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Research paper

Non-valued Changeover Time Measures for Hiddxen Time Loss in Automotive Mechanical Component Production

Abdul Rasib A. H.1, Mohamad Rafaai Z. F.2

1Fakulti Teknologi Kejuruteraan Mekanikal dan Pembuatan, Universiti Teknikal Malaysia Melaka, Melaka, Malaysia
2Fakulti Kejuruteraan Mekanikal, Universiti Tenaga Nasional, Selangor, Malaysia

Abstract

Generally, Hidden Time Loss exists besides all procedures and thus it has the direct influence on the rate of productivity. In the line of production, the most prominent tool to measure the performance is Overall Equipment Efficiency. Availability of equipment is one of the component to measure Overall Equipment Efficiency to cater the Hidden Time Loss. Though, in manual assembly and semi-automatic assembly procedure, the Overall Equipment Efficiency is not good fit to measure operational performance of assembly procedure. Along the manual assembly and semi-automatic assembly procedures some Hidden Time Loss has occurred particularly when same line of production provides high variety of product. Therefore, the current research introduces the Non-valued Changeover Time as one component of Time Loss Measures in assemble produces. A comprehensive literature analysis is done on the production operations along with the measures of performance to develop the Non-valued Change-over Time structure. Basically, a case study of two companies of automotive manufacturing is used to find the validity of structure of Non-valued Change-over Time. It is concluded that Non-valued Change-over Time is one of the measure of Hidden Time Loss in manual as well as semi-automatic assembly procedures.

Keywords: *Hidden Time Loss (HTL), Overall Equipment Efficiency (OEE), non-valued, change-over time, performance measure*

1. Introduction

In the present emerging industries, the primary competitive edge for the manufacturing firms is the product variety to fulfill the varied demands of the customers [1]. Also, manufacturing industry has to face intense challenge to compete for the price, minimum lead time and quality of the products [2]. Therefore, it is essential for the companies to detect the activities which are not adding value in overall processes and lead time of manufacturing of each product type to sustain and improve the efficiency.
The need of high variety of products has influenced the lead time as time period is required to prepare the product line having diverse product qualifications. This is normally known as change-over time. The rate of change-over time is increased with the increase in the variety of product. On this matter, the non-value added activities are known as the time between the last product of preceding order being generated that is leaving the procedure and the new up-coming product of next procedure [3][4]. Singh and Khanduja [5] indicates that setup is the procedure of accomplishment of activities in a certain sequence, which are performed to gain the constraints on production before the beginning of any product manufacturing. Taken together, the non-value added activities can never be avoided but steps can be taken to minimize them. Hence, in order to reduce the loss of time in change-over activities, improved operating performance is essential which is based on flexibility of procedures. To gain the competitive advantage, the organizations need to pay attention on their ability of manufacturing flexibility, apart from the quality, cost, and delivery of the products [6 - 8]. Therefore, this research paper has introduced the different elements of change-over time as the Time Loss measure by determining NVCOT in the reference of automotive industry assembly procedures. This study is significant as it determine the Hidden Time Loss occurred because of change-over activities as the amount of varieties in the products continue to enhance all the time in the automotive industry. Additionally, this research illuminates the outcome of non-valued change-over time for assembly productive time in reference with features of assembly like diverse models, right-left parts/elements, and rear-front parts/components.

2. Understanding The NVCOT (non-valued change-over time)

McIntosh *et al.* [9] indicated that change-over comprises of the accomplishment of run-up, run-down and setup activities. He describes the run-up phase is the time of re-establishment of stable state production, when quality and efficiency is established on requirements. Whilst, Shingo [10] pointed out that extensive down-time is experienced in change-over activities. Also, in the changeover activities, setup can be classified into two basic categories; Internal and External setup. In accordance with Moxham and Greatbanks [11], internal setup is referred as the setup that is executed when the machine is stopped whereas external setup relates to activities that are accomplished during the in-operation machine. In this respect, other than the use of resources that are adding value for the end users, all the activities are barely wastage. The outcome of this study evidently indicated that internal setup has the contribution for time loss because to accomplish it, machine must be stopped. Furthermore, Ferradas and Salonitis [4] identified that the activities of internal setup are performed only if machine is shut-down while external activities can be performed when the machine is running during its normal procedures.

During internal setup, the non-value added activities are very important subject to show concerns like modifications to restart the production due to the directives that relates to procedural setup and its trial [12][13]. As stated by Gilmore and Smith [14], the causes of change-over procedure was unproductive time, basically considered as the time spent on waiting for basic resources like setters, tooling and fitters when not available. Furthermore, Van Goubergen and Van Landeghen [15] established that change-overs in product line generally need minutes, hours, or sometimes days to get completed. So, it is crucial to minimize the time to setup by reducing the activities which are not adding value to the overall production [5]. Operational performance can be improved effectively by using the fundamental concept of Just In Time tools like Multi-Skill Employee and 5S particularly to reduce unproductive time in change-over activities that happen due to the lack of suitable operational techniques particularly on change-over activities [13][16]. This absence of appropriate methods might be caused by the deficiency of skillful and knowledgeable workers. It has been determined that operational performance is directly influenced by inefficiency of time management in operational procedures [17-18]. In accordance with Boysen *et al.* [19], the availability of flexible machinery and workers causes considerable decrease in non-valued Change-over Time for mixed model assembly lines. In this situation, various products might be manufactured together in inter-mixed item sequences (one lot size) on similar line. Thus, more investigation is needed on NVCOT structure to decide the Hidden Time Loss that occurred by general non-value added activities during changeover procedure.

3. NVCOT Structure

A. Development of structure of NVCOT

Figure. 1 shows the primary NVCOT structure concluded from the past search on literature regarding production operations and operational performance. As it is given in earlier section describing the two basic types of setup in changeover methods; (i) internal setup (ii) external setup.

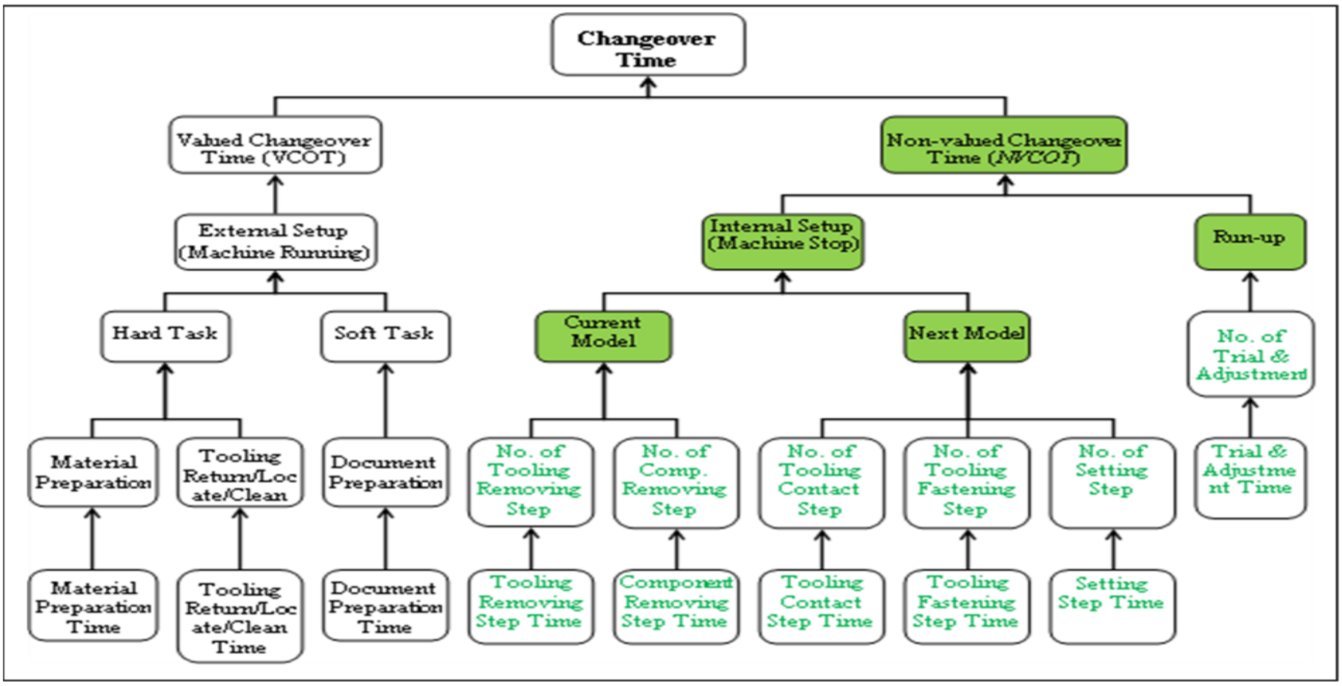

Fig. 1 Initial structure of NVCOT

In current study, the non-valued change-over time (NVCOT) are counted from the internal setup procedure activities involving run-up methods. These procedures happen because of change-over between new model and current model. Olson and Villeius [20] defines the run-up as a process taking time to make fine modifications and inspection that is done through restart of manufacturing up to the most adequate level and production speed has been achieved. Activties like component removal and tool removal are commonly used activities in curent model internal setup in which the assembly procedures are ceased. In the case of internal setup for new model, the commonly used activities are tool fastening, tool contacting and setting process. In this manner, the attachment done in actual (fastening and contacting) or dies removal or tooling are categorised as an setup time internal activities [21]. Patel *et al.* [22] indicated another aspect that must be considered significant for time loss in machine setting is the possibility of error. At the end, the run-up activities taking place are considered as the part of structure of NVCOT. McIntosh *et al.* [9] describes that when the consistent production conditions are re-established by delivering good quality level and optimum productivity, it is known as Run-up period.

Inclusively, the Time Loss is considered as the accumulated time utilized for several number of activities known as the non-valued change-over time activities.

B. Verification of NVCOT Structure

The confirmation of the structure of NVCOT is the objective of the current study in the realistic situation. In order to verify the structure of NVCOT, the comments made the respondents and the outcomes of the face to face survey are used. The professionals were used as the practitioners like managers, engineers etc. these practitioners were selected from five companies involved in manufacturing. During the verification of the structure of NVCOT, total seven respondents participated. Fig. 2 shows an example of answered face-to-face survey for the structure of NVCOT.

There are three sections in the face to face survey for the structure of NVCOT: (i) Run-up. (ii) Internal setup (iii) overall changeover time. Likert scale is used as the bases of the structure of NVCOT:

(i) most appropriate is equal to 1, (2) partly appropriate is equal to 2 and (iii) appropriate is equal to 3 .

Initial 'Framework of Time Loss Measurement Structure' Comments by Industrial Practitioner

(Please tick (√) your selection in applicable ☐)

No	Item	Slide No.	Appropriate Level	Comment
(1)	Overall 'Initial Framework of Time Loss Structure' suitability and effected to the Time Loss increasing.	10	1 ☐ 2 ☐ 3 ☑	
	(a) Time cluster suitability and effectiveness.	10	1 ☐ 2 ☐ 3 ☑	
(2)	Overall changeover structure suitability and effected to the Time Loss increasing.	11	1 ☐ 2 ☐ 3 ☑	
	(a) Setup structure suitability and effected to the Time Loss increasing.	11	1 ☐ 2 ☐ 3 ☑	FOLLOW SMED CONCEPT (REFER SMED SLIDE)
	(b) Run-up structure suitability and effected to the Time Loss increasing.	11	1 ☐ 2 ☑ 3 ☐	ONE PIECE FLOW CONCEPT MORE SUITABLE AND NEED TO ADD QUALITY CHECK FOR CONFIRMATION

Fig. 2 NVCOT verification checklist

C. Finalization of NVCOT Structure

The results of verification are presented in table 1. The verification analysis results of opinions is reported by using the majority rule.

Among one of the decision rules is the majority rule according to which alternative is chosen on the basis of majority that is, having more than 50% votes [23]. As mentioned by Fukuyama *et al.* [24], the conflict analysis model is utilized in order to model this rule. In order to determine the verifications of the results, three conditions are used;

(i) Appropriate if greater than fifty percent, the components of initial final including the fundamental items will be in the model of isolation

(ii) Appropriate partly if greater than 50 percent, improvement will be observed in the description of components of fundamental items and fundamental items as well.

(iii) Not appropriate if greater than fifty percent, components along their fundamental items will not remain in the model of isolation**.**

Table 1

Result of analysis for the verification of NVCOT structure

No	Section	Not-appropriate	Partly-appropriate	Appropriate
1	Overall Changeover Time	0 (0.0%)	3 (42.9%)	4 (57.1%)
2	Internal Setup	0 (0.0%)	3 (42.9%)	4 (57.1%)
3	Run-up	0 (0.0%)	3 (42.9%)	4 (57.1%)

Source: As per calculation by author

The analysis results demonstrates that the recommended NVCOT structure is suitable as shown in Figure 1.

4. NVCOT Equation

Determination of total TL which is caused by the activities of changeover is the objective of the equation of NVCOT. NVCOT structure is used to develop the equation of the NVCOT. So, the NVCOT equation can be written as:

$$NVCOT = \sum_{i=1}^{n}(CM)_i + \sum_{j=1}^{n}(NM)_j + \sum_{k=1}^{n}(RU)_k \qquad (1)$$

Where,

Current Model total NVCOT is *CM*.

Next Model total NVCOT is *NM*.

Total NVCOT for Run-up is *RU*.

In this respect, $NVCOT \geq 0$.

The total of components removing steps and tooling removing steps is used in order to determine CM's NVCOT. The equation is written as

$$CM = (x_{tr}t_{tr}) + (x_{cr}t_{cr}) \qquad (2)$$

Where,

Tooling removed number is xtr

Time which is taken for tooling removed is ttr

Component removed number is xcr

The time which has been taken to remove is tcr

CM ≥ 0 in this regard.

Table 2 shows the conditions considered for *CM*'s NVCOT.

Table II

Conditions for NVCOT of CM

No.	Condition	Description
1	$x_{tr} = 0$	When the same tool is used
2	$x_{tr} = 1$	When a specific tool is used
3	$x_{tr} > 1$	When different tools are used
4	$x_{cr} = 0$	When the same component is used
5	$x_{cr} = 1$	When a specific component is used
6	$x_{cr} > 1$	When different components are used

Source: As per calculation by author

The total of setting step, tool fastening step and tooling contact steps are used to find out the NM's NVCOT. It can be written in step as in equation below.

$$NM = (x_{tc}t_{tc}) + (x_{tf}t_{tf}) + (x_{s}t_{s}) \qquad (3)$$

Where,
Tolling contacted number is xtc
Contact tooling time taken is ttc
Fastened tooling time taken is xtf
Tolling set number is xs
Tooling set time taken is ts
NM is greater than 0 in this regard

Table III shows the conditions considered for NM's NVCOT

Table III
Conditions for NVCOT of NM

No.	Condition	Description
1	$x_{tc} = 0$	When the same tool is used
2	$x_{tc} = 1$	When a specific tool is used
3	$x_{tc} > 1$	When different tools are used
4	$x_{tf} = 0$	When the same tool is used
5	$x_{tf} = 1$	When a specific tool is used
6	$x_{tf} > 1$	When different tools are used
7	$x_s = 0$	When running the same model
8	$x_s = 1$	When running the specific model
9	$x_s > 1$	When running the different model

Source: As per calculation by author

Finally, as written in Equation (4), the NVCOT for RU is evaluated by Trial & Adjustment method.

$$RU = x_t t_t \tag{4}$$

Trials and adjustments number is xt
Trial and adjustment time taken is tt
RU is greater or equal to zero in this regard

Table 4 shows the conditions considered for *RU*'s NVCOT

Table IV Conditions for NVCOT of RU

No.	Condition	Description
1	$x_t = 0$	When a trial product is run as the real product
2	$x_t \geq 1$	When a trial products is run as a sample product

Source: As per calculation by author

5. Validation Of Nvcot Equation

To validate the equations of the NVCOT is the objective of validation which are developed to determine the TL over changeover activities. Case studies are used to validate the equations of NVCOT. These case studies are from Malaysian based automotive companies named A, B, C, D and E. There are three major parts of the case studies:

D. Data Collection

Two types of data are collected in this case study; (i) Secondary Data and (ii) Primary

Data. The recorded historical changeover data is referred as the primary data of changeover time. When historical data is not available then the secondary data of changeover time is collected. The sources of data from the manufacturing companies is mentioned in table 5. In the current study, data of production input and changeover time are used to find out the frequency of changeover occurred in a day, week or month. If the company is involved in selling the products in trial. Adjustments, then the run up time will be zero.

Then the secondary data of changeover time is gathered. The sources of data from the manufacturing companies is mentioned in table 5. In the current study, data of production input and changeover time are used to find out the frequency of changeover occurred in a day, week or month. If the company is involved in selling the products in trial. Adjustments, then the run-up time will be zero.

Table V
Sources of data collection

Sources of Data	Company A		Company B	Company C	Company D		Company E	
	Head Lamp (HL)	Rear Combination Lamp (RL)	Intake Manifold (IM)	Door Latch (DL)	Front Corner (FC)	Fuel Tank (FT)	Right Hand Door Insert (RH)	Left Hand Door Insert (LH)
Production Input (Production schedule)	Primary Data	Primary Data	Primary Data	Primary Data	Primary Data (p)	Primary Data	Primary Data	Primary Data
Changeover Time (Changeover Time Record)	Primary Data	Primary Data	Primary Data	Secondary Data	Primary Data		Secondary Data	

Source: As per calculation by author

E. Data Analysis

To evaluate the value of NVCOT at every firm in the case study is the objective of data analysis. In the present study, Microsoft Excel was used to analyse the data.

i. Company A

Data analysis is conducted for only two products for company A: (i) Real Combination Lamp (RL) and (ii) Head Lamp (HL). In the present scenario, two types of Changeover Records the Changeover Time: (i) Model Change Time and (i) Jig Changing Time. The change time taken between left product and right product is referred as jig changing time. The time required to change different models is referred as Model Change. The data was collected from 2009 to 2013 (five years) on the monthly basis among two different shifts.

To determine the NVCOT monthly, the data was analysed by using Changeover Time Record Data. The representation of all the data is in minutes. The calculation of NVCOT of the Company A is presented in Example 1

Example 1:

Monthly basis Model Changing Time = 45 minutes
Monthly basis Jig Changing Time = 50 minutes
Hidden Loss of Product
Day shift

Thus,
Monthly NVCOT of January= Total Model Changing Time + Total Jig Changing Time
= 45+50
= 95 min. @ 1.58 hrs.

The similar technique has been used for NVCOT evaluation of certain month night shifts. The outcomes of NVCOT of Monthly basis for year 2009-2013 are shown in the graphs by doing plotting.

ii. Company B

The data analysis for company B is conducted only one product that is Intake Manifold (IM). There are three different series/ model (1.8, 2.4, and 2.0) and four different products (like W1, W2, W3 and w4) in company B. But the changeover happened among four groups in following scenarios (i) 1.8/2.0 to 1.8/2.0 (Same Model and Different product) (ii) 1.8/2.0 to 2.4 (Same Product, Different Model); (iii) 1.8/2.0 to 2.4 (Different Product, Different Model); and (iv) 2.4 to 1.8/2.0 (Different Product, Different Model). In this scenario, the time taken to change different models and products is referred as the changeover time. For analysis, three the production inputs of three consecutive months are used.

In order to determine the daily NVCOT, the average of changeover time is multiples with the frequency of daily changeover. In this situation, production input of every product is used to determine the changeover frequency. The sample calculation for company b of NVCOT is mentioned in Example 2.

Example 2:

Average Change-over Time = 1333.90 sec.
Change-over activity: From (Product W1, Model 1.8/2.0) to (Product W3, Model 2.0)
Change-over Freq. = 1 time

Therefore,
Change-over Category (i) = Average Change-over Time x Changeover Freq.
= 1,333.90 x 1
= 1,333.90 sec. @ 22.23 min. @ 0.37 hrs.

Whereas, Category of Change-over (ii), (iii), and (iv) = 0 sec. Therefore, the NVCOT of Daily basis is evaluated by having sum of all categories' change-over time, involving Run up time. In this situation, Run up time = zero.

Therefore,
Daily NVCOT = Category (i) Changeover + Category (ii) Changeover + Category (iii) Changeover + Category (iv) Changeover + Run up
= 1,333.90 + 0 + 0 + 0 + 0
= 1,333.90 sec. @ 22.23 min. @ 0.37 hrs.

The outcomes of NVCOT of Daily basis of month of Nov 2014, Dec 2014, and Jan 2015 are shown in the graph been plotted.

iii.Company C

Only one product is used for the data analysis of Company C that is Door Latch (DL). There are five different models and six products in company C as mentioned in Table 6. Whereas, there are only four categories in which changeover occurs as follows: (i) product changeover, (ii) Model changeover (iii) right and left changeover (iv) Front and rear changeover. Following are the situations in which the changeover occurred: (i) Front Left (FL) to Rear Right (RR), (ii) Rear Left to front Left (FL), (iii) Front Right (FR) to Rear Left (RL) and Rear Right (RR) to Front Right (FR). Moreover, there are four different parts in each lot: (i) FL, ii) RL, (iii) FR, (iv) RR As the sum in one lot there are around three hundred twenty parts. In this scenario, the time of changeover refers to time taken for changing among Right and Left, Front and Rear, different Products and Models. Movement of lots in the production is resented in figure 3 for more understanding.

Two lots related to production are the basis of production movement. For analysis, three the production inputs of three consecutive months are used

Table VI
List of product variety and model variety for Company C

Product	Product Variety	Model Variety
Door Latch (DL)	X1	S, S+, E, V, MA, PH
	X2	E, S, V, MA, SIN
	X3	S, V, V+, MA, KQ
	X4	1.8, 2.0, 2.0 Navi
	X5	2.0 (2WD), 2.0 (4WD), 2.4 (4WD)
	X6	2.0 VTI, 2.0 VTIL, 2.4 VTIL

Source: As per calculation by author

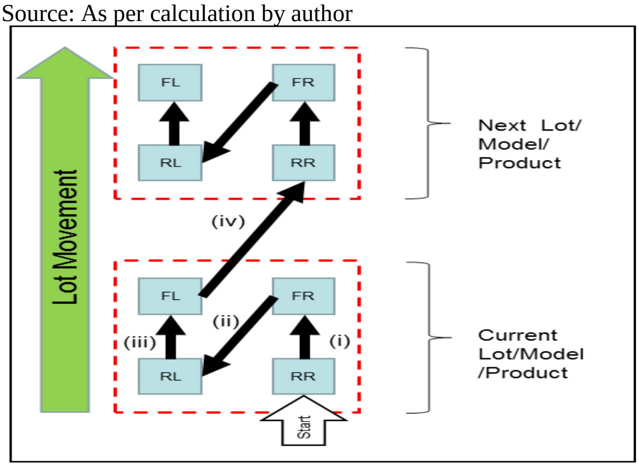

Figure. 3 Lot movement in production

Notes:

1. Rear Right is referred as RR
2. Front Right is referred as FR
3. Rear Left is referred as RL
4. Front Left is referred as FL
5. Changeover situations are referred as (i), (ii), (iii) and (iv).

The average changeover time is multiplied by daily changeover time in order to determine the Daily NVCOT. Production inputs related to each product is used to determine the changeover frequency in this case. Calculation of NVCOT is presented for Company C in Example 3.

Example 3:
Total lot size: 11 lots

Therefore,
Changeover Frequency for Changeover situation (i) = 11 times
Changeover Frequency for Changeover situation (ii) = 11 times
Changeover Frequency for Changeover situation (iii) = 11 times

While,
Changeover Frequency for Changeover situation (iv) = 10 Times

Therefore,
Changeover situation (i) = Average Changeover Time x Changeover Frequency
= 53.14 x 11
= 584.54 seconds @ 9.74 minutes

Changeover situation (ii) = Average Changeover Time x Changeover Frequency
= 71.83 x 11
= 790.13 seconds @ 13.17 minutes

Changeover situation (iii) = Average Changeover Time x Changeover Frequency
= 57.18 x 11
= 628.98 seconds @ 10.48 minutes
Changeover situation (iv) = Average Changeover Time x Changeover Frequency
= 77.31 x 10
= 773.10 seconds @ 12.89 minutes

The same way, the changeover among two products that are different like Product X6 and Product X1 is considered as change of product and referred as product changeover. Once in a day it occurred only. So, for the model changeover, frequency of changeover is equal to one. For example:

Changeover Category (iii) = Changeover Freq. x Average Changeover Time
= 1 x 87.32
= 87.32 sec. @ 1.46 min.

The same way, the changeover among two products that are different like Product X6 and Product X1 is considered as change of product and referred as product changeover. Once in a day it occurred only. So, for the model changeover, frequency of changeover is equal to one. For example:

Changeover Category (IV) = Changeover Freq. x Average Changeover Time
= 1 x 85.80
= 85.80 sec. @ 1.43 min.

So, in order to determine the Daily NVCOT summation of situations of Changeover including run-up time and changeover time from whole categories is included. Run-Up time is equal to zero in this case.

Thus,
Daily NVCOT = Situation (i) Changeover + Situation (ii) Changeover + Situation (iii) Changeover + Situation (iv) Changeover + Category (iii) Changeover + Category (iv) Changeover + Run-up
= 584.54 + 790.13 + 628.98 + 773.10 + 87.32 + 85.80 + 0
= 2,949.87 seconds @ 49.16 minutes @ 0.82 hours

iv. Company D

Two products are used for data analysis for Company D; (a) Fuel tank (FT) (a) front Corner (FC). For FC there are two products in Company D (such as Y1 and Y2), and for FT there are two products (like Y3 and Y4). So in this case, time taken in order to change different products is referred as changeover time. Inputs of consecutive three months such as November 2014, December 2014 and January 2015 are used for data analysis.
To determine Daily NVCOT, run-up time including daily changeover frequency is multiplied by average changeover time. In order to determine the changeover frequency through production input related to each product and Run-up time equals to zero. The calculation of NVCOT for Company D is presented in Example 4.

Example 4:
Product FC
Changeover activity: From Product Y1 to Product Y2
Average Changeover Time = 10.20 minutes
Changeover Frequency = 1 time

Therefore,
Daily NVCOT = (Average Changeover Time x Changeover Frequency) + Run-up
= (10.20 x 1) + 0
= 10.20 minutes @ 0.17 hours

Source: As per calculation by author

The similar technique is used for FT to evaluate the Non-Valued Change-Over Time for a particular day.

v. Company E

Two different types of products are selected for the data analysis of Company E; (i) Left handle door Inside (LH), and Right handle door inside (RH). There are two models i.e. CHROME and POM for LH and RH in Company E. The time taken for different models, front and rear is referred as time required for changeover in this case. Inputs of consecutive three months such as November 2014, December 2014 and January 2015 are used for data analysis.
The Daily basis Non-Valued Change-Over Time is evaluated by multiplying Run-Up time including changeover frequency with Average Changeover Time. Changeover frequency can be determined by using the Run up time equal to zero and production input of each product. Calculation of NVCOT for Company E as sample is presented in Example 5.
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Example 5:
Product HL
Changeover Activity:
(i) From Model POM to Model Chrome
(ii) From Rear Right to Front Right
Average Changeover Time for Model Change = 52.68 seconds
Average Changeover Time for Rear to Front Change = 5.39 seconds
Changeover Frequency for Model Change = 1 time
Changeover Frequency for Rear Right to Front Right Changeover = 2 times

Therefore,
(i) Changeover Activity (i) = Average Changeover Time x Changeover Frequency
= 52.68 x 1
= 52.68 seconds

(ii) Changeover Activity (ii) = Average Changeover Time x Changeover Frequency
= 5.39 x 1
= 5.39 seconds

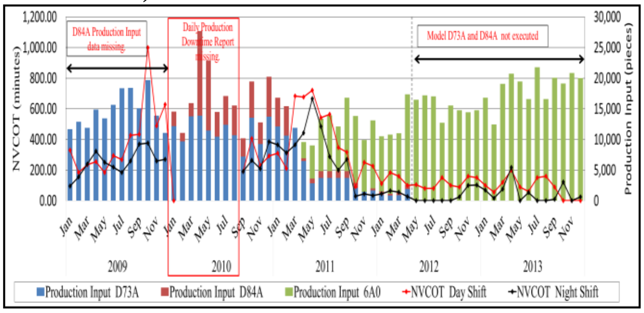
Thus, the Daily NVCOT can be determined by the summation of changeover time from all activities including Run-up time. In this case Run-up time equals to zero.

Therefore,
Daily NVCOT = Changeover Activity (i) + Changeover Activity (ii) + Run-up
= 52.68 + 5.39 + 0
= 63.46 seconds @ 1.06 minutes @ 0.02 hours

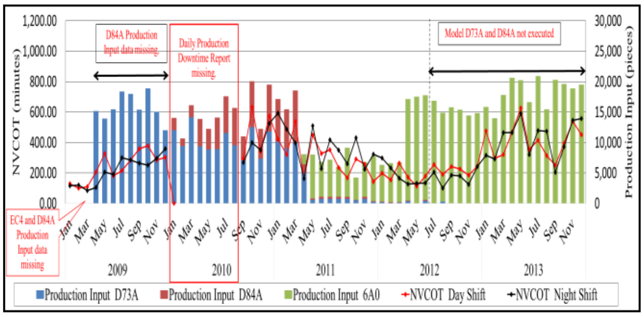
The same method is used for LH to determine the NVCOT for a particular day.

Source: As per calculation by author

C. Results and Discussion
Plotted graphs are used to represent the results of Non value change over time for every company on the basis of period of time related to each company.
i. Company A
The results of NVCOT for product Head Lamp (HL) is presented in figure 4 (a). Whereas, the results related of NVCOT for product Real Combination Lamp (CL) are presented in figure 4 (b). These values are from 2009 to 2013 showing the showing the production input results versus NVCOT related to different shifts (Night shift and Day Shift). There are three different models in this case namely 6A0, D84A and D7A. Time Records are missing. There was no production for D8A and D73A for RL and HL from the beginning of May 2012. Whereas, there was production of RL in months like June and August 2012 for the models D84A and D73 A.
It's evident from both figures that as the frequencies are changed in the model, NVCOT is increased for both products RL and HL. Kemal Karasu *et al.* [25] supported these results. He revealed that, average setup time and setup frequencies must be focused for the reduction of setup time. Higher NVCOT results are presented by RL in this case as compared to HL. As mentioned in table 7, RL has less workstation as those of HL, but there is no complicated setup process. Moreover, as mentioned in table 6, for RL the setup process is more complicated to produce Hot plate welding. It is because a stable and suitable temperature should be reached before beginning the process of welding. Hence, complex setup time and frequency do not affect the NVCOT. As observed by Johnson [26], setup time reduction can be improved by the reduction of time per setup or setups. Furthermore, Singh and Khanduja [27] mentioned that in order to improve the setup reduction of time, there should be externalisation of online activities and avoiding the activities that add non- value).



(a) HL



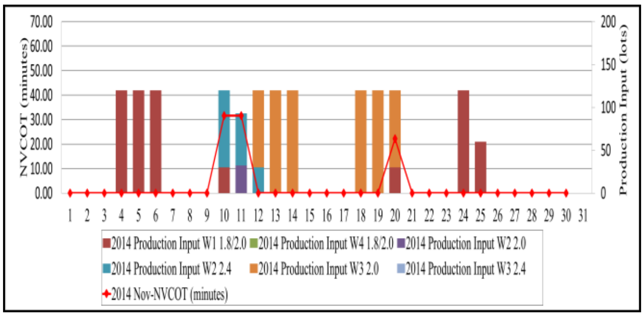
(b) RL

Figure 4 Monthly Non-valued Changeover Time (NVCOT) for Company A (2009 ~ 2013)

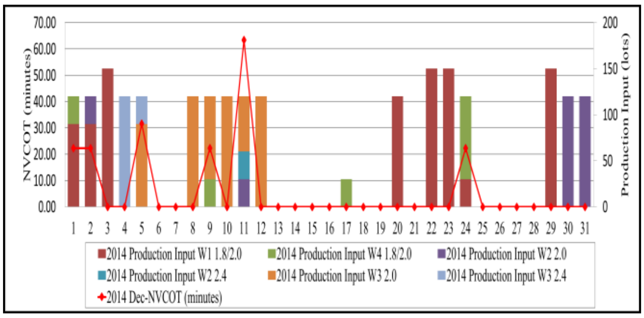
Table V11
Main process for company A (Based on workstation)

Workstation	Head Lamp (HL)	Rear Combination Lamp (RL)
1	Final Inspection.	Lighting Test.
2	(a) Screwing Pivot (b) Adjustable Screw (c) Lighting Machine	(a) Screwing LED Assembly (b) Leak Test
3	(a) Cover and Bulb Setting (b) Leak Test	(a) Cooling Conveyor (b) Auto Bulb Insert (c) Pin A and Pin B Setting
4	(a) Lens Pressing and Screwing (b) Cover and Socket Assembly Setting (c) Auto Bulb Insert	(a) Air Blower **(b) Hot Plate Welding** (c) Annealing Oven
5	(a) Projector Assembly (b) Pivot Setting (c) Reflector B Setting (d) Air Blow (e) Hot Melt	
6	(a) Setting Lens A& B to Extension (b) Setting Lens C to Extension	
7	(a) Air Blow (b) Setting extension to lens	

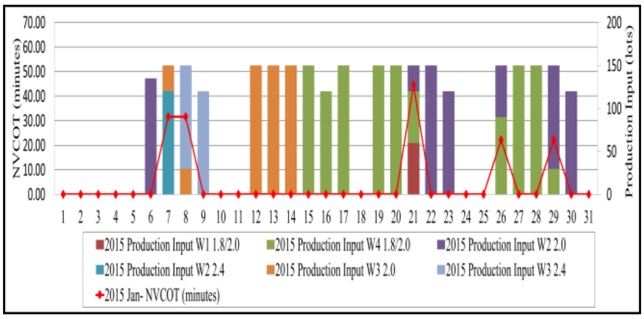
ii. Company B
The results of NVCOT for product Intake Manifold is presented in Figure 5 (a) for November 2014 whereas, the results of NVCOT for month December 2014 for IM product are presented in figure 5 (b) and the results for January 2015 for IM product are presented in figure 5 (c). The results of production inputs VS NVCOT are shown in all of the figures. There are three different models such as 2.4, 2.0 and 1.8; and four different models like W1, W2, W3 and W4 in this case



(a) Nov 2014



(b) Dec 2014



(c) Jan 2015

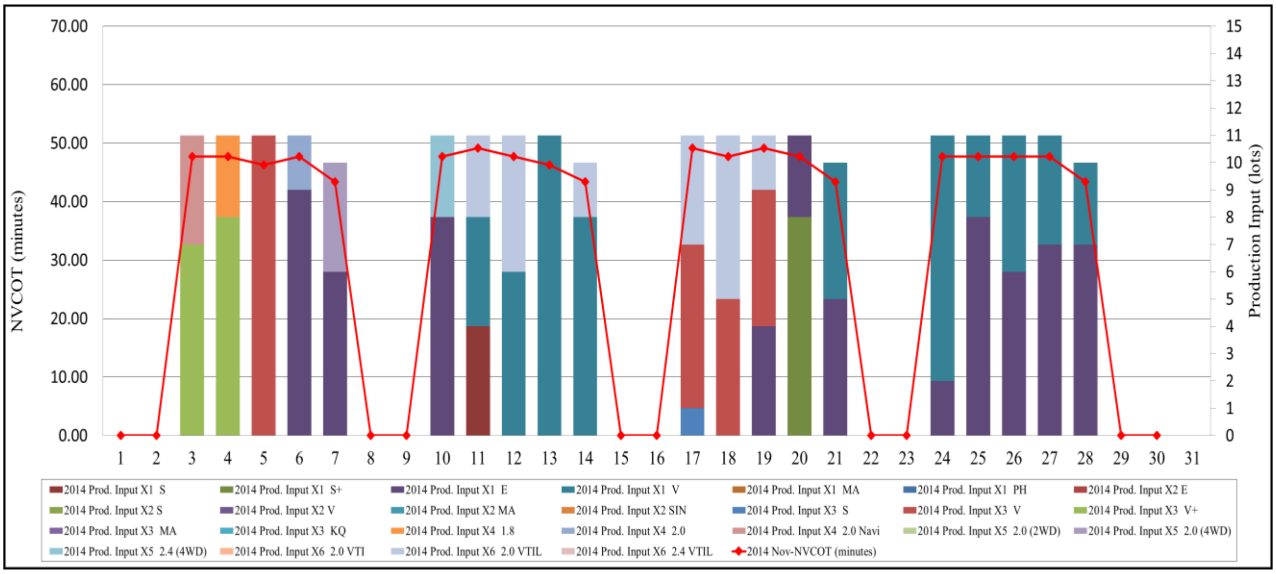
Fig. 5 Daily Non-valued Changeover Time (NVCOT) for Company B

As the results of Company A illustrated that, the model change and the frequency of the product change has the impact on the results of NVCOT. A mentioned in figures 5 (a), (b) and (c), there is consistency among the results of NVCOT with model change and product change.

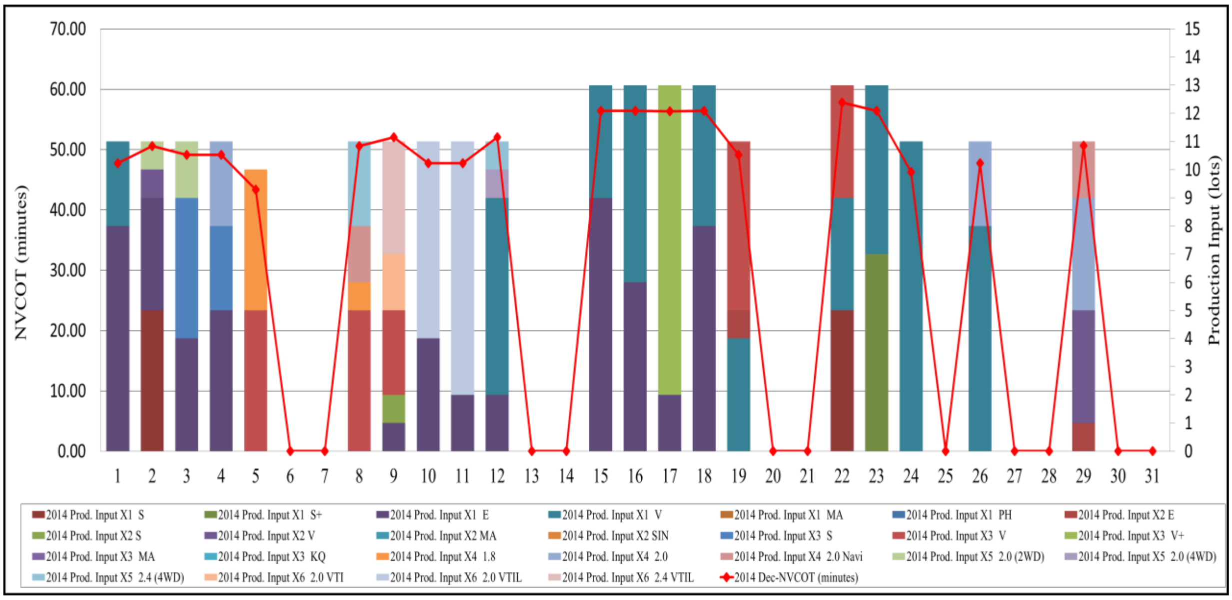
iii.Company C

The results of NVCOT related to product Door Latch for November 2014 are shown in figure Fig. 6 (a). Whereas, the results of same product for December 2014 are presented in Fig. 6 (b) and the results for the January 2015 are presented in Fig. 6 (c). Figures demonstrate the results of inputs VS NVCOT. There are twenty five models and six products such as X1, X2, X3, X4, X5 and X6 in this case as mentioned in table 5.

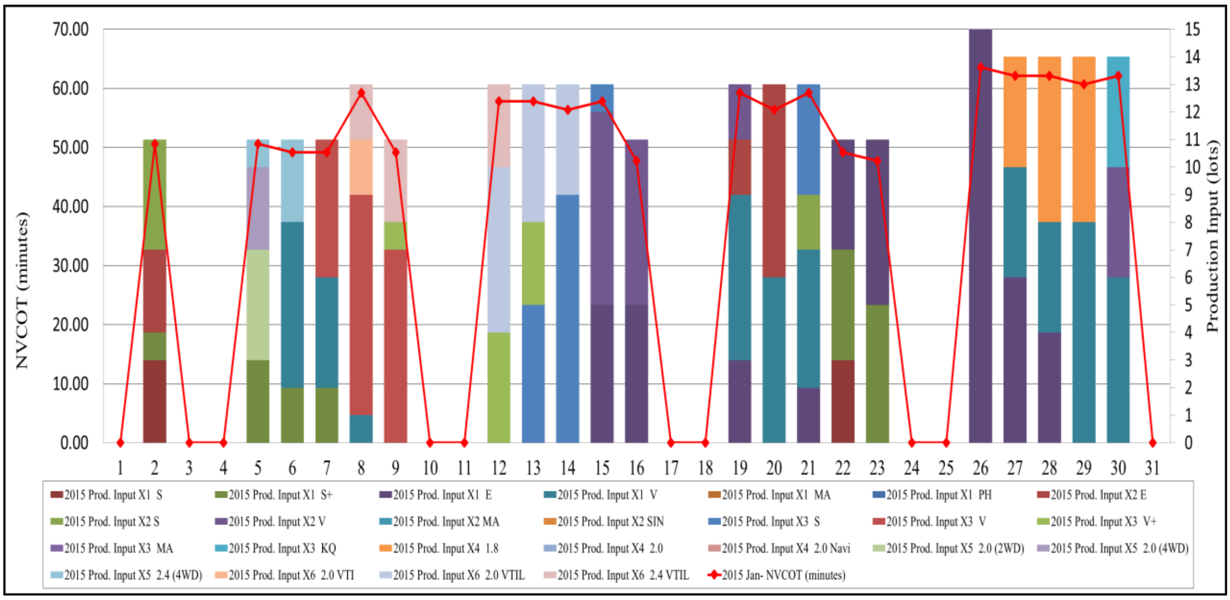
Similar to the results of Company A, frequency of the front and rear change, left and right change, model change and product change affect the results of NVCOT. As mentioned in Figures 6 (a), (b) and (c), there is consistency among the frequency of front and Rear change, Left and right change, Model change and product change with the results of NVCOT.



(a) Nov 2014



(b) Dec 2014

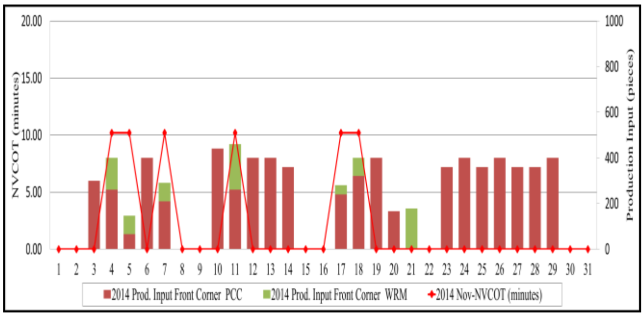


(c) Jan 2015

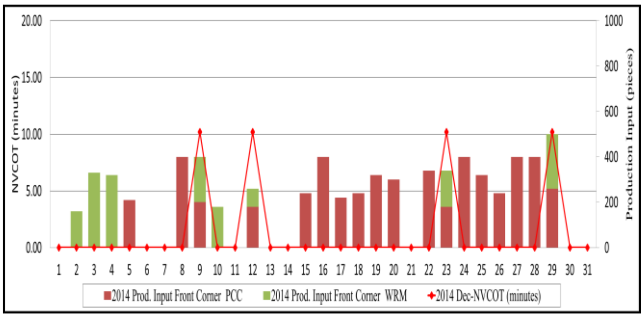
Fig. 6 Daily Non-valued Changeover Time (NVCOT) for Company C

iv. Company D

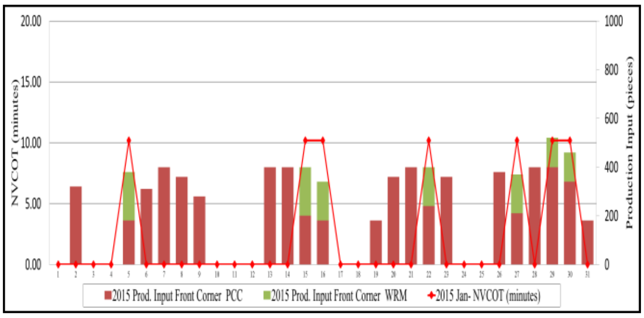
The results of NVCOT for the product Front Corner (FC) for November 2014 are presented in figure 7 (a), the results of NVCOT for the product Front Corner (FC) for December 2014 are presented in figure 7 (b) and the results of NVCOT for the product Front Corner (FC) for January 2015 are presented in figure 7 (C). on the other hand, the results of NVCOT for the product Fuel Tank (FT) for November 2014 are presented in figure 8 (a), the results of NVCOT for the product Fuel Tank (FT) for December 2014 are presented in figure 8 (b), the results of NVCOT for the product Fuel Tank (FT) for January 2015 are presented in figure 8 (c). The results of production inputs VS NVCOT are shown in all of the figures. There are two products varieties such as Y3 and Y4 for FT and two products for FC such as Y1 and Y2



(a) Nov 2014

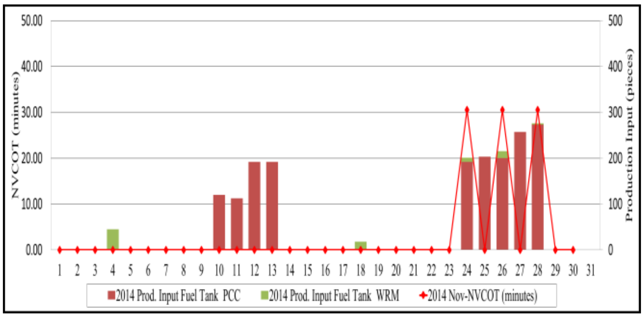


(b) Dec 2014

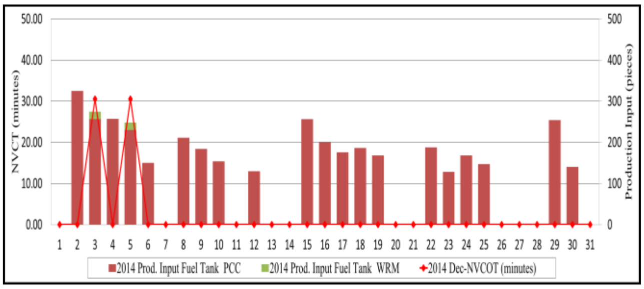


(c) Jan 2015

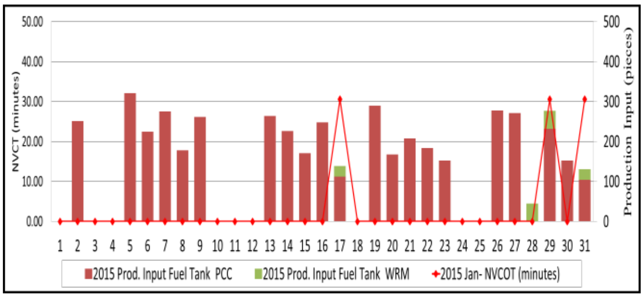
Fig. 7 Daily Non-valued Changeover Time (NVCOT) for Company D – FC



(a) Nov 2014



(b) Dec 2014



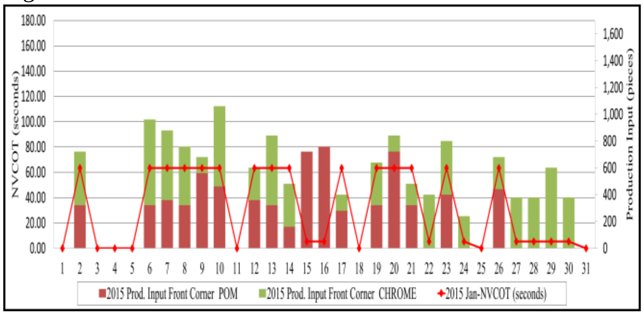
(c) Jan 2015

Fig. 8 Daily Non-valued Changeover Time (NVCOT) for Company D – FT

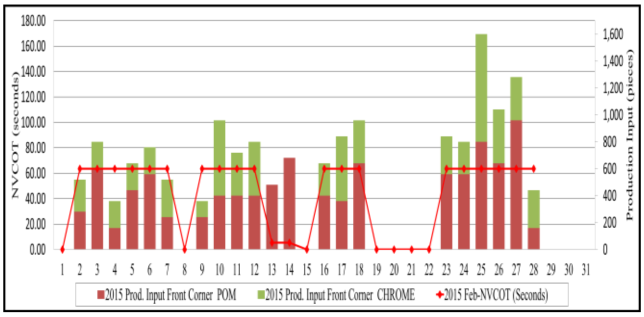
Similar to the results of Company A, the frequency of product change has the impact on the results of NVCOT. There is consistency among the frequency of products and results of NVCOT as shown in figure 7 (a), (b) and (c) and figures 8 (a), (b) and (c).

v. Company E

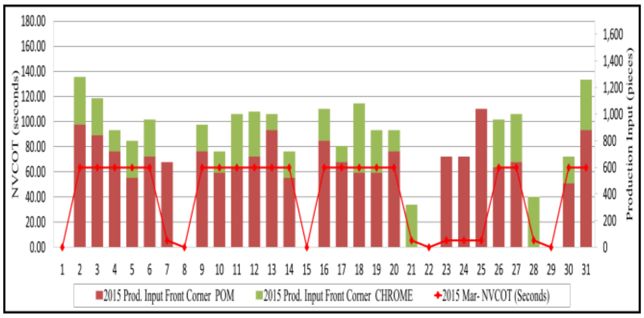
The results of Non-valued Change-over Time are shown in Figure. 9 (a) for the Right Handle Door inside product (RH) in January 2015, Figure. 9 (b) shows the outcomes of Non-valued Change-over Time for Right Handle products in February 2015, and Figure. 9 (c) illustrates the results of Non-valued Change-over Time for Right Handle products in March 2015. Figure. 10 (a) demonstrates the outcomes of Non-valued Change-over Time for Left Handle Door inside (LH) product in January 2015, Figure. 10 (b) shows the results of Non-valued Change-over Time for Left Handle Door inside product in February 2015, while the results of Non-valued Change-over Time for Left Handle Door inside product in March 2015 are shown in Figure 10 (c). All the figures present the results of the inputs of Production (Pieces) against Non-valued Change-over Time (seconds). In this situation, there are two models ranges (i.e. production input POM, and production input CHROME) for Right Handle and Left Handle.



(a) Jan 2015

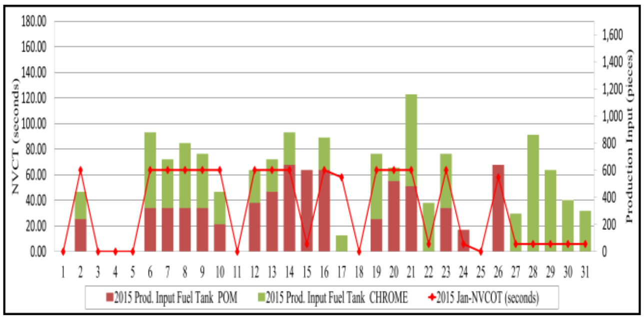


(b) Feb 2015

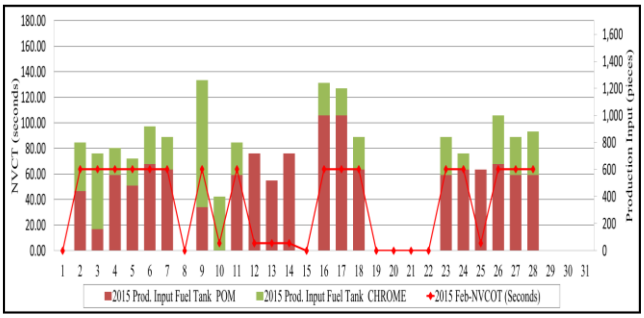


(c) Mar 2015

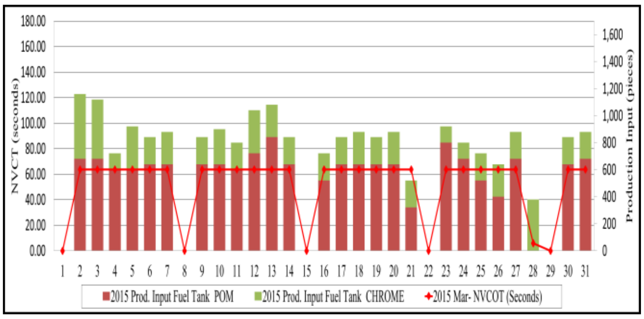
Fig. 9 Daily Non-valued Changeover Time (NVCOT) for Company E – RH



(a) Jan 2015



(b) Feb 2015



(c) Mar 2015

Fig. 10 Daily Non-valued Changeover Time (NVCOT) for Company E – LH

Similar to the results of Company A, the frequency of Front and Rear Change and product change effect the results of NVCOT. The results of Rear change and product change are consistent with the results of NVCOT as mentioned in figure 9 (a), (b) and (C) and figure 10 (a), (b) and (C).

Thus, the results conclude that there is influence of factors on NVCOT as shown in table 8

Table V11

Main process for company A (Based on workstation)

Workstation	Head Lamp (HL)	Rear Combination Lamp (RL)
1	Final Inspection.	Lighting Test.
2	(a) Screwing Pivot (b) Adjustable Screw (c) Lighting Machine	(a) Screwing LED Assembly (b) Leak Test
3	(a) Cover and Bulb Setting (b) Leak Test	(a) Cooling Conveyor (b) Auto Bulb Insert (c) Pin A and Pin B Setting
4	(a) Lens Pressing and Screwing (b) Cover and Socket Assembly Setting (c) Auto Bulb Insert	(a) Air Blower **(b) Hot Plate Welding** (c) Annealing Oven
5	(a) Projector Assembly (b) Pivot Setting (c) Reflector B Setting (d) Air Blow (e) Hot Melt	
6	(a) Setting Lens A& B to Extension (b) Setting Lens C to Extension	
7	(a) Air Blow (b) Setting extension to lens	

Notes:

1. Head Lamp is referred as HL
2. Rear Combination Lamp is referred as RL
3. Intake Manifold is referred as IM
4. Door Latch is referred as DL
5. Front Corner is referred as FC
6. Fuel Tank is referred as FT
7. Right hand handle door inside is referred as RH
8. Left hand handle door inside is referred as LH

6. Conclusion

The present research paper has presented the NVCOT (non-valued change-over time) structure as well the NVCOT equations that are used to evaluate the Time Loss. In this respect, the three key components that are explained related to NVCOT are, Current Model (CM), Next Model (NM) and Run-up (RU).

The case study of 5 manufacturing firms of automotive industry has helped to prove the equations of NVCOT. The Time Loss occurred due to non-valued change-over time activities in the case of manual and semi-auto assembly in automotive production is commonly affected by four basic factors; (i) Front and Rear, (ii) Right and Left, (iii) Model Variety, and (iv) Product Variety

Hence, this paper concludes that NVCOT (non-valued change-over time) is one of the factor of Time Loss in manual and semi-auto assembly procedures.

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