for Managers a difficult task to deal with. This work presents a model designed to quantify the impact of the Human Factor into an assembly line with the aim of reducing operational errors and safety human errors
The model is based on the assessment of two macro factors:
- Task complexity: that summarises all factors contributing to physical and mental workload requirements to perform a given operative task;
- Human capability: that summarises the individual physical and cognitive abilities.
The model would allow a better matching between workers and operative tasks with the objective of reducing the risk of human error in quality and safety.

1. Introduction

The Human Factor remains a crucial element of a production system despite the level of automatization in manufacturing industry is considerably increased and working-procedures, driving the working activity, limit the probability of human errors (Baines et al., 2005).
The Human Factor (HF) analysis has been approached in different manufacturing branches:
Quality management analysed the human factor with the aim of reducing errors related (Miller et al., 1987), Safety sector approached the HF to reduce the occupational accidents occurrence due to unsafe human behaviour, Work Organization management related the HF to the ergonomic with the reducing the operative risk-related (Lin et al., 2001).
The influence of HF was even analysed at designing stage (Naghdali et al., 2014).
Many studies on Human Performance modelling suggest that the human factor has to be approached as a complex system, where behaviour, cognition, physiology and working condition deeply interact (Leva M.C et al., 2016). In manufacturing field, characterized by a relevant use of human resources, the interaction between HF and the working condition of all workers involved has a relevant influence on production efficiency.
A better matching of workers to different working-places will probably reduce the defects generation and the unsafe actions frequency.
A possible way to reach this objective it is to model a system able to assess and predict the HF contribution to production efficiency, in other words a model able to define and assess the Human Performance (HP).
Relevant research in this field suggested how to design a HP model.
A multi-disciplinary approach based on Sociology, Phycology and Engineering discipline is frequently adopted (Baine & Benedettini, 2007) meanwhile Eklund (1997) showed that Physical ergonomics has to be related to quality performances.
This paper presents an operative model to assess the HF into assembly line for safety and quality optimization.The aim of this work is to model the HP to give a contribution to the management of Human Factor into the industrial process.

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This research adopted an operative approach based on Straeter (2000) results.
HP was assumed as directly dependent from two macro-factors:
•Task complexity (TC): It resumes the amount of physical and mental resources asked to a worker to perform a specific task.
•Human capability (HC): It resumes the resources that the worker can express under the real working condition.
Section 2 presents the development of the project and the structure of the model, meanwhile section 3 shows the Operative Model deducted from the case study.
Section 4 gives an illustration of the project future development.

2. Methods

This project was developed in a manufacturing industry characterised by heavy use of human resources into assembly process. In this industry the HF and the HP have a strong influence on production efficiency and quality results. The project was carried out in 5 steps as resumed in Figure 1.

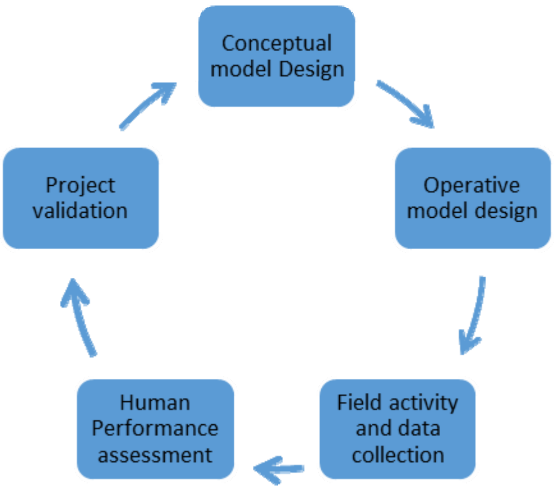

Figure 1: Project evolution.

First step was dedicate to the design of the Conceptual Model.
Conceptual Model defines the drivers having an influence on HP.
Second step was characterised by the Operative model design that represents the projection of conceptual model into the industrial life. All drivers identified into the conceptual model have to be replaced by a measurable quantity into the Operative model.
Third step was characterised for an intensive data field collection.
This step involved directly the workers of the plant with skill tests performed during the working activity.
In addition to this descriptive parameters of TC were collected with task analysis of working places.
Results of step 3 have been used to assess the HP of the case study.
On the basis of the results some modification in the management of human resources have been done, results of this intervention are under monitoring phase and will be used to validate or modify the model.
This model was designed on an assembly line of 15 working station involving 50 workers. This paper presents results related up to the fourth step, the last step is on-going.

2.1 Conceptual model

The HP model represents, as mentioned in Introduction, the interaction between two macro factors: Human Capability (HC) and Task complexity (TC).
Figure 2 shows the Human Performance conceptual model designed.
TC is the result of the contribution of two factors: ”Mental Workload” (MW) and “Physical Workload” (PW), both depending to several variables.
PW summarizes the total amount of motion, postural effort and time spent to perform correctly a given task.
Bad ergonomics combined with time pressure (saturation) have been estimated to cause about 50% of all quality deviations (Lin, 2001).

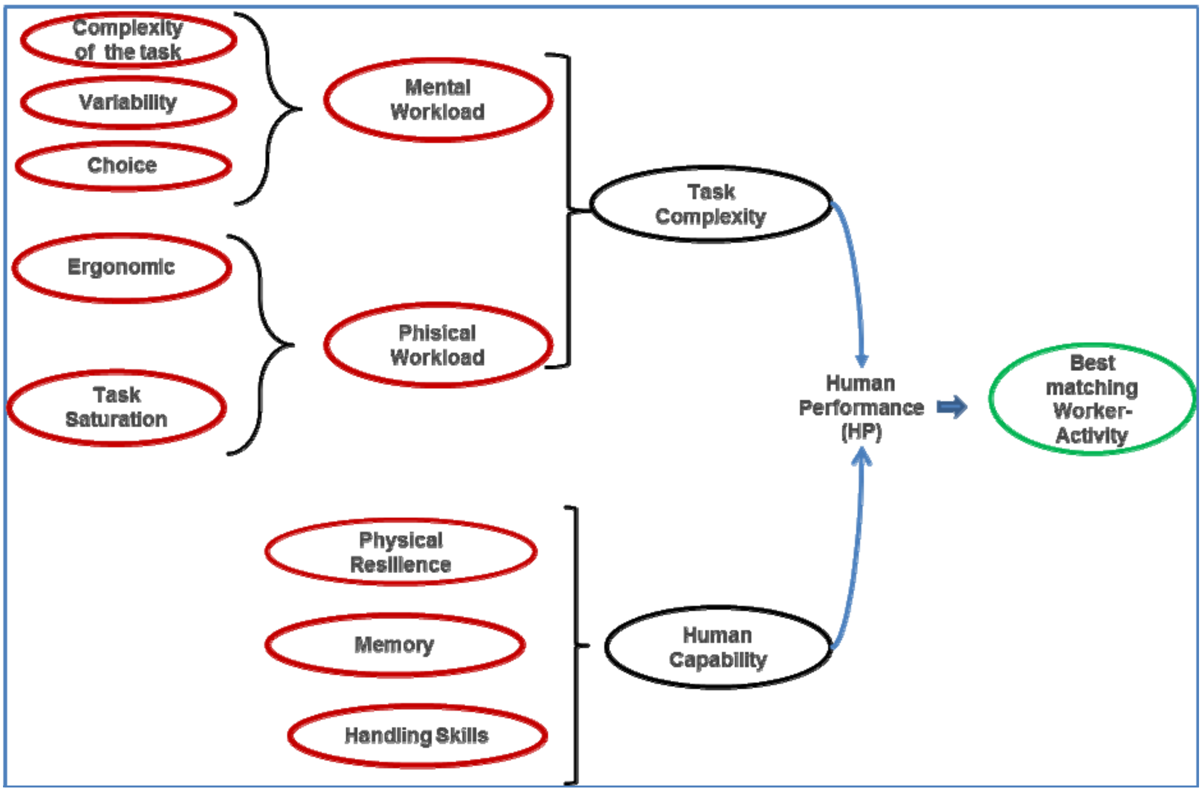

Figure 2: HP conceptual model.

In addition to the above mentioned factors the environmental workload (Jung, 2001), which include improper temperature, lighting, noise, vibration, has an influence on PW: its physiological effects can contribute to a loss of human performance (Grandejan, 1985).

This factor, because has the same level for all the working-places of the assembly line wasn't considered at this level of the project. MW according to Kahneman (1979) was defined as: "a factor directly related to the proportion of the mental capacity of an operator spends on task performance"

The MW assessment has been approached in different way such as: physiological measures under simple task normative condition (Kramer, 1991), cognitive performances, subjective analysis (Didomenico, 2008) and combined approach (Miyake, 2001).

According to Falck (2014) operating in a field research in industry plant it would be more suitable assessing the MW factor, with a combination of subjective measurement and indirect task related variable quantification, instead of approaching it with physiological measurement and cognitive normative test.

Human Capability (HC), as mentioned in Straeter (2000), collects the total amount of resources that a worker have to perform a given task under environmental working condition.

The HC factor is given by the contribution of several human skills. In particular the Human skills that have been considered in relation to the case study have been defined, after a detailed analysis of the working activity:

- Handling Skills: Precision, Manual Handling, Coordination.
- Memory: remembering the sequence of operations
- Physical Resilience: the ability of maintaining a constant performance during the shift.

2.2 Operative model

The Conceptual model defined in the previous section represents the starting point to operative model design. To pass from Conceptual model to Operative one it was necessary identifying at least one observable and measurable variable for each factor taken into account into the Conceptual model.

In order to gain this objective, with reference to TC definition, a task analysis (Stanton, 2004) combined with a deep analysis of working-places was performed.

Results of this process is summarized in Figure 3.

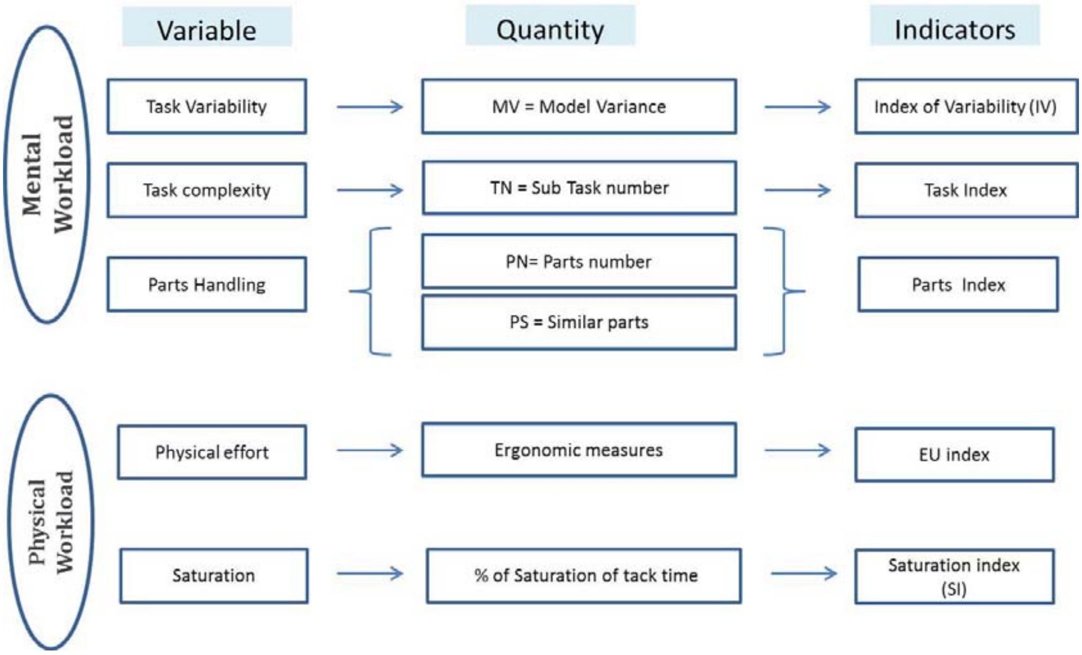

Figure 3: TC operative model.

HC operative definition (Stanton, 2005) was done with a set of ability test designed for this specific purpose. Each factor identified into HC conceptual model was linked to a specific variable measurable with a skill test as summarized in Figure 4.

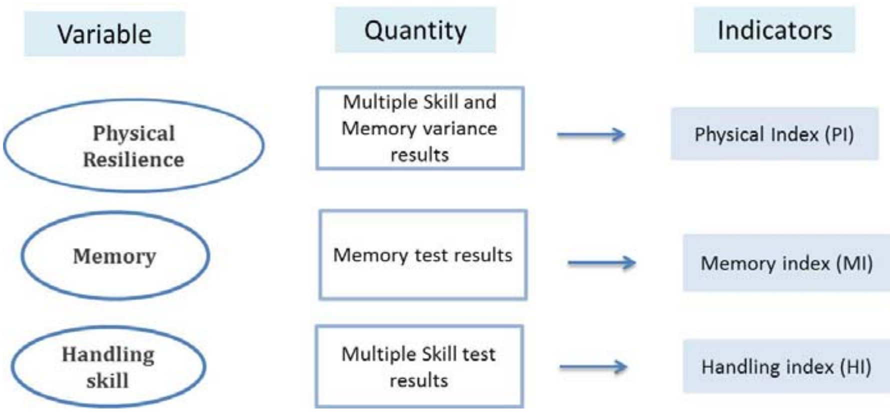

Figure 4: HC operative model.

As an example the "Memory skill" was assessed recording the time spent by a worker to replicate a symbol sequence shortly showed.
Handling skills were measured with 3 "ability tests" that simulate some typical operations performed during the working activity. The HC of each single workers was assessed recording the time spent to complete all tests and recording the number of errors done.
All observable variables selected have been measured with a numerical quantity. In order to allow the confrontation between quantities with different nature and scale, all the quantities were harmonized in a common numerical index.

2.3 HP Assessment

HP assessment was defined according to the logic scheme proposed by Conceptual model (Figure 2) and in compliance with the numerical quantity defined with the Operative model. The HP calculation was done according the scheme showed in Figure 5.

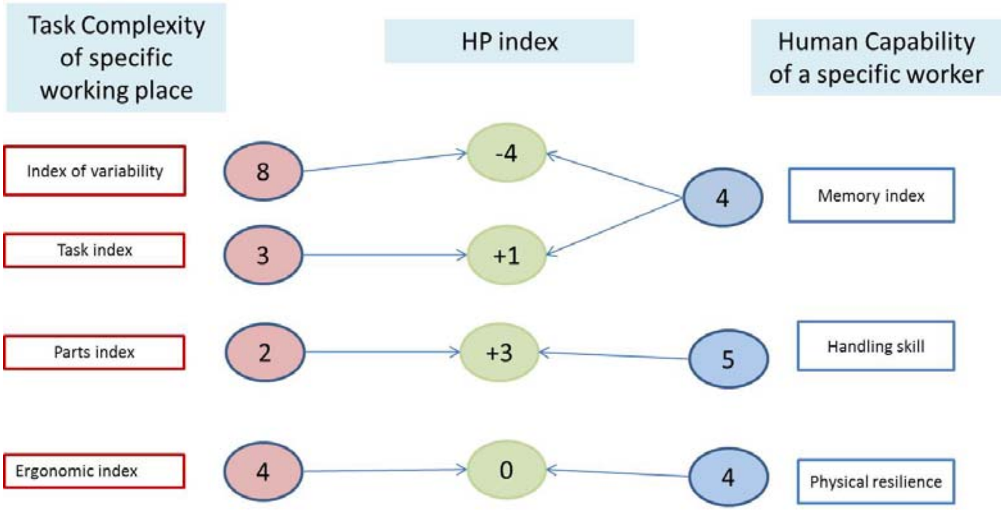

Figure 5: HP assessment scheme.

For each matching worker/working-place is possible to assess the related HP with the comparison of the TC characterized by 4 index (Variability, Task, Parts, EU) and the HC of a worker characterized by 3 index (Memory, Handling, Physical resilience).
This scheme of calculation is based on the operation "$HC_{index} - TC_{index}$" and provides the definition of 4 HP index. On the basis of the HP index two Human Performance assessment index were defined:
•HP- : represents the sum of all negatives HP index.
•HP*: represents the sum of all positive values of HP index.
The assessment for each assembly line of HP- and HP* will allows a quantitative calculation of the potential Human Performance related to the matching workers-working places.

3. Experiments

On the basis of the operative model the data field collection involved 15 working places for TC assessments, and more than 50 workers for the HC assessment. All the possible matchings Workers /Working-places were defined with the calculation of HP assessment index. Figure 6 resume the results of this approach showing, as an example, for tree working-places and 13 workers all the relative HP assessment index. In the proposed figure workers are identified by a letter from A to M and working places by a number from 1 to 3. Each cell contains the relative HP assessment index calculated according to the scheme reported in figure 5. To help the interpretation of results a colour scale was set: Red for bad matching (HP assessment index< -2), Yellow for acceptable matching (HP assessment index between from -2 to -1) and Green for good matching.

		Workers												
		A	B	C	D	E	F	G	H	I	J	K	L	M
Working places	1	-4	-6	-2	-5	0	-2	0	2	4	6	0	-2	-1
	2	-6	0	-8	-1	-2	0	-2	-2	0	-4	-8	0	0
	3	2	3	4	5	-2	-1	-4	-5	0	0	1	2	-1

Figure 6: HP assessment index.

4. Conclusions

An empirical method to HP assessment was developed and applied into an assembly line.
The proposed approach allowed the assessment and the comparison of two factors, TC and HC, representative of requirements necessary to perform a given task and the human capability potentially available. On the basis of this scheme a matching matrix was calculated and results could help the Industry Management in better identifying the best matching workers-working places. In order to validate the method and to verify the effectiveness of theoretical and operative hypothesis the results obtained were used to set a

new configuration of the assembly line. A period of 3 months will be used to monitor the operative results of the new configuration workers-tasks and quality indicators will be collected.

The comparison of quality data ante and post re-configuration will allows the evaluation of the impact of the method. This method is case study sensitive, results and model validity are strictly related to the field of application. In order to extend his validity a larger set of case studies has been planned. Actually 2 more complex assembly lines involving 150 workers are studied.

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