Optimizing production cost using ergonomic data

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Keywords. Occupational Human Factors, production economics forecasting, work-related ill health, productivity loss

1. Introduction

This paper presents a case study application of a novel Operations Research (OR) approach to forecasting production system level financial performance using Human Factors (HF). OR models rarely include HF aspects in predicting financial outcomes, which may lead to overestimating the profitability of the system. They usually assign a fixed value to employee performance and do not investigate Work-related ill health (WIH) risk factors and their financial and operational consequences when forecasting financial results.

2. Methods

We demonstrate a hierarchical, 3-level approach with worker, workstation, and system level sub-models). At the individual level; workers are assumed to have three health states: healthy, in-pain but at work (presenteeism), or injured and absent - in which case a replacement worker is assumed and claim costs are added. Individual health states are predicted over time based on the quantified physical risk factor exposures and risk ratios obtained from epidemiological studies. A Markovian modelling method was used to determine the probability of an employee being in each of the possible health states in a given period. At the 'Workstation Level' the productivity and quality of an operator will depend on their health state, as well as the design of the workstation itself. Here conventional production economic costs are included such as the cost of the materials, labour time, overhead costs. Each worksation's performance is passed on to the 'System Level' model which accounts for the configuration of workstations including aspects like bottlenecks. Then a mathematical model was developed for the production system to replicate its production behavior and incurred total cost. This system level mathematical model was optimised to calculate the best-case (lowest) total production cost and production profile for the system based on in-data provided.

We present a proof of principle demonstration based on a seven workstation auto parts production facility. Seven physical risk factors for WIH of the shoulder and back were quantified in the field for each workstation. Since this system had no recent sickness absence reports the resulting model had only normal and presenteeism health staes. Optimal production costs were estimated without HF (providing a referent index at 100) and with HF WIH effects. A one-factor analysis was conducted examining the effects of varying a cumulative spine load in a single station – the system bottleneck which also had the highest measured workload. Production volume was held constant in all models.

3. Results

When all seven risk factors were considered at their quantified levels the total cost of production was 1.23% greater then when the costs were calculated without including HF effects. Figure 1 illustrated the effects of varying the single Cumulative Spinal Load risk factor for the bottleneck workstation. This showed that the underestimation of costs, compared to non-HF assessement, could be as low as 0.7% and as high as 1.5% extra as this single risk factor was changed. For comparison, the observed cumulative compression as quantified was 20.6 Mega Newton seconds per full time shift (MNs/shift) – the mid point on Figure 1. The calculated cost was aligned with the historical data of the facility according to managers of the facility.

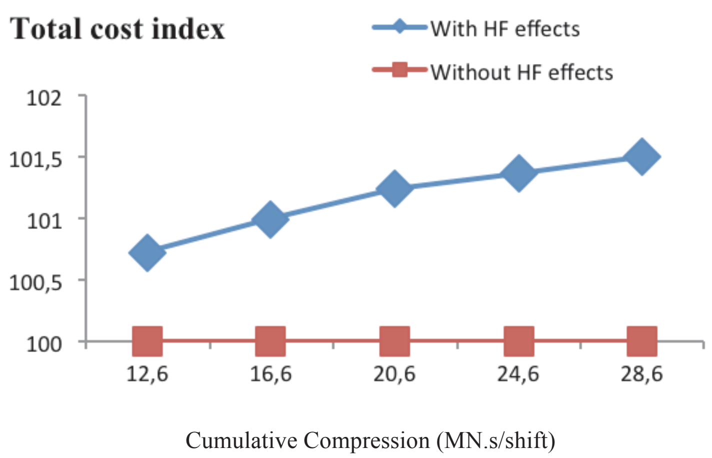

Figure 1: Total cost index change versus cumulative compression level variations in a single workstation while all other risk factors are kept constant

4. Discussion and Conclusions

This study has demonstrated the feasibility of predicting total production costs based on conventional economic data supplemented with WIH risk factor data that can be quantified in the field. This is a unique capability as conventional economic models usually ignore HF aspects and health economic models do not account for system level production costs. Furthermore this system allows potential improvements in HF to be evaluated in terms of total production costs for the system.

In this particular case, there were no recent lost time accidents so the impact of HF in economic terms was limited to presenteeism effects. While it is technically possible to include changes in quality levels, we were unable to isolate the human factors related fraction of quality deficits in the system in this case Furthermore the available research quantifying the mathematical relations between HF and production quality is sparse. Future work must focus on broadening the application of the technique to more sites as well as followup studies to examine the actual financial costs incurred by the company. While validity concerns remain, this technique may provide a valuable tool to help managers understand the impact of poor HF in terms of the performance of the company.

Acknowledgements

This work was made possible with financial support from the Workplace Safety and Insurance Board of Ontario. The participation of company personnel is also acknowledged.

Chapter 14
Human factors guidelines for CCTV- control centre design – part II

CCTV and other ICT support for supervisory tasks in healthcare

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Abstract. Psychogeriatric patients are required by Dutch law to be supervised by a healthcare professional at all times during daycare. We investigated how technology can support healthcare professionals during these supervisory tasks. Our research shows that sensors and associated digital processing intelligence cannot be employed effective and efficient yet in these settings. The knowledge and the insights of the healthcare professional are of utmost importance to perform the supervision. Through repeated experimental research with a variety of sensors we found that the best sensor solution in this care context is a combination of two cameras and a microphone.

Keywords. CCTV, healthcare, supervision, incidents, sensors

1. Introduction

Psychogeriatric patients are required by current Dutch law to be supervised by a healthcare professional (HP) at all times during daycare. Daycare takes place in a communal living room usually populated by 6 to 8 patients. An HP, present in the room, is responsible for supervision of these patients, but will also need to provide care to individual patients (e.g. assisting in toilet visits or changing the clothes of an individual patient). When the HP is away to apply this individual care, the communal living room is not supervised. In practice such a situation would mean that a double staffing of HPs is required to be compliant with the law. Mostly because of various financial issues, that double staffing becomes less and less a viable option. We were therefore asked by two nursing homes to investigate how technology can support HPs during their supervisory tasks, especially when individual care is being applied and, as a result of that, the communal living room is temporarily unsupervised.

1.1 Context

The supervisory tasks of the HPs were identified using observations and interviews in four departments of two nursing homes. The applicability of various sensors was also surveyed. Then a literature study revealed which sensors would have the most added value to be included in laboratory studies. During these laboratory studies we worked with non-patients who reenacted a scene taken from the communal living room in which various common incidents took place. The results of the registrations by sensors of this reenactment were evaluated with various HPs.

1.2 Dutch documents and studies about nursing homes

In several Dutch documents we found a strong preference for a patient and HP centered implementation of new technology in healthcare. The Dutch Ministry of Health investigated home automation in 2009 ("Toepassing van domotica," 2009) and concluded that a lot of research is carried out in pilot projects in nursing homes but a proper transfer of knowledge is often not the case. Further, only few nursing homes are capable of successfully supporting their strategic vision with new technology. The ministry also found that new technology is often purchased because of availability instead of a good fit on the care needs. Better alignment of care needs, working processes and technology is required, according to the ministry. Bierhof and Kröse (2006) share this vision.

Nijhof et.al. (2009) found that the effects of care technology on dementia patients, extramural caregivers and other HPs have not yet been studied extensively. The researchers state that more insight is required regarding the effects of technology on issues like quality of life, feeling of safety, and work satisfaction.

While reviewing these documents we found that a clear definition of supervisory tasks was not available, not even on a governmental level. We therefore had to establish a definition of these tasks. Based on desk research, observations and interviews with the HPs, we defined supervisory tasks as: *"Part of ensuring a safe living environment for the patients"*. To guarantee such an environment, supervision must make it possible, preferably pre-emptive, to detect dangerous situations in order to make a timely appropriate response possible. Such a potentially dangerous situation is defined as an *incident*.

We strive to have our work contribute to a better understanding of the need for and possibilities of alignment of working processes, technology and care needs. We further investigate the effect of this technology on HPs through a series of evaluations.

1.3 Literature review

Cox, Hayter and Ruane (2010) investigated alternative approaches to enhanced observation and, among others, stress that more research is needed into the area of mental health nursing. Authors state that ways of less intrusive monitoring should be feasible. Park and Bowers (2001) describe that nurses find special observation procedures stressful and that patients are disliking it.

Steward and Bowers (2012), while researching the procedures around special observation, see a shift towards the deployment of less qualified staff because of the high costs of special observation. Next to that, decisions surrounding special observation are usually resource based and not entirely based on the patients' need. Authors indicate CCTV as an alternative mean to ensure patient and staff safety. Because of increased patient visibility, nurses' time can be freed up and that can enable greater engagement with patients and delivery of more therapeutic activities. Steward and Bowers see the need for future research into electronic surveillance.

In a broader sense, the literature states that a clear and unambiguous policy should be implemented for observation and supervision among patient units (Khan, Rice & Tadros, 2013). Kettles and Addo (2009) stress the need for local work to be published to inform the debate and practice of special nursing interventions. We intend to contribute to both these goals.

Considering the available literature, we conclude that most research deals with enhanced observation (intensive nursing care) and special observation (preventing disturbed psychiatric patients from harming themselves or others). Our research focuses on supervisory tasks support in a communal living room setting. The literature further shows a need for visible practical cases regarding supported supervision.

2. Methods

The question guiding the study is: how can technology support HPs during their supervisory tasks, especially when individual care is being applied and thus the communal living room is unsupervised. To investigate this question we had to use an iterative approach of observation in the communal living rooms, interviewing the HPs and conducting experiments. The latter are necessary because testing solutions in practice with psychogeriatric patients is rather impossible. In an exploratory pre-investigation, we became familiar with the supervisory tasks in the communal living rooms. Based on these assessments we selected suitable sensors and then experimented with this sensors in a laboratory setting. A first experiment was conducted to determine the most suitable combination of sensors, a second experiment to achieve an even better fit of the sensor combination on the tasks of the HP's and to evaluate the results. The cascading experimental setup was required because of the thin body of knowledge regarding this specific deployment of equipment.

2.1 Sensor selection

During the exploratory pre-investigation, a number of promising, affordable and commonly available sensors were selected:

- Video cameras: 2 HD webcams (Microsoft LifeCam Cinema), 2 SD video cameras (Sony DSR-PD170P), and 1 other SD video camera (Microsoft Kinect for Xbox 360)
- Microphones: 1 ordinary mono microphone and 1 ordinary stereo microphone
- 1 range camera used to construct a 2D depth image of the scene (Microsoft Kinect for Xbox 360)
- 1 infrared camera (Microsoft Kinect for Xbox 360)
- Tracking systems: 1 Ubisense tracking system and 1 EagleVision tracking system.

Monitoring a reenacted communal living room situation using these sensors, we would be able to carefully select the best fitting (combination of) sensor(s).

2.2 Experiment preparation

For each part of the experiment we assembled a unique group of non-patients to reenact the communal living room situation.

The first experiment was conducted in a laboratory with access to the advanced tracking systems "Ubisense" and "EagleVision". The results of this first part were evaluated with students in healthcare.

The second experiment was aimed at achieving a better fit of the sensor system on the tasks of the HP's and was therefore much more tailored to facilitate recognition of actual identified events in the communal living room. Our own laboratory was used during this experiment, also because it is a space that is somehow comparable with a communal living room. HPs were part of the evaluation team for this experiment.

3. Results

3.1 Exploratory pre-investigation and sensor selection

In the exploratory pre-investigation we conducted observations to analyze the tasks of HPs during daytime care in communal living rooms. We also investigated the related areas in the nursing home and how they are (supposed to be) supervised. In this way, we identified possible supervisory problems. We further looked at patient behavior, situations in a communal living room that require professional intervention, and accompanying performed actions by healthcare professionals. Both the initial sensor selection and the script for reenactment were based on these observations.