

Formulation of Nao Equation According to Nao Framework

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Article History: Received: 10 November 2020; Revised 12 January 2021 Accepted: 27 January 2021; Published online: 5 April 2021

Abstract: Companies in manufacturing often find strategies to increase production efficiency and quality to be competitive in the long run. These strategies make companies remain profitable in a highly competitive market. Nonetheless, attempting to maintain a shorter production lead time is also vital as efficiency becomes a competitive priority. Whenever there are longer lead times, overtime is taken into account to meet the target. Overtime can be the most cost-effective way for companies to achieve their quality needs.

Nevertheless, if poorly managed, overtime could quickly outstrip financial gains. This study aimed to establish the manufacturing industry model of non-value-added overtime (NAO) and formulate NAO equations. In this regard, the NAO equations were acquired from the critical factors of NAO. The vital aspects of NAO were then presented through the activities flow in the input/output manufacturing concept. The study results indicated that the highest critical factors contributed to the three processes: pre-process, in-process, and post-process.

Keywords: overtime, performance measure, working hour, operation management, non-value-added

1. Introduction

Under the new age of globalisation, companies face difficulties producing products to compete and thrive globally. To satisfy consumer demands, most companies face a worldwide challenge and have to compete in providing a wide variety of products and increase their manufacturing output. To that end, time measurement is one of the activities used to improve operational performance. Nevertheless, numerous employers are pressurising their employees to do much more without considering the expenses sustained during the overtime.

Overtime shall be defined as extended hours of working that exceed standard hours by the International Labor Organization (ILO) (Seo, 2011). Overtime is used to boost production to meet the demand rate. Even so, overtime may increase operating costs and negatively impact employees' psychological health. Therefore, global organisations like the ILO and national regulatory bodies, thus enforce overtime limit (Akgeyik, 2017). By doing so, overtime can be carried out only if needed. However, if no urgent orders are required, it could also be unnecessary.

This paper aimed to formulate the equations involved in NAO by considering the critical factors of unnecessary overtime based on operational aspects. The equations were obtained once verification of the NAO framework was performed in manufacturing industries. The crucial elements of NAO were established through the literature study on production operations.

2. Overview Of Unnecessary Overtime In Manufacturing Operations

All employees are entitled to rest a full day under the Labor Act of Malaysia (1955). Therefore, they are supposed to operate a maximum of six days a week. Eight hours of work per day shall be standard, and 48 hours per week shall be the maximum. When an organisation works fewer than six days a week, the maximum number of employees is 10 hours per day (not includes breaks) and 48 hours per week. Fortunately, an employee can extend the above regular working hours under some conditions or with common consent. Dewi *et al.* highlighted that companies should face an unprecedented challenge by supplying several products that have previously hampered their profitability to remain competitive in this era (Dewi et al., 2013). Companies should be working on productivity as it is essential to ensure a production line's efficiency. Mpanza & Nyembwe (2015) stated that the optimal use of available resources and various variables impact productivity measures.

Womack & Jones (1997) claimed that productivity is the production ratio for all manufacturing resources. Career, capital, energy, raw materials and time are all resources. Productivity also means cost savings directly.

Sidabutar NA, Matondang AR, (2019) said productivity includes procedures, quality control and technology. Therefore productivity will change if overtime work in a company is completed. The change is because productivity depends on how overtime is utilised. Two types of overtime involved, which are unnecessary and necessary overtime. Poornashree & Ramakrishna (2019) stated that non-value-added activities preoccupy energy, space, and time but do not add value to the target. In the language of lean production, non-value-added activities (NVAA) are graded as waste. Ebrahim *et al.* (2017) indicated that additional time would be required to reach the output objective. However, unnecessary overtime happens when time loss occurs.

Many activities can lead to a loss of production time (e.g., system failure, waiting, and lack of workforce). The activities are generally called entity, content, system, process, management, and climate reasons; perhaps anything similar regarding the method, material, man, machine, and environment (4 M 1 E). Excessive work closely linked to the operating system results in the typically hidden cause of loss of time (Dewi *et al.*, 2013). Non-value added activities or unnecessary work will lead to unnecessary overtime. Consequently, excessive overtime evaluation in the manufacturing industries is essential. Therefore, the overtime rules should be taken seriously, as employees have to be charged while overtime is worked.

According to Ebrahim *et al.* (2015), The Input-Output (IO) model introduces a production system's standard principle. The operation flow is divided into three stages throughout a production system: i) inputs, ii) operations, and iii) outputs. Input process activities include customer receiving of orders, procurement of parts, preparation and delivery of components, sub-assembly, and changeover. Activities in the second stage (operations) involve installing, manufacturing, inspection, and assembling. Eventually, processes in the final stage (outputs) also affect the pre-distribution inspection (PDI), moving, and distribution. A specified lead time, which suits the product's model, controls all procedures.

2. NAO Structure

i. Development of the NAO structure

Figure 1 shows the main NAO structure finalised from production and operational performance literature research. Therefore in the last five years, a total of 30 papers released intended to classify the elements that are likely to contribute to NAO. The literature studies focused on operating costs and production management, manufacturing management, organisational and quality studies, industrial engineering, and performance. This literature study shows the collection of significant factors, including an explanation of seven Lean Manufacturing (LM) waste (i.e. motion, defect, overproduction, transportation, waiting, inventory and over-processing) and specific and measurable elements.

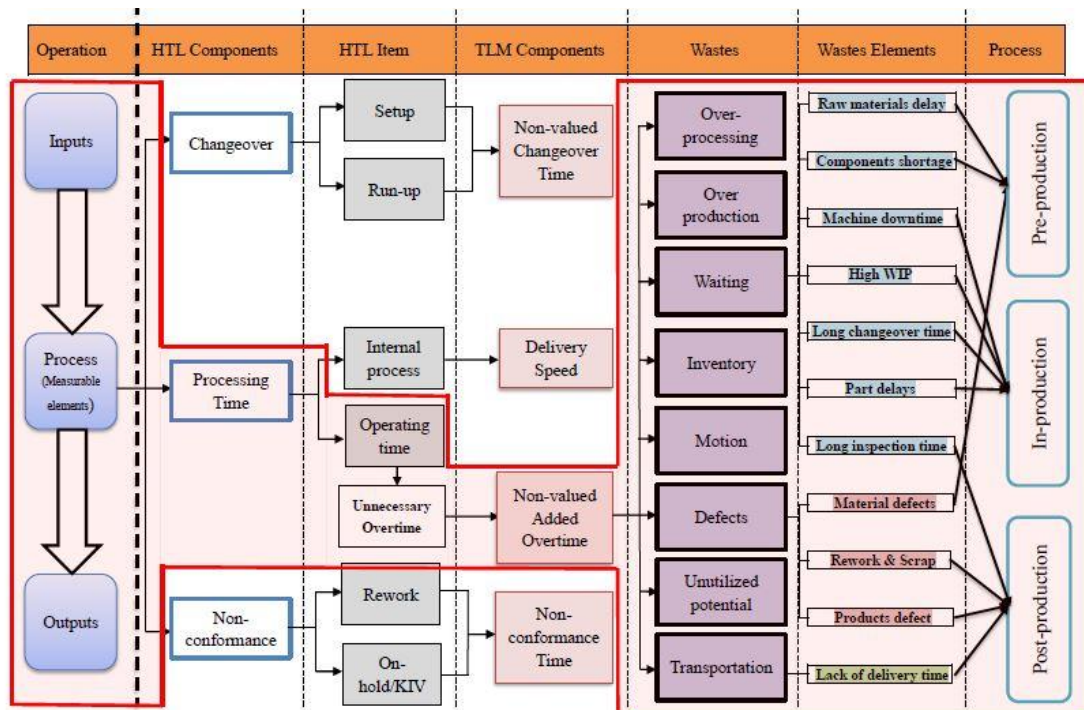


Figure 1 Initial Structure of NAO

In this study, all observed elements were categorised according to Lean Manufacturing's (LM) seven waste. Figure 1 outlines the conceptual NAO factor model built through the fundamental theory of 'Input-Output (IO)' manufacturing, which focused on production. Visual elements in the three phases of manufacturing were defined as critical elements for NAO; i) pre-process, ii) in-process, and iii) post-process. Changeover time, processing time, and non-conformance time were clarified as primary elements of Hidden Time Loss (HTL) components, as stated in a previous study (Ebrahim et al., 2015). This framework was implemented from the previous framework built by Ebrahim et al. (2015). However, a research gap was found between the processing times, as the previous study did not study unnecessary overtime factors. Therefore, this study comes out with the critical aspects of NAO from a detailed review of manufacturing elements in the elements of operations in manufacturing and a connection with the current manufacturing performance steps.

Ohno (1988) identified the seven types of waste in the production process: motion, waiting, defects, transportation, overproduction, inventory, and over-processing. Then, all time-related elements were divided into two categories: measurable and non-measurable components.

By referring to Hair et al., (2019), measurable measurements measure measurable objects or physical quantities such as mass, temperature, and length. Then, the critical factors of NAO have been filtered by quantifiable elements. Primarily focused on the principle of the 'Input-Output (IO)' design, three pathways were determined in this model: i) inputs, ii) operations, and iii) outputs. Nazarian et al. (2010) ensured that most work in production processes is based on the time it happened and the time of purely value-added processes. Time is an essential resource element used in this regard.

Besides, the critical factors of NAO were established through the activity route. Finally, the manufacturing processes were divided into three main stages: i) pre-process, ii) in-process, and iii) post-process.

ii. Verification of NAO Structure

To verify the NAO structure, the respondents' comments and the outcomes of the interviews were used. A total of 12 professionals responded. The participants included managers, engineers, and department heads from three manufacturing companies. Figure 2 shows an example of answered interview questions for the NAO structure.

There were seven columns involved for the structure of NAO: (i) Operations, (ii) Hidden Time Loss (HTL) Components, (iii) HTL Items, (iv) Time Loss Measures (TLM) Components, (v) Wastes, (vi) Wastes Elements, and (vii) Process. By referring to Figure 1, a focused column is where the study takes place. The interview questions used a scale of 1 to 5 to rate each question asked: (1) strongly disagree, (2) disagree, (3) neutral, (4) agree, and (5) strongly agree.

Initial 'Framework of the Factors for Unnecessary Overtime' Comments by Industrial Practitioners

(Please tick (✓) your selection inapplicable □)

No	Item	Appropriate Level	Comment
(1)	Overall 'Initial Framework of the Factors for Unnecessary Overtime' suitability and effected to the Overtime increasing.	1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/>	
(2)	The suitability and effectiveness of Hidden Time Loss (HTL) Components and effected the Overtime increasing.	1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/>	
(3)	Overall HTL Item structure suitability and effected the Overtime increasing.	1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/>	
	(a) Unnecessary Overtime suitability and effected to the Overtime increasing.	1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/>	
(4)	Non-value Added Overtime (NAO) suitability and effected to the Unnecessary Overtime increasing.	1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/>	
(5)	Overall Wastes structure suitability and effected to the Overtime increasing.	1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/>	

Figure 2 NAO Verification Checklist

iii. Finalisation of NAO Structure

Table 1 presents the results of the verification. Following the majority rule, the verification results of the opinions were reported.

The majority rule is a regulation that makes a decision based on the majority, having more than 50% votes (Kuhn & Poole, 2000). As Kuhn, T, and Poole S (2000) mentioned, this rule was modelled using the conflict analysis model. Three conditions were used to determine the results verification;

- i) Strongly agree and agree if $\geq 50\%$, the components and their specifications will remain in an isolated model of the initial fundamental items.
- ii) Neutral, if $\geq 50\%$, the explanations will enhance the initial fundamental items and their components.
- iii) Strongly disagree and disagree if $\geq 50\%$, an isolated model shall remove the initial fundamental elements and components.

Table 1 Verification Analysis Results

Section	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Overall Initial Framework	0 (0.0%)	0 (0.0%)	1 (8.3%)	4 (33.3%)	7 (58.3%)
HTL Components	0 (0.0%)	0 (0.0%)	1 (8.3%)	5 (41.7%)	6 (50%)
HTL Items	0 (0.0%)	0 (0.0%)	1 (8.3%)	7 (58.3%)	4 (33.3%)
Unnecessary Overtime	0 (0.0%)	0 (0.0%)	1 (8.3%)	6 (50.0%)	5 (41.7%)
NAO	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (41.7%)	7 (58.3%)
Overall Wastes	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (25.0%)	9 (75.0%)

3. Equation of NAO

The NAO equation was developed based on the proposed NAO framework. As shown in Figure 1, NAO is measured through the total of NAO for Total Wastes involved in Lean Manufacturing. In this regard, Total Wastes consists of Over-processing, Overproduction, Waiting, Inventory, Motion, Defects, Unutilised Potential, and Transportation. Therefore, the NAO equation can be written as:

$$NAO = OProd + OPres + Wtg + Ivt + Mtn + Dft + UP + Tp \tag{1}$$

Where,

NAO: Non-Value Added Overtime

OProd: Overproduction

OPres: Over-processing

Wtg: Waiting

Ivt: Inventory

Mtn: Motion

Dft: Defects

UP: Unutilised Potential

Tp: Transportation

In this respect, NAO is ≥ 0 .

However, according to the verification results, the final framework was obtained. The framework is shown in Figure 3 below.

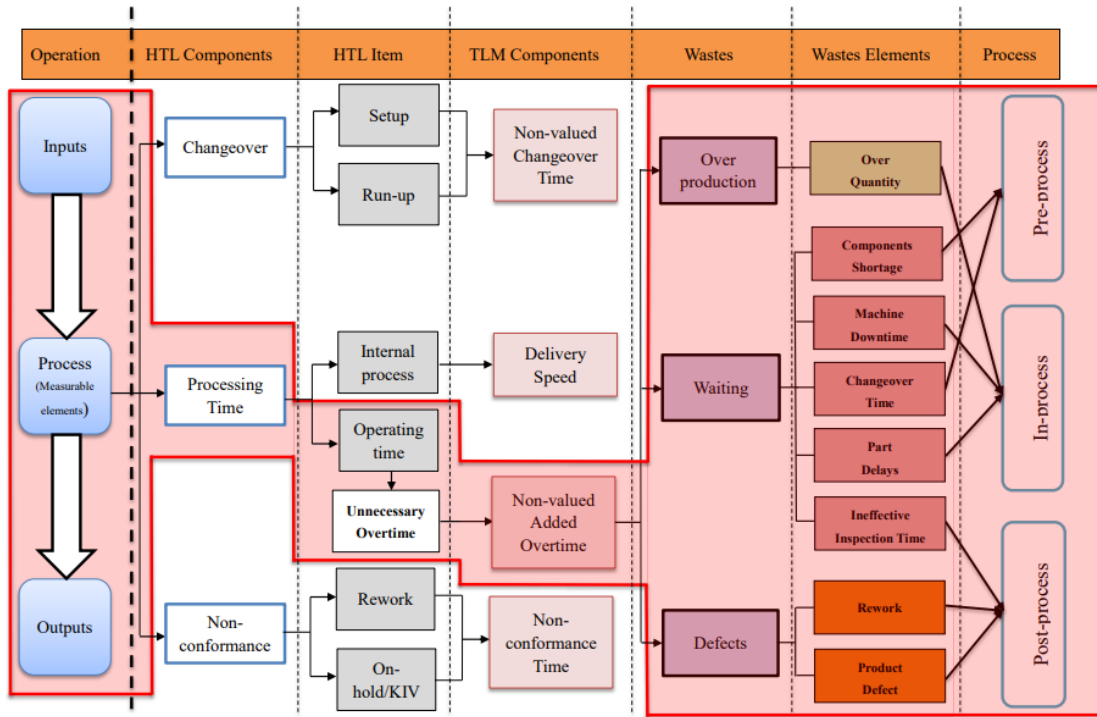


Figure 3 Final NAO Framework

Figure 3 outlines the overall framework of NAO after verification by industrial practitioners. Since there are no wastes elements on Over-processing (OPres), Motion (Mtn), Unutilized Potential (UP), Inventory (Ivt), and Transportation (Tp) thus, it is equal to zero. Therefore, the finalised equation is shown below:

$$NAO = OProd + Wtg + Dft \tag{2}$$

The equation provided above can be used for daily, weekly, monthly, or yearly data. It is suitable for each time being and with industrial suitability. However, this equation is only for internal and external production lines and does not include production lines from sub-com or vendors.

In this regard, the equation of each involved element is explained in further detail. For Overproduction (OProd), the involved waste element is over-quantity. Since there is only one waste element involved, thus OProd = Over-quantity. Therefore, the equation for the element is:

$$OProd = (X_{act} - X_{cap})t_s \tag{3}$$

Where,

OProd: Overproduction

X_{act} : Actual quantity of output

X_{cap} : Machine capacity

t_s : Standard time

In this regard, $OProd \geq 0$

For Waiting (Wtg), there are five sub-elements involved. Therefore, there are five main equations for each sub-element. Each sub-elements equation will be explained in detail. The involved waste elements are Components Shortage (Cs), Machine Downtime (Mcd), Changeover Time (Chgt), Part Delays (Pd), and Ineffective Inspection Time (Iit). Therefore, the equation for the elements is:

$$Wtg = Cs + Mcd + Chgt + Pd + Iit \tag{4}$$

Where,

Wtg: Waiting

Cs : Components shortage

Mcd: Machine downtime

Chgt: Changeover time

Pd: Part delays

It: Ineffective inspection time

In this regard, $Wtg \geq 0$

Firstly, the equation of sub-elements for Components Shortage (Cs) is as below:

$$Cs = Cs_{qty} \times t_s \quad (5)$$

Where,

Cs : Components shortage

Cs_{qty}: Quantity of components shortage

t_s: Standard time

In this regard, $Cs \geq 0$

$$Cs_{qty} = \sum (y_n - x_n) \times n \quad (6)$$

Where,

Cs_{qty}: Quantity of components shortage

Y_n: Planned quantity of total components

X_n: Actual amount of entire components

n: Number of workstations

In this regard, $Cs_{qty} \geq 0$

Secondly, the equation of sub-elements for Machine Downtime (Mcd) is as below:

$$Mcd = t_d - m_{dt} \quad (7)$$

Where,

Mcd: Machine downtime

t_d: Total downtime

m_{dt}: Planned machine downtime

In this regard, $Mcd \geq 0$

$$t_d = h_{plan} - h_{act} \quad (8)$$

Where,

t_d: Total downtime

h_{plan}: Planned working time

h_{act}: Actual working time

In this regard, $t_d \geq 0$

Thirdly, the equation of sub-elements for Changeover Time (Chgt) is as below:

$$Chgt_{tot} = Chgt \times n \quad (9)$$

Where,

Chgt_{tot}: Total changeover time

Chgt: Changeover time

n: Frequency of changeover

In this regard, $TChgt \geq 0$

Next, the equation of sub-elements for Part Delays (Pd) is as below:

$$Pd = p_{del} \times t_s \tag{10}$$

Where,

Pd: Part delays

p_{del} : Quantity of part delays

t_s : Standard time

In this regard, $Pd \geq 0$

$$P_{del} = P_{plan} - P_{act} \tag{11}$$

Where,

p_{del} : Part delays

p_{plan} : Quantity of planned output

p_{act} : Quantity of actual output

In this regard, $p_{del} \geq 0$

Lastly, the equation of sub-elements for Ineffective Inspection Time (IIt) is as below:

$$IIt = It \tag{12}$$

Where,

IIt: Ineffective inspection time

It : Total inspection time

In this regard, $IIt \geq 0$

For Defect (Dft), there are two sub-elements involved. Therefore, there will be two main equations for each sub-element. Each sub-elements equation will be explained in detail. The involved waste elements are Rework (Rew) and Product Defect (Pdf). Therefore, the equation for the elements is:

$$Dft = Rew + Pdf \tag{13}$$

Where,

Dft: Defect

Rew: Rework part

Pdf: Product defect

In this regard, $Dft \geq 0$

Firstly, the equation of sub-elements for Rework (Rew) is as below:

$$Rew = 0.5 (\sum t_{s,r}) \tag{14}$$

Where,

Rew: Total rework time

t_s : Standard time

r: Total number of reworks at the end of a process

In this regard, $Rew \geq 0$

By referring to (Hamzah et al., 2019), the rework time takes 50 percent from the Total Standard Time. According to (Jaber & Khan 2010), it is assumed that production and rework per unit time are 5 and 10 units, respectively. Lastly, the equation of sub-elements for Product Defect (Pdf) is as below:

$$Pdf_{tot} = Pdf \times t_s \tag{15}$$

Where,

Pdf_{tot} : Total time of product defect

Pdf: Quantity of product defect

t_s : Standard time

In this regard, $\text{Pdf}_{\text{tot}} \geq 0$

$$\text{Pdf} = \sum(t_s d) \quad (16)$$

Where,

Pdf: Quantity of product defect

t_s : Standard time

d: Total number of defects at the end of a process

In this regard, $\text{Pdf} \geq 0$

4. Conclusion

This paper introduced the structure of non-value-added overtime (NAO) and the NAO equations that will be used to determine the unnecessary factors that contribute to time loss. In this respect, Lean Manufacturing (LM) wastes are considered as significant aspects of NAO. The formulated equations of NAO will be applied in industries to validate whether these equations are compatible with the selected companies. The next step is to conduct a case study at the selected companies and perform process validation through data collection.

5. Acknowledgments

Special thanks to the author for granting facilities and useful data to complete the present study are given by FRGS-RACER/2019/FTKMP-COSSID/F00412 grant, Fakulti Teknologi Kejuruteraan Mekanikal Dan Pembuatan and Fakulti Kejuruteraan Pembuatan, Universiti Teknikal Malaysia (UTeM).

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