New Trends and Issues Proceedings on Humanities and Social Sciences

Volume 4 Issue 10 (2017) 208-217

www.prosoc.eu
ISSN 2547-8818

Selected Paper of 6th World Conference on Business, Economics and Management (BEM-2017)
04-06 May 2017, Acapulco Hotel and Resort Convention Center, North Cyprus

# Ergo-Scheduling

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**Suggested Citation:**

Senyigit, E. & Atici, U. (2017). Ergo-Scheduling. *New Trends and Issues Proceedings on Humanities and Social Sciences.* [Online]. *4*(10), pp 208-217. Available from: www.prosoc.eu

Selection and peer review under responsibility of Prof. Dr. Çetin Bektaş, Gaziosmanpasa University, Turkey


**Abstract**

In this paper we consider scheduling problem under ergonomic risk factors. We recruit OCRA index to control musculoskeletal disorder along schedule. Modern manufacturing systems competition power depends on cost, time and flexibility level. Despite of high level automation in manufacturing system, flexibility depends on human workforce. From this perspective, for gaining high rate production, workforces have to endure high frequency manual job. This case causes musculoskeletal disorder. Musculoskeletal disorder which had to be control is one of the most important ergonomic risks in work environment. We used OCRA index mean value for ergonomic risk assessment. We also named this new type of scheduling as Ergo-Scheduling.

Keywords: Ergonomic risk assessment, scheduling, single machine scheduling, deterioration, OCRA Index;

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## 1. Introduction

The orientation to the market conditions and the customer satisfaction occur by the people's contribution even in the firms which they have adapted the automation substantially. Especially, there is too much contribution belonging to the people in the companies which do the maintenance and repair, and which have a dense handling.

Our motivation for this study bases on three main reasons. One of the main reasons is that; there is an obligation to do the assessment by a force of laws, regulations and national/international standards, and the risk values effect on the production efficiency and the labour schedule. For example, the standards related to the ergonomic risks were revealed with ISO 11228-3. Moreover, the rules and procedures of risk assessment which will be done in terms of the occupational health and safety in the workplaces were regulated with “The Risk Assessment Regulation of The Occupational Health and Safety" which was published on 28512 numbered official gazettes in our country. Our motivation's second reason is that the repetitive duties which are done during the production activities cause Musculoskeletal Disorders (MSD) which occurs with respect to the occupation in the various parts of a body. MSD is the most important one in the ergonomic risks. The ergonomic risks generally cause the production and quality losses (Mossa et al.). The effect of ergonomic risks on the production amount the production time in total and the labour schedules have not been reviewed in the literature. Our motivation's third reason was considered within the scope of the social responsibility. It is to provide the infrastructure support which gives the opportunity to the employment of disabled personnel. So they would directly contribute to the production rather than their restricted employment in the departments.

### Nomenclature

| | |
|---|---|
| $n_{ATA}$ | Number of actual technical actions |
| $n_{RTA}$ | Number of recommended technical actions |
| $f$ | The average frequency of actions in the task |
| $t$ | Duration of the task |
| $RF$ | Reference frequency of technical actions during a work cycle |

## 2. Literature Review

Employers who work in the repetitive handling duties are exposed to the risk of MSD. So, the employees are exposed to the various ergonomic risks while the high production rapid brings with a high physical labor. The job rotation is adopted by the planners in order to avoid from the ergonomic risks. Conventionally, the subjects of ergonomics and human performance were separately reviewed (Mossa, et al., 2016).

The disorders and physical injuries which result in the pain and which occur on the employees' lower, upper and back limbs related to the job are named as the musculoskeletal disorders. The risk assessment of the jobs which cause to MSD have been defined as static position and body movement, manual loading (above 3 kg), force exertion, repetitive movements, hand-arm vibration, whole-body vibration, energetic loading, local mechanical stress (Ringelberg, et al., 1990).

The risk assessment and management were founded in the scientific field 30-40 years ago. The risk principles and methods were developed in order to designate how the assessment, management and conceptualisation will be done. Today, these principles and methods constitute the base of risk management, and there are many theoretical and practical studies which have been recorded in this field (Aven, 2016).

One of these studies is the subject on Rapid Entire Body Assessment (REBA). REBA was developed for the field applicators as a tool of postural analysis. Especially, it was designed to assess the employees' position in the service and health sectors as an ergonomic during their working (Hignett and McAtamney, 2000).

Li and Buckle (1999) developed software in order to assess the change in the exposure to a risk for MSD. The risk factors which are included in the literature were evaluated in the software. The ergonomic risk assessments and MSD risk were considered. The method was named as Quick Exposure Check (QEC) and as it provides an opportunity to make quickly the complex ergonomic risk assessment method which is difficult to be learns.

The study on the assessment of Work-related musculoskeletal disorder (WMSD) risk factors' exposure related to the work was done with the taxi drivers by using QEC. It was recorded that MSD which occurs in the employees' due to the job is a common health problem over the world. The results also showed that WMSD is an improper posture in the taxi drivers, and it arises from the repetitive movement and the stress depending on work (Bulduk. et al., 2014). The exposed ergonomic risks are associated with the employees' posture and human-machine interface.

The ergonomic risk-indexed subject was done for the repetitive movements of upper limbs were considered by Veronesi. It was stated that the repetitive activities caused the occupational diseases. It was recorded that physical injury risk are affected by cycle time, repetitive movements. Veronesi J. RJ et al. developed Ergonomic Risk Veronesi Index for upper limbs repetitive activities (IVRE-ARMS). They determined that there was a statistical relation between OCRA and IVRE-ARMS by using Kendall Tau test. They stated that IVRE-ARMS can do the multiple data and bio mechanic analysis like OCRA, so it can enrich the tools of ergonomic risk assessment (Veronesi et al., 2015).

Moreover, IVRE-ARMS method which was developed by Veronesi J. RJ et al. bases on ISO 31000, ISO 11226 and ISO 11228-3 as additional to OCRA Index, Rula, REBA, Moore and Garg, Tor-Tom and Hal. IVRE-ARMS was consisted of a logical mathematical term which include all of the variances in all of the factors being analyzed at the percentage rates. Each of limbs was separately evaluated in the analysis. It was recommended that make an improvement according to the risk score which was obtained at the end of analysis.

The scheduling was done with the general job dependent learning curve by Mosheiov and Sidney (2003). The learning curve in the study was considered as a function of repetition of the production process. The approach provided the more realistic property for the minimization problem of total flow time and completion duration for a single machine.

The collective work scheduling on a single machine was done by Mosheiov and Oron (2006). The preparation time was considered as a function of collective work number which was processed previously. The objective is the minimization of total flow time. It was assumed that the operation time is equal and the unit operation time. The works are categorized in the certain volume. As the collective works are done, the positive preparation times occur.

The research on the express scheduling problems in the process was done by Allahverdi. (2016). More than 300 studies, between 1993 and 2016, were inspected within the scope of the study. It was informed in most of the reviewed studies that they took the maximum completion time and total completion time as the performance scale.

The single machine scheduling for the time- deterioration works was done by Raut et al., (2008). The problem includes many cases such as the web-page-loaded and multiple scheduling belonging to the real world. The difficulty level of the problem which was considered in the study was categorised as NP-hard. A more performance was done from the current heuristic algorithm with the recommended heuristic algorithm.

The electric purchasing was worked for the risk-based production scheduling and the constant power dense processes by Zhang et al. (2016). The production scheduling and the electric system's supply were evaluated together simultaneously in the study. The integrative scholastic complex-integer linear programming model which aims the determination of production demand and electricity prices as the uncertain two important sources was provided. The simulative risk value was measured and included into the model. These parameters which were used are the parameters related to the electric production systems and irrelevant the ergonomic risk and scheduling parameters related to our subject.

The production cycle time reduction by ergonomic workforce scheduling was considered by Moussavi et al., (2016). The coefficient was found in the criteria of the consistence between the employee and bench, height, age, experience and capability. It was shown as one of the important evidences for our study that the ergonomic effects on the operation time.

It was revealed by Demirkol-Akyol Ş. and Baykasoğlu A. (2016) and Mossa, G. et al. (2016) that the index of OCRA which is one of the ergonomic risk evaluation methods for the employee depends on the repetition frequency of works in the shift process. As the repetition frequency of the works increases, the function of ergonomic risk which is exposed changes. In this case, it affects the works' scheduling performance criterion. Moreover, a relation between the works' repetition frequency and the scheduling performance criterion which was informed by Kundakci N. (2013) wasn't found in the literature revise which was done. Our contribution to the literature wasn't obviously considered previously and it is the review of scheduling problems' ergonomic risk factors that we think that they will take the scheduling problem solutions to the real life in one more step.

This article was organized as the following: we provided the study introduction on the section 1, the literature review related to the subject on the section 2, we will provide the formulation of the problem that we consider on the section 3, the conclusion and further studies will be stated on the section 4.

## 3. Problem Statement

The ergonomic risk assessment was applied to the problem to determine the lot size by Battini et al. (2015) in the literature, and the name of problem was given as ergo-lot-sizing, assembly line worker assignment and balancing problem under ergonomic risk factors was considered by Demirkol-Akyol and Baykasoğlu. (2016), and the problem was named as ERGOALWABP. We will describe the problem as Ergo-Scheduling anymore.

Demirkol-Akyol Ş. and Baykasoğlu A. (2016) and Mossa, G. et al. (2016) described OCRA index which is used in the risk assessment for the occupational diseases as the equation-1 and equation-2,3 on the calculation of ergonomic risks.

$$OCRA\ Index = \frac{\text{Actual frequency}}{\text{Recommended frequency}} \quad (1)$$

$$OCRA = \frac{n_{ATA}}{n_{RTA}} \quad (2)$$

$$OCRA = \frac{f.t}{RF.t} \quad (3)$$

As it is shown at the equation 4, it was evaluated that the fixed learning rate has a decreasing effect during the processing time (Mosheiov G. And Sidney J.B. (2003), the ergonomic risk factor on the ergo-scheduling will have an increasing effect on the processing time.

$$p_{ir} = p_i r^a \tag{4}$$

The machine scheduling was done with the deterioration value as an exponential with the time by Voutsinas and Pappis, (2002). The processing time and the deterioration types were shown diagrammatically at Figure-1. The time-based change of deterioration was stated as an increasing one as it is at Figure -2.

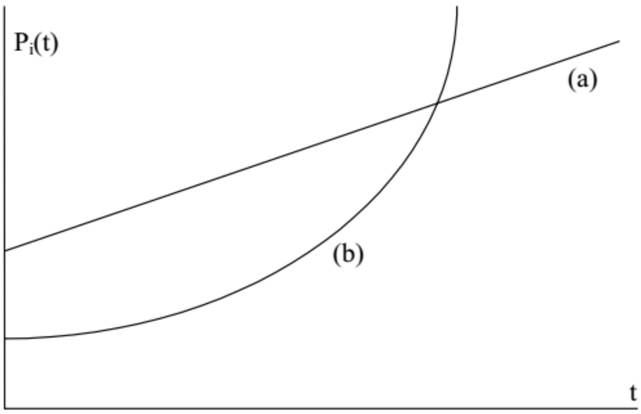


**Figure-1 The processing time and the deterioration types (Voutsinas G. T. and Pappis C. P., 2002)**

We will use the equation-5 which is recommended for the single machine scheduling for the exponential learning effect and the time-based deformity by Huang et al. (2010) in our study.

$$p_{i[r]} = p_i \left(1 + \sum_{l=1}^{r-1} p_{[l]}\right)^a \alpha^{r-1} \tag{5}$$

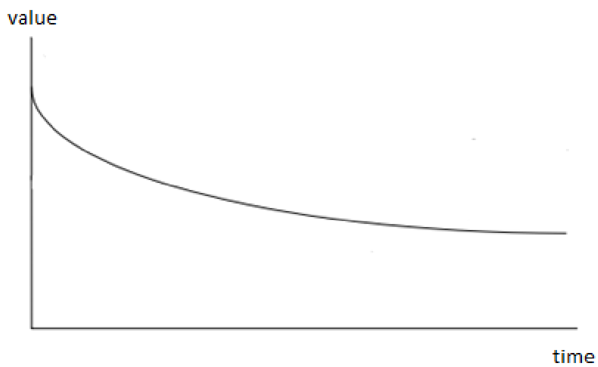


**Figure-2 The time-based change of deterioration (Voutsinas and Pappis, 2002)**

As the repetition number which is exposed in the ergonomic risks-depended deterioration time, it will be correct to model the ergonomic risk in time as an increasing one as it was on the equation-5. We can rewrite OCRA index average of $r^{th}$ job, as it was on the equation-6 (Mossa, G et al., 2016).

$\mu_{OCRA(r)}$ : rewrite OCRA index average of $r^{th}$ job

$$\mu_{OCRA(r)} = \frac{1}{r}\sum_{l=1}^{r} OCRA_l \tag{6}$$

**Table-1 OCRA Index and Risk Level (Mossa, et al., 2016).**

| OCRA Index | Risk level |
|---|---|
| 0-2.2 | Acceptable |
| 2.3-3.5 | Uncertain |
| 3.6-4,5 | Low |
| 4,6-9 | Medium |
| Over 9 | High |

It can be understood from Table-1, the upper limit of the average OCRA index values is 9. The risk is unacceptable when OCRA index value is higher than 9. Thus, the job should be divided in 9 in order to include OCRA index average of jobs $r^{th}$ proportionately to the scheduling as it is on the equation-7.

$$\alpha_l = \frac{1}{9}\mu_{OCRA(r)} \tag{7}$$

We can rewrite the equation which was recommended by Voutsinas G. T. and Pappis C. P. (2002) for the "S” scheduling after this phase. The completion time of $r^{th}$ job under the ergonomic risk factors is as it is on the equation-8.

$$p_{i[r]} = p_i\left(1+\sum_{i=1}^{r-1} p_{[l]}\right)^a \left(\frac{1}{9r}\sum_{l=1}^{r} OCRA_l\right)^{r-1} \tag{8}$$

## 4. Solution Algorithm

We will follow the same method on the solution equations by Huang et al. (2010). So the ‘I’ and ‘j’ job of schedule of S and S' are scheduled on the each other's line as it is at Figure-3. The completion time for ‘I’ and ‘j’ job of S and S' schedules can be written as it is on the equations of 9,10,11,12.

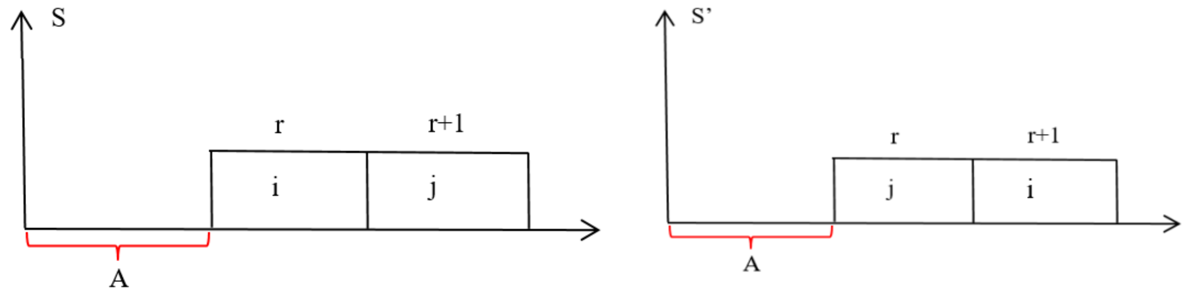


**Figure-3. S and S' schedules**

$$C_i(s) = A + p_i\left(1+\sum_{l=1}^{r-1} p_{[l]}\right)^a \left(\frac{1}{9r}\sum_{l=1}^{r} OCRA_l\right)^{r-1} \quad (9)$$

$$C_j(s) = A + p_i\left(1+\sum_{i=1}^{r-1} p_{[l]}\right)^a \left(\frac{1}{9r}\sum_{l=1}^{r} OCRA_l\right)^{r-1} + p_j\left(1+\sum_{l=1}^{r-1} p_{[l]} + p_i\right)^a \left(\frac{1}{9r}\sum_{l=1}^{r} OCRA_l\right)^{r} \quad (10)$$

$$C_i(s') = A + p_j\left(1+\sum_{i=1}^{r-1} p_{[l]}\right)^a \left(\frac{1}{9r}\sum_{l=1}^{r} OCRA_l\right)^{r-1} \quad (11)$$

$$C_j(s') = A + p_j\left(1+\sum_{i=1}^{r-1} p_{[l]}\right)^a \left(\frac{1}{9r}\sum_{l=1}^{r} OCRA_l\right)^{r-1} + p_i\left(1+\sum_{i=1}^{r-1} p_{[l]} + p_j\right)^a \left(\frac{1}{9r}\sum_{l=1}^{r} OCRA_l\right)^{r} \quad (12)$$

Accept as $p_j > p_j$. If we show as $C_j(s) > C_j(s')$, we find that S' schedule is more dominant one.

$$\begin{aligned} C_j(s') - C_j(s) = &\left[A + p_j\left(1+\sum_{i=1}^{r-1} p_{[l]}\right)^a \left(\frac{1}{9r}\sum_{l=1}^{r} OCRA_l\right)^{r-1} + p_i\left(1+\sum_{i=1}^{r-1} p_{[l]} + p_j\right)^a \left(\frac{1}{9r}\sum_{l=1}^{r} OCRA_l\right)^{r}\right] \\ &- \left[A + p_j\left(1+\sum_{i=1}^{r-1} p_{[l]}\right)^a \left(\frac{1}{9r}\sum_{l=1}^{r} OCRA_l\right)^{r-1} + p_i\left(1+\sum_{i=1}^{r-1} p_{[l]} + p_j\right)^a \left(\frac{1}{9r}\sum_{l=1}^{r} OCRA_l\right)^{r}\right] \end{aligned} \quad (13)$$

$$\begin{aligned} C_i(s') - C_j(s) = &\left[(p_j - p_i)\left(1+\sum_{i=1}^{r-1} p_{[l]}\right)^a \left(\frac{1}{9r}\sum_{l=1}^{r} OCRA_l\right)^{r-1}\right] + \left[p_i\left(1+\sum_{i=1}^{r-1} p_{[l]} + p_j\right)^a \left(\frac{1}{9r}\sum_{l=1}^{r} OCRA_l\right)^{r}\right] \\ &- \left[A + p_j\left(1+\sum_{i=1}^{r-1} p_{[l]}\right)^a \left(\frac{1}{9r}\sum_{l=1}^{r} OCRA_l\right)^{r-1}\right] \end{aligned} \quad (14)$$

$$\frac{C_i(s')-C_j(s)}{p_{j\left(1+\sum_{i=1}^{r-1}p_{[l]}\right)^a\left(\frac{1}{9r}\sum_{l=1}^{r}OCRA_l\right)^{r-1}}}=(1-\frac{p_i}{p_j})+\frac{p_i}{p_j}\left(1+\frac{p_j}{1+\sum_{i=1}^{r-1}p_{[l]}}\right)^a\left(\frac{1}{9r}\sum_{l=1}^{r}OCRA_l\right)-\left(1+\frac{p_i}{1+\sum_{i=1}^{r-1}p_{[l]}}\right)^a\left(\frac{1}{9r}\sum_{l=1}^{r}OCRA_l\right) \tag{15}$$

$$\lambda=\frac{p_i}{p_j} \quad x=\frac{p_i}{1+\sum_{i=1}^{r-1}p_{[l]}}$$

Accept as,

$$\frac{C_i(s')-C_j(s)}{p_{j\left(1+\sum_{i=1}^{r-1}p_{[l]}\right)^a\left(\frac{1}{9r}\sum_{l=1}^{r}OCRA_l\right)^{r-1}}}=(1-\lambda)+\lambda(1+x)^a\left(\frac{1}{9r}\sum_{l=1}^{r}OCRA_l\right)-(1+\lambda x)^a\left(\frac{1}{9r}\sum_{l=1}^{r}OCRA_l\right) \tag{16}$$

We obtain from Voutsinas G. T. and Pappis C. P. (2002) lemma 2.

$$\frac{C_i(s')-C_j(s)}{p_{j\left(1+\sum_{i=1}^{r-1}p_{[l]}\right)^a\left(\frac{1}{9r}\sum_{l=1}^{r}OCRA_l\right)^{r-1}}}<0$$

$$C_j(s)>C_i(s')$$

So, we can state that it is necessary to range the optimal schedule by the smallest processing time.

## 5. Conclusion and Future Works

Our purpose in this study is to introduce a new deterioration type which hasn't been previously considered in the scheduling literature, and to review the single machine scheduling problem with the usage of this deterioration type that we named as the ergonomic risk factor. It was revealed as a need to review the machine scheduling under the ergonomic risk factors with this study and we were to name the problem as Ergo-Scheduling. Moreover, when it is taken as an average value of OCRA index of the ergonomic risk factors, it is parallel with the linear deterioration in the single machine scheduling. The optimal schedule on the solution which was obtained is on the order of smallest processing time. The ergonomic risk value should be included to the single machine scheduling problem as a time-based variable in the further studies and the problem should be reconsidered.

## Acknowledgements

This study is supported by Erciyes University Scientific Research Projects Unit in the scope of “Scheduling Under Ergonomic Risk Factors” coded FDK-2017-7265 project.

**References**

Allahverdi, A. (2016). A survey of scheduling problems with no-wait in process, European Journal of Operational Research, 255, 665-686.

Aven, T. (2016). Risk assessment and risk management: Review of recent advances on their foundation, *European Journal of Operational Research*, 253, 1-13.

Battini, D., Glock, C.H., Grosse, E.H., Persona, A., & Sgarbossa, F. (2015). Ergo-Lot-Sizing: Considering Ergonomics in Lot-Sizing Decisions, IFAC-PapersOnLine, 48, 326-331.

Biskup, D., Herrmann, J., Gupta, N.D.J., 2008, Scheduling identical parallel machines to minimize total tardiness, *International Journal of Production Economics*, 115, 134-142.

Demirkol-Akyol, Ş. & Baykasoğlu, A., (2016). ErgoALWABP: A Multiple-Rule Based Constructive Randomized Search Algorithm For Solving Assembly Line Worker Assignment And Balancing Problem Under Ergonomic Risk Factors, *Journal of Intelligent Manufacturing*, https://doi.org/10.1007/s10845-016-1246-6 .

Hignett S. and McAtamney L. (2000). Rapid Entire Body Assessment (REBA), Applied Ergonomics, 31, 201-205.

Huang, X., Wang, J.B., Wang, L.Y., Gao, W.J. & Wang, X.R. (2010). Single machine scheduling with time-dependent deterioration and exponential learning effect, *Computers & Industrial Engineering*, 58, 58-63.

ISO 11228-3:2007 - Ergonomics Manual handling -Part 3.

J. A. Ringelberg, Th. Koukoulaki, Risk Estimation for Musculoskeletal Disorders in Machinery Design - Integrating a User Perspective, Bucciarelli, London, 1990.

James, R.J.W. & Buchanan, J.T., (1997). A neighbourhood scheme with a compressed solution space for the early/tardy scheduling problem, *European Journal of Operational Research*, 102, 513-527.

Li G., Buckle P., (1999). Evaluating change in exposure to risk for musculoskeletal disorders: A practical tool. Suffolk: HSE Books, England, 1999.

Mosheiov, G., (2001). A common due-date assignment problem on parallel identical machines, *Computers & Operations Research*, 28, 719-732.

Mosheiov, G., Oron, D. (2006). Single machine scheduling with batch-dependent setup times, Information Processing Letters, 98, 73-78.

Mosheiov, G. & Sidney, J.B. (2003). Scheduling with general job-dependent learning curves, *European Journal of Operational Research*, 147, 665-670

Mossa, G., F. Boenzi, F., Digiesi, S., Mummolo, G. & Romano, V.A. (2016). Productivity and ergonomic risk in human based production systems: A job-rotation scheduling model, *International Journal of Production Economics*, 171, 471-477.

Moussavi, S.E., Mahdjoub, M. & Grunder, O., (2016). Reducing production cycle time by ergonomic workforce scheduling, IFAC-PapersOnLine, 49, 419-424.

Otto, A. & Scholl, A., (2011). Incorporating ergonomic risks into assembly line balancing, *European Journal of Operational Research*, 212, 277-286.

Raut, S., Swami, S. & Gupta, J.N.D., (2008). Scheduling a capacitated single machine with time deteriorating job values, *International Journal of Production Economics*, 114, 769-780.

Sridharan, V. & Zhou, Z. (1996). A decision theory based scheduling procedure for single-machine weighted earliness and tardiness problems, *European Journal of Operational Research*.

Veronesi J.R.J, Pereira, R.M. & Veronesi R.P.S. (2015). Index of Ergonomic Risk for Activities Repetitive of Members Upper Limbs, *Procedia Manufacturing*, 3, 4456-4463.

Voutsinas, G. T. & Pappis, C. P. (2002). Scheduling jobs with values exponentially deteriorating over time, *International Journal of Production Economics*, 79, 163-169.

Wang J.B. (2009). Single-machine scheduling with learning effect and deteriorating jobs, *Computers & Industrial Engineering*, 57, 1452-1456.

Zhang, Q., Cremer, J.L, Grossmann, E.I., Sundaramoorthy, A. & Pinto, J.M., (2016). Risk-based integrated production scheduling and electricity procurement for continuous power-intensive processes, *Computers & Chemical Engineering*, 86, 90-105.