UNNECESSARY OVERTIME AS A COMPONENT OF TIME LOSS MEASURES IN ASSEMBLY PROCESSES

Z., Ebrahim[1] and A.H., Abdul Rasib[2]

[1]Faculty of Manufacturing Engineering,
[2]Postgraduate Center,
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya,
76100 Durian Tunggal, Melaka, Malaysia.

Email: [1]zuhriah@utem.edu.my; *[2]amirgunma@hotmail.com

ABSTRACT: Hidden Time Loss (HTL) that occurs along the production process has a significant effect on productivity. Overall Equipment Efficiency (OEE) is the most popular performance measurement tool used in the production line. Equipment performance is one of the measure components of OEE that caters to HTL. However, OEE does not really fit in measuring operation performance of assembly process especially the semi-auto assembly and the manual assembly process. There would be an amount of HTL occurring along the semi-auto assembly and manual assembly processes that become critical when a high level of product variety is involved at the same production line. Thus, the purpose of this paper is to introduce the Unnecessary Overtime (UOT) as one of the components of Time Loss Measures (TLM) in assembly processes. The structure of UOT has been developed through a thorough literature study on manufacturing operation and its performance measures. The UOT structure is validated by using case study at five automotive manufacturing companies. The results prove that the UOT has contributed to HTL though the actual process time is shorter than standard process time. Thus, it can be concluded that UOT is one of the components of TLM in semi-auto and manual assembly processes.

KEYWORDS: *Time Loss, Overtime, Non-value added, Assembly Process, Measure.*

1.0 INTRODUCTION

In the new era of manufacturing industries, product variety has been recognized as one of the foremost competitive edges for manufacturing companies in order to meet customers' diverse demands [1]. Thus, the manufacturing companies have to offer a variety of products, and achieving minimal time loss would be the most challenging for them. Besides, they are also facing an intensive competition in product quality, market price, and minimal lead time [2]. In this case, it is important for the manufacturing companies to identify the non-value added activities along the manufacturing lead time accounted for each type of product in order to sustain the efficient productivity.

Thus, this paper introduces the components of Unnecessary Overtime (UOT) as the measure of HTL through determination of internal process in the context of assembly processes at the automotive industry. The significance of this study is to determine the HTL due to assembly process activities as the number of product variety in the automotive industry keeps increasing. In addition, this paper clarifies the effect of UOT on the assembly productive time in the context of assembly features such as left-right parts/components, front-rear parts/components, different products, and different models.

2.0 UNDERSTANDING THE UOT

According to Battaia et al. [3], on manual mixed-model lines, not only one but a set of similar products (variants or models) are assembled. Boyle [4] identifies the types of flexibility (i.e. volume, product mix, and new product). Thus, the implication of flexibility causes the volume and product mix, number of variants, and cost to be more significant parameters in manufacturing companies. Normally, for mixed- model assembly line, a set of tasks for each variant is assigned according to the company's operating time. In this study, the operating time refers to the total working time in a day or month. In this regards, the operating time for the tasks is essential to be controlled properly to meet customer demand. However, Klassen and Rohleder [5] claimed that when the flexibility level is increased the potential items (i.e. part-time employees, scheduling, overtime, using cross-trained employees, and calling on potential customers to generate business) should work on developing demand and capacity. This will increase the chance that one will cover for the lack of another, and in turn increase profits.

Indeed, the customer will confirm the supplier production capacity through the operating time. The capacity feasibility of the facility for producing an order on time will be clarified through the operating time as a major portion of lead time [6]. Thus, the maximum level of production capacity can be achieved through appropriate constraint of overtime in the company's operating time. Smith [7] claimed that additional overtime could extend operating hours while maintaining the existing workforce size. According to Mathur and Süer [8], the overtime serves to minimise the number of tardy jobs, but overtime can incur additional costs to a company.In this regards, there is a possibility for the unnecessary overtime to cater to the required volume. Thus, the unnecessary overtime is the additional time more than is needed and can be considered as HTL. Therefore, the scope of this study is confined to overtime. In this study UOT as a TLM component.

3.0 THE STRUCTURE OF UOT

Figure 1 presents the initial structure of UOT resulted from literature studies on manufacturing operations and its performance. Based on the UOT structure, it consists of Total Overtime and Necessary Overtime.

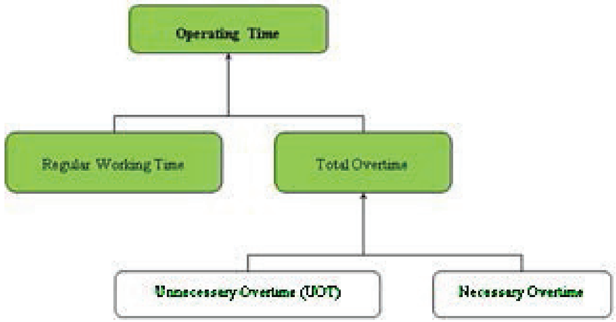


Figure 1: Initial structure of UOT

In this study, Regular Working Time refers to the company's official operating time. Total Overtime refers to the total of additional operating time. Thus, necessary overtime can be referred as additional operating time needed to achieve production target. Total Overtime is needed when the demand or Production Input exceeds Regular Production Capacity. In this regard, Regular Production Capacity refers to the maximum capacity generated from the Regular Working Time. In some cases, overtime known as Total Overtime is necessary when demand exceeds the maximum capacity. In practice, overtime is used to overcome quality issues, shortage of workers, machine breakdown, shortage of components, etc. Thus, this study introduces the terms Necessary Overtime and UOT.

4.0 UOT EQUATION

The UOT equation has been developed based on the proposed UOT. As shown in Figure 1, UOT is measured through the deduction of Necessary Overtime from Total Overtime for an assembly line as written in Equation (1). The UOT for Total Overtime is determined by deduction of Regular Working Time from Operating Time as written in Equation (2). The UOT for Necessary Overtime is determined by deduction of the actual time taken of Regular Production Capacity per day or month from the actual time taken of an assembly line Production Input per day or month as written in Equation (3). Table 3 presents the conditions that contribute to UOT that based on total operation time (t_{op}) and regular working time (t_{rw}). Thus, UOT can be determined as:

$$UOT = t_{tot} - t_{not} \tag{1}$$

Where,
t_{tot} is total overtime given to achieve the assembly line target.
t_{not} is necessary overtime based on the following calculation.
In this regard, $UOT \geq 0$.

This study determines the total of UOT for Total Overtime,

$$t_{tot} = t_{op} - t_{trw} \tag{2}$$

Where,
t_{op} is total operation time that includes necessary overtime and unnecessary overtime.
t_{rw} is regular working time as the standard company operating time.
In this regard, $t_{tot} \geq 0$.

This study determines the total of UOT for necessary overtime,

$$t_{not} = t_{apbn} (P_i - P_c) \tag{3}$$

Where

t_{apbn} is actual process bottleneck of processing time.
P_i is production input per day or month.
P_c is regular production capacity in a day or month.
In this regard, $t_{not} \geq 0$.

Table 2 presents the conditions considered for UOT.

Table 2: Conditions for UOT

Condition	No	Detail	Description	Effect	UOT Potential
$t_{op} > t_{rw}$	1	$P_i > P_c$	Production Input exceeds capacity	Overtime is required	Yes
	2	$P_i = P_c$	Problem in assembly line (Machine, components, worker skill, manpower, and quality)		
	3	$P_i < P_c$	Problem in assembly line (Machine, components, worker skill, manpower, and quality)		
$t_{op} = t_{rw}$	4	$P_i > P_c$	Sub-contract to outsource vendor and high-skilled level worker	Overtime is not required	No
	5	$P_i = P_c$	Production plan is matched with capacity without any problem		
	6	$P_i < P_c$	Problem in assembly line (Machine, components, worker skill, manpower, and quality) but the production target is achieved in regular working time		
$t_{op} < t_{rw}$	7	$P_i < P_c$	Production target is achieved in regular working time	Overtime is not required	No

5.0 VALIDATION OF UOT EQUATION

The objective of validation is to validate the UOT equations that have been developed for determining HTL through operating time. The validation of UOT equation is carried out through case studies at five automotive manufacturing companies in Malaysia named as Company A, B, C, D, and E.

5.1 Data Collection

Table 3 presents the summary of operation characteristics based on product name at the five manufacturing companies. In this study, data of Actual Process Cycle Time, Overtime Record, and Production Input are used to determine the UOT that occurred in a day or month

Table 3: Summary of operation characteristics

Company	A		B	C	D		E	
Product Name	Head lamp	Rear Combination Lamp	Intake Manifold	Door Latch	Front Corner	Fuel Tank	Right Hand Door	Left Hand Door
Main Position	Front	Rear	Front	Front and Rear	Front	Back	Front and Rear	Front and Rear
Detail Position	Right and Left	Right and Left	None	Right and Left	Right and Left	None	Right	Left
Regular Working Time (hr)	18.75	18.75	9.25	9.50	24.00	9.50	9.00	9.00
Productive Working Time (hr)	16.75	16.75	7.92	8.00	21.00	8.25	8.00	8.00

5.2 Data Analysis

The purpose of the data analyses is to determine the value of UOT at each company in the case study (i.e. A, B, C, D, and E). In this study, the Microsoft Excel Software was used as a tool to analyse the data.

For Company A, the data analysis is executed for only two types of products: (i) Head Lamp (HL), and (ii) Rear Lamp (RL). In this case, the Actual Process Cycle Time Records are used to determine the bottleneck which is represented by the longest Actual Process Cycle Time for a particular day. The Overtime Records are used to clarify monthly additional operating time.

The Production Input is used to determine how many units would be processed per month for a continuous period of five consecutive years (2009 to 2013). From the analysis, the UOT for the RL is presented in the form of Monthly UOT. The same method is used for the RL to determine the Monthly UOT for a particular month

For Company B, the data analysis is executed for only one type of product, which is Intake Manifold (IM). The Production Input is used to determine how many units would be processed per day for a continuous period of three consecutive months (i.e. November 2014, December 2014, and January 2015). From the analysis, the UOT for the IM is presented in the form of Daily UOT. For Company C, the data analysis is executed for only one type of product, which is Door Latch (DL). Similar types of data were used as Company B. For Company D, the data analysis is executed for only two types of products: (i) Front Corner (FC), and (ii) Fuel Tank (FT). Similar types of data were used as Company B and Company C.

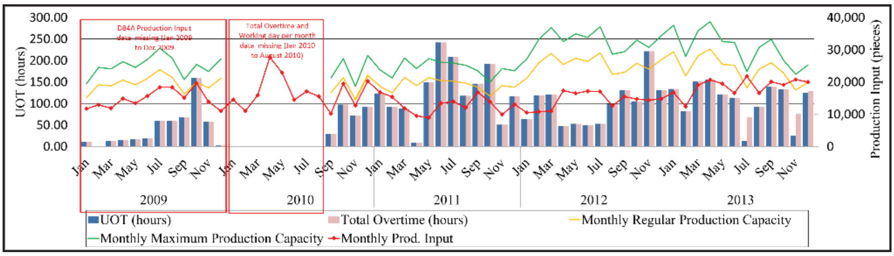
For Company E, the data analysis is executed for only two types of products: (i) Right-Hand Handle Door (RH) and (ii) Left-Hand Handle Door (LH). The Overtime Records are used to clarify daily additional operating time. The Production Input is used to determine how many units would be processed per day for a continuous period of three consecutive months (i.e. January 2015, February 2015, and March 2015). From the analysis presents the UOT for the RH and LH in the form of Daily UOT. The same method is used for the LH to determine the Daily UOT for a particular day.

5.2 Results and Discussion

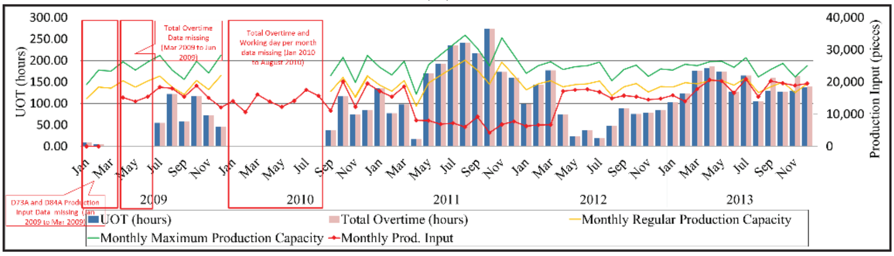
The results of UOT for each company are presented in plotted graphs that are based on the Total Overtime, Production Input, and Regular Production Capacity for products HL and RL. Due to limited page provided, two plotted graphs are presented for company A, B, and C only. The Regular Production Capacity is generated by using Regular Working Time of the company. The Maximum Production Capacity is generated using additional working time. Additional working time is different in each manufacturing company. In this regard, three situations of UOT can be observed from the plotted graphs: (i) UOT does not occur, (ii) UOT is equal to Total Overtime, and (iii) UOT is shorter than Total Overtime. All the presented figures show the results of Daily/Monthly Production Input (Pieces) versus Daily/Monthly UOT

5.3.1 Company A

Figure 3 (a) presents the results of UOT for Head Lamp (HL) product, Figure 3 (b) presents the results of UOT for Rear Combination Lamp (RL) product from the years 2009 to 2013.



(a)



(b)

Figure 3: Monthly UOT for Company A (a) HL and (b) RL

Through observation, situation (i) occurs as can be seen in Figure 3 (a) (February 2009) in which overtime is not provided at all, because the Production Input is less than Regular Production Capacity. Hence, the UOT is equal to zero. Situation (ii) occurs as can be seen in Figures 3 (a) and 3 (b); the UOT equals to Total Overtime. When the Production Input meets the Regular Production Capacity, overtime is not necessary. Nevertheless, overtime is provided because of certain reasons. A possible reason for this situation is related to setup frequency through implementation of a smaller batch. Logically, as a smaller batch increases, the frequency of setup increases. Therefore, as the frequency of setup increases, the Regular Production Time decreases. The reason is supported by Johnson [11]

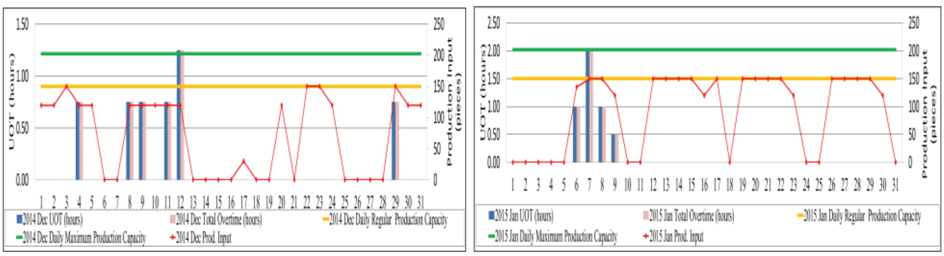
In other aspects, the high frequency setup often has potential to cause worker mistakes and machine problems. According to Li and Rong [12], the whole production system and just-in-time objective could be affected by a high frequency setup which often leads to high risk of worker mistakes and machine failures. The time loss affected by the setup time could not be covered by buffer time. Thus, even though Production Input could meet Regular Working Time, overtime is desperately required to overcome these issues and considered as an UOT.

Situation (iii) occurs as can be seen in Figures 3 (a) and 3 (b); the Production Input is more than Regular Production Capacity. In this case, overtime is necessary. However, the additional working time required is more than the necessary overtime. As a result, UOT occurs. There are several reasons for the UOT to occur. One of the reasons is inappropriate overtime planning.

This situation occurs because the current Actual Process Cycle Time for each process is not clarified in a timely manner by a production person-in-charge. Therefore, the capability of a worker is not accurately estimated in order to determine the appropriate production capacity. This reason is supported by Mathur and Suer [8]

5.3.2 Company B

Figure 4 (a) and Figure (b) present the results of Unnecessary Overtime (UOT) for Intake Manifold (IM) for December 2014 and January 2015 respectively



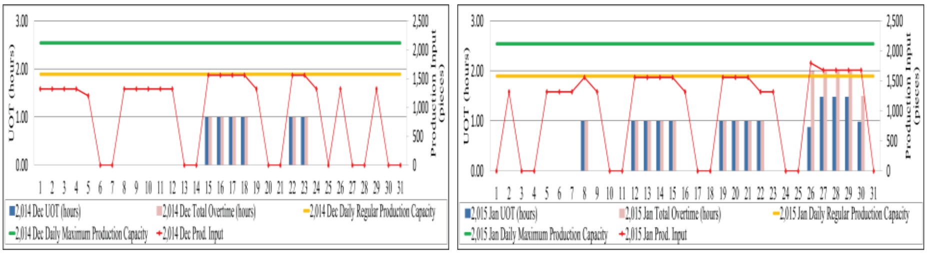
(a) (b)

Figure 4: Daily UOT for Company B (a) December 2014 and (b) January 2015

In this case, there are four different product varieties (i.e. W1, W2, W3, and W4) and three different model varieties (i.e. 1.8, 2.0, and 2.4). As can be seen in both figures, UOT occurred in two situations: (i) UOT does not occur and (ii) UOT is equal to Total Overtime. Similar to Company A, situation (i) occurred because overtime is not provided at all in which the Production Input is less than Regular Production Capacity. Hence, the UOT is equal to zero. Situation (ii) occurred when Production Input meets Regular Production Capacity. The reason for this situation is similar to Company A

5.3.3 Company C

Figure 5 (a) and Figure 5 (b) presents the results of Unnecessary Overtime (UOT) for Door Latch (DL) for December 2014 and January 2015 respectively. In this case, there are six different product varieties (i.e. X1, X2, X3, X4, X5, and X6) and twenty-five different model varieties. As can be seen, UOT occurred in three situations as mentioned earlier. Through observation, situation (i) occurred because overtime has not been provided at all in which the Production Input is less than Regular Production Capacity. Hence, the UOT is equal to zero. Situation (ii) also occurred where the UOT equals to Total Overtime. In this situation, when Production Input meets Regular Production Capacity, overtime is not necessary. The reason for this situation is similar to that of Company A. Situation (iii) occurred in January 2015 with Production Input of more than Regular Production Capacity. In this case, overtime is necessary. However, the additional working time required is more than the necessary overtime. As a result, UOT occurred. The reason for this situation is similar to that of Company A.



(a) (b)

Figure 5: Daily UOT for Company B (a) December 2014 and (b) January 2015

5.3.4 Company D

Here, results of Unnecessary Overtime (UOT) are presented in two months (i.e. December 2014 and January 2015) for Front Corner (FC) and Fuel Tank (FT). In this case, there are two product varieties (i.e. Y1, and Y2) for FC and two product varieties (i.e. Y3, and Y4) for FT.

It is observed that situation (i) occurred in both months FC and FT productions because overtime was not provided at all as Production Input is less than Regular Production Capacity. Hence, the UOT is equal to zero. Situation (ii) occurred as UOT equals to Total Overtime. In this situation, when Production Input meets Regular Production Capacity, overtime is not necessary. The reason for this situation is similar to Company A. Situation (iii) occurred as Production Input is more than Regular Production Capacity which necessitates overtime. However, the additional working time required is more than the necessary overtime. As a result, UOT occurs. The reason for this situation is similar to Company A.

5.3.4 Company E

In this case, there are two model varieties (i.e. POM, and CHROME) for RH and LH. Based on observation, situation (i) occurred at RH and LH production. Similar to Company A, situation (i) occurred because overtime is not provided at all as Production Input is less than Regular Production Capacity. Hence, the UOT is equal to zero. Situation (ii) also occurred where the UOT equals to Total Overtime. The reason for this situation is similar to that of Company A. Overall result of UOT for all five companies is summarized in Table 4.From Table 4, it can be concluded that the three situations of UOT can occur at any type of assembly feature (i.e. Right-Left part, Front-Rear part, and single part).

Table 4: Summary of Situations for Each Company and Product on UOT

Company	A		B	C	D		E	
Situation	Product							
	HL	RL	IM	DL	FC	FT	RH	LH
(i) UOT not occurred	√		√	√	√	√	√	√
(ii) UOT equal to Total Overtime	√	√	√	√		√	√	√
(iii) UOT is shorter than Total Overtime	√	√		√		√		

6.0 CONCLUSION

This paper introduced the structure of Unnecessary Overtime (UOT) and the equations of UOT that are used to determine Hidden Time Loss (HTL) in assembly operations. Two major components of UOT have been clarified as; (i) Total Overtime and (ii) Necessary Overtime. The equations of UOT were validated by case studies at five manufacturing companies in automotive industry. From the results of the case studies, three conclusions have been determined; (i) overtime is necessary when Production Input is more than capacity, (ii) UOT can occur in assembly production in two situations either equal to Total Overtime or shorter than Total Overtime, (iii) UOT can occur at any type of assembly feature (i.e. Right-Left part, Front-Rear part, and single part). In short, UOT is one of the components of HTL in manual assembly and semi-auto assembly processes

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