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Research Article

Productivity Improvement in Cable Assembly Line by MOST Technique

Giriraj Bondhare*, Amit Pawar and Gaurav Deshpande

Department of Industrial Engineering, Vishwakarma Institute of Technology, Pune, India

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Abstract

This paper highlights a methodology developed for standardization in the process activities in wiring harness industry by using Maynard's Operation Sequence Technique. (MOST) Due to high uncertainty in demand, most accurate forecasting is difficult. It is very difficult to meet the demand with existing supply especially in labor intensive operations. Also, due to non-standard operation time, the throughput was less and resource utilization is more. In such cases, industrial engineering (IE) techniques is used for solving the existing manufacturing situation and identifying the potential for increased productivity. MOST (Maynard Operation Sequence Technique) is a good application of work measurement technique that allows better productivity and Resource Optimization. The objective of MOST technique is to reduce the work content and thereby improve the productivity of the process. There is also scope for the improvement in minimizing the Non value Added Activities (NVA) and workplace layout redesign.

Keywords: *Maynard's Operation Sequence Technique (MOST), Work measurement, Work Content, Non value Added Activities (NVA), Workplace layout.*

1. Introduction

This paper project work is carried on the wiring harnesses manufacturing company in India. The production system of this company having project wise special assembly line. The company is mainly in the assembly of wiring cables such as HVAC, Steering wheel supplied to the original equipment manufacturers (OEM's).

Work measurement is the process of the analysis of the work and determination of the time required for the certain process. And mainly based on highly manual task. Work measurement is the predictive type of work measurement. The introduction of the Methods Time Measurement (MTM) system in the 1940s was an important step towards the predictive work measurement. Which is defined as `a procedure which analyses any manual operation to perform it. MTM assigns to each motion a predetermined time standard which is determined by the nature of the motion.

One of the major problems in applying MTM to manufacturing operations is that it is time consuming, since an observer must observe and document each movement in great detail. The development and release of the MOST in the 1960s which is much simpler and more efficient. It classifies all human movements into three basic categories, and the description of each category is done by assigning values to only a few standard parameters.

*Corresponding author: **Giriraj Bondhare**

2. Literature Review

Maynard Operation Sequence Technique (MOST) developed by Kjell Zandin and H. B. Maynard and Company, Inc. in 1974. MOST is based on MTM. The movement of objects follows consistently repeating patterns and the repeated patterns in the sequence of MTM have been consolidated. MOST times represent ranges of motions and do not required precise measurement. MOST gives very accurate results because ranges are statistically derived.

Basic MOST

MOST Work Measurement Systems has defined work in terms of operation, sub operation, time standard, activity, method step, sequence model, sub activity and MOST analysis. The concept of MOST and the basic MOST sequence models has three versions Basic MOST for the activities between 20 sec to 2 min and are clearly discussed by focusing on MOST as a productivity improvement technique. Mini MOST for the activities shorter than 20 sec. The Maxi MOST system is for the activities above 2min. It helps an Industrial Engineer as a tool to measure, and control manufacturing methods and cost. MOST focuses on three types of object movements Such as General Move, Control Move, and Tool Use.

Time Measurement Unit used in MOST

The time measurement unit (TMU) is used as a time unit for MOST study.
1 T.M.U = 0.036 sec
= 0.0006 min
= 0.00001hr.

Table 1 Basic MOST Sequence Model

Basic MOST		
Activity	Sequence Model	Sub-Activities
GENRAL MOVE	ABG-ABP-A (GET-PUT-RETURN)	A=ACTION DISTANCE
		B=BODY MOTION
		G=GAIN CONTROL
		P=PLACEMENT
CONTROLLED MOVE	ABG-MXI-A (GET-MOVE-RETURN)	M=MOVE CONTROL
		X=PROCESS TIME
		I=ALIGNMENT
TOOL USE	ABG-ABP_ABP-A (GET TOOL-PLACE TOOL-TOOL ACTION-PLACE TOOL-RETURN)	F=FASTEN
		L=LOOSE
		C=CUT
		S=SURFACE TREAT
		M=MEASURE
		R=RECORD
		T=THINK

3. Methodology

This paper project work is carried on the Wire cable manufacturing company in India. Paper work is mainly focus on NVA Identification & Elimination and Resource Optimization. And space and resource optimization using MOST. This work carried out following steps.

3.1 Initial line study

Initial study includes the detailed activity mapping and process details of all operation, activities and sub activities.

Table 2 Workstation Wise existing Manpower

Sr. No.	Workstation Description	Operations	Manpower /Day
1	1st sub assembly (PTC)	PTC Sub	1
2	2nd sub assembly	2nd sub assembly	1
3	Sub assembly completion	2nd sub completion	8
4	Assembly(Taping)	Taping Assembly on board	

Findings from the study

a) Underutilization of capacity.
b) Presence of the NVA activates
c) Elimination of Bottleneck activity.
d) Imbalance of work content.
e) Improper utilization of resources

3.2 Work Measurement using MOST

Following Product break up must be carried out while doing the work measurement using MOST. And direct observation method is adopted while doing line balancing. Procedure for the work measurement using MOST follows the following sequence. (See Fig 2).

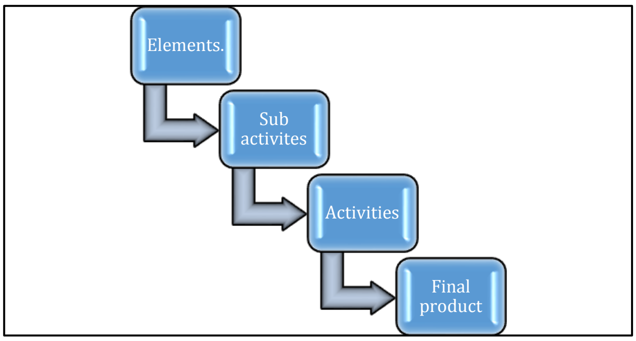

Fig. 1 Work Measurement Procedure

Using MOST, cycle time (CT) and work content (CW) of each operation are calculated. Complete sequence of operations and actual time by using MOST technique is studied. The concept of the cycle time (CT) and work content (CW) is well understand by following explanation.

Cycle time represents the total time required for final finish product formation and Content of work represents the amount of the manual work present in to a job. In our case Content of Work is equal to the Cycle Time. Cycle time helps in calculating the capacity of a production line and The Content of the Work helps to calculate the manpower required for the certain task. Most important concept in the line balancing sheet is engagement .Which easily understood by following explanation

Engagement=Work Content/Unit X Quantity Produced) / (No of Operators Deployed) engagement is a dynamic measure and will vary on daily basis as per the conditions. In our case engagement is as compared to 420 min.

Table 3 Cycle time and Manpower (before)

Sr. No.	Operations	Cycle Time (Sec)	Manpower/Day
1	PTC Sub	16.92	1
2	2nd sub assembly	23.40	1
3	2nd sub completion	25.26	8
4	Taping Assembly on board	105.45	

3.3 NVA Identification & Elimination and Resource Optimization

After detailed MOST Study next task is analysis of the VA/NVA in process & NVA activities are focused to eliminate or reduce.

Table 4 Balancing sheet with NVA Study (Before)

SR No.	Activity	Element	VA/NVA	TOTAL
1	**1st sub assly (PTC)**	PICKUP THE HSG AND INSERTION OF LEAD	VA	**16.92**
		PICKUP LEAD AND INSERT INTO THE HSG	VA	
		Gain control over other end of the lead	VA	
		PICKUP THE HSG AND INSERTION OF LEAD	VA	
		PICKUP LEAD AND INSERT INTO THE HSG	VA	
		HSG locking	VA	
		PUT THE SUB ON TABLE	VA	
		Tie the sub-assembly	NVA	
		move 1-2 steps to put the bunch to next W S	NVA	
2	**2nd sub assly**	Untie the bunch	NVA	**23.40**
		PICKUP THE HSG AND INSERTION OF LEAD	VA	
		PICKUP LEAD AND INSERT INTO THE HSG	VA	
		HSG locking	VA	
		PUT THE SUB ON TABLE	VA	
		Tie the sub-assembly	NVA	
		move 3-4 steps to put the bunch to next W S	NVA	
3	**Sub assembly completion**	Untie the bunch	NVA	**25.6**
		1-2 steps for sub-assemly	NVA	
		PICKUP THE HSG AND INSERTION OF LEAD	VA	
		PICKUP LEAD AND INSERT INTO THE HSG	VA	
		HSG locking	VA	
		PUT ASIDE THE ASSY ON HANGER	VA	
		PICKUP THE HSG AND INSERTION OF LEAD	VA	
		PICKUP LEAD AND INSERT INTO THE HSG	VA	
		HSG locking	VA	
		Move 1-2 steps towards Assembly	NVA	
4	**On Board Assembly**	PLACEMENT OF SUB ASSLY/ SINGLE SPLICE ON BOARD (WITHIN REACH)	VA	**105.45**
		ROUTE & INSERT A SINGLE LEAD ON BOARD IN TO HSG	VA	
		PLACEMENT OF SUB ASSLY/ SINGLE SPLICE ON BOARD (WITHIN REACH)	VA	
		COLLECT THE TAPE REEL & PLACEMENT ON POSITION (WITHIN REACH)	VA	
		APPLICATION TAPE ON THE LEAD AS PER LENGTH	VA	
		CUT THE TAPE & HOLD IN HAND	VA	
		PLACEMENT ON POSITION (WITHIN REACH)	VA	
		APPLICATION TAPE ON THE LEAD AS PER LENGTH	VA	
		CUT THE TAPE & HOLD IN HAND	VA	
		PLACEMENT ON POSITION (WITHIN REACH)	VA	
		APPLICATION TAPE ON THE LEAD AS PER LENGTH	VA	
		APPLICATION TAPE ON THE LEAD AS PER LENGTH	VA	
		CUT THE TAPE & HOLD IN HAND	VA	
		PLACEMENT ON POSITION (WITHIN REACH)	VA	
		APPLICATION TAPE ON THE LEAD AS PER LENGTH	VA	
		APPLICATION TAPE ON THE LEAD AS PER LENGTH	VA	
		CUT THE TAPE & HOLD IN HAND	VA	
		PLACEMENT ON POSITION (WITHIN REACH)	VA	
		APPLICATION TAPE ON THE LEAD AS PER LENGTH	VA	
		APPLICATION TAPE ON THE LEAD AS PER LENGTH	VA	
		CUT THE TAPE & HOLD IN HAND	VA	
		PLACEMENT ON POSITION (WITHIN REACH)	VA	
		APPLICATION TAPE ON THE LEAD AS PER LENGTH	VA	
		CUT THE TAPE & HOLD IN HAND	VA	
		move 3-4 steps to put the Assembly	NVA	

Table 5 Line balancing scenario using MOST (Before)

Activity	Total time	Current MP/Shift	Current Engagement/shift (Min)
1st sub assembly (PTC)	16.9	1	212
2nd sub assembly	23.4	1	293
Sub assembly completion	25.6	8	205
On board assembly	105.5		
TOTAL	171	7	236.7

Table 6 Balancing by MOST Study (After)

Sr. no.	Workstation	Sub-operations	ELEMENT	CT (SEC)	CW (SEC)	FREQ	TCT (SEC)	TCW (SEC)	VA/NVA	Proposed Prod./ Shift (NOS)	Proposed MP./ Shift (NOS)	Proposed Engagement/ Shift (Min)
1	1st sub assembly (PTC)	pick up the 2P HSG in LH and Lead in RH, insert	PICKUP THE HSG AND INSERTION OF LEAD	3.24	3.24	1	3.24	3.24	VA	**900**	**1**	**221**
		pick up the lead and insert	PICKUP LEAD AND INSERT INTO THE HSG	2.52	2.52	1	2.52	2.52	VA			
		move to the other side of splice	Gain control over other end of the lead	1.08	1.08	1	1.08	1.08	VA			
		pick up the 2P HSG in LH and Lead in RH, insert	PICKUP THE HSG AND INSERTION OF LEAD	3.24	3.24	1	3.24	3.24	VA			
		pick up the lead and insert	PICKUP LEAD AND INSERT INTO THE HSG	2.52	2.52	1	2.52	2.52	VA			
		lock the HSG	HSG locking	1.44	1.44	1	1.44	1.44	VA			
		kept aside	PUT THE SUB ON TABLE	0.72	0.72	1	0.72	0.72	VA			
2	2nd sub assembly	pick up the 10P HSG in LH and Lead in RH, insert	PICKUP THE HSG AND INSERTION OF LEAD	3.24	3.24	1	3.24	3.24	VA	**900**	**1**	**292**
		pick up the lead and insert	PICKUP LEAD AND INSERT INTO THE HSG	2.52	2.52	5	12.6	12.6	VA			
		lock the HSG	HSG locking	1.44	1.44	2	2.88	2.88	VA			
		kept aside	PUT THE SUB ON TABLE	0.72	0.72	1	0.72	0.72	VA			
3	Sub assembly completion on board	pick up the 10P HSG in LH and Lead in RH, insert	PICKUP THE HSG AND INSERTION OF LEAD	3.24	3.24	1	3.24	3.24	VA	**900**	**1**	**340**
		pick up the lead and insert	PICKUP LEAD AND INSERT INTO THE HSG	2.52	2.52	3	7.56	7.56	VA			
		lock the HSG	HSG locking	1.44	1.44	1	1.44	1.44	VA			
		kept aside	PUT ASIDE THE ASSY ON HANGER	0.72	0.72	1	0.72	0.72	VA			
		pick up the 10P HSG in LH and Lead in RH, insert	PICKUP THE HSG AND INSERTION OF LEAD	3.24	3.24	1	3.24	3.24	VA			
		pick up the lead and insert	PICKUP LEAD AND INSERT INTO THE HSG	2.52	2.52	2	5.04	5.04	VA			
		lock the HSG	HSG locking	1.44	1.44	1	1.44	1.44	VA			
4	On Board Assembly	Laying the sub on assly board	PLACEMENT OF SUB ASSLY/ SINGLE SPLICE ON BOARD (WITHIN REACH)	2.88	2.88	1	2.88	2.88	VA	**900**	**4**	**387**
		Route and insert the other sub in to HSG	ROUTE & INSERT A SINGLE LEAD ON BOARD IN TO HSG	3.6	6.6	1	3.60	6.60	VA			
		Laying the splice on assly board	PLACEMENT OF SUB ASSLY/ SINGLE SPLICE ON BOARD (WITHIN REACH)	2.88	2.88	2	5.76	5.76	VA			
		vertical 9mm tape full taping (40mm)	COLLECT THE TAPE REEL & PLACEMENT ON POSITION (WITHIN REACH)	6.48	6.48	1	6.48	6.48	VA			
			APPLICATION TAPE ON THE LEAD AS PER LENGTH	1.08	1.08	3	3.09	3.09	VA			
			CUT THE TAPE & HOLD IN HAND	0.72	0.72	1	0.72	0.72	VA			
		vertical 9mm tape full taping (10mm)	PLACEMENT ON POSITION (WITHIN REACH)	5.4	5.4	1	5.40	5.40	VA			
			APPLICATION TAPE ON THE LEAD AS PER LENGTH	1.08	1.08	1	1.20	1.20	VA			
			CUT THE TAPE & HOLD IN HAND	0.72	0.72	1	0.72	0.72	VA			
		9mm tape Spiral taping (310mm)	PLACEMENT ON POSITION (WITHIN REACH)	5.4	5.4	1	5.40	5.40	VA			
			APPLICATION TAPE ON THE LEAD AS PER LENGTH	1.08	1.08	15	####	####	VA			
		branch taping	APPLICATION TAPE ON THE LEAD AS PER LENGTH	1.08	1.08	4	4.32	4.32	VA			
			CUT THE TAPE & HOLD IN HAND	0.72	0.72	1	0.72	0.72	VA			
		9mm tape Spiral taping (70mm)	PLACEMENT ON POSITION (WITHIN REACH)	5.4	5.4	1	5.40	5.40	VA			
			APPLICATION TAPE ON THE LEAD AS PER LENGTH	1.08	1.08	3	3.60	3.60	VA			
		branch taping	APPLICATION TAPE ON THE LEAD AS PER LENGTH	1.08	1.08	4	4.32	4.32	VA			
			CUT THE TAPE & HOLD IN HAND	0.72	0.72	1	0.72	0.72	VA			
		9mm tape spiral taping (120mm)	PLACEMENT ON POSITION (WITHIN REACH)	5.4	5.4	1	5.40	5.40	VA			

			APPLICATION TAPE ON THE LEAD AS PER LENGTH	1.08	1.08	6	6.17	6.17	VA			
		vertical 9mm tape full taping (40mm)	APPLICATION TAPE ON THE LEAD AS PER LENGTH	1.08	1.08	3	3.09	3.09	VA			
			CUT THE TAPE & HOLD IN HAND	0.72	0.72	1	0.72	0.72	VA			
		vertical 9mm tape spiral taping (150mm)	PLACEMENT ON POSITION (WITHIN REACH)	5.4	5.4	1	5.40	5.40	VA			
			APPLICATION TAPE ON THE LEAD AS PER LENGTH	1.08	1.08	8	8.53	8.53	VA			
			CUT THE TAPE & HOLD IN HAND	0.72	0.72	1	0.72	0.72	VA			

Which are highlighted in the MOST Template sheet. Then starts with the line balancing which is clearly mentioned in the sheet. The line balancing scenario before NVA elimination is explain in the table no 5. Average engagement before NVA elimination is 237 min out of 420 min.

In table 5 before scenario all the time indicates the presence of NVA in their activities. Here workstation four is the bottleneck workstation and workstations three and four i.e. Sub assembly completion and on board assembly are combined operations, which are done on the board itself. There is no separate manpower for the Sub assembly completion operation. Hence it indicates scope for improvement in cycle time, resources and engagement.

Table 7 Cycle time and Manpower (after)

Sr. No.	Operations	Cycle Time (Sec)	Manpower /Day
1	PTC Sub	14.76	1
2	2nd sub assembly	19.44	1
3	2nd sub completion	22.68	1
4	Taping Assembly on board	103.20	4

First challenge is to removing the NVA operations from the assembly line. As shown on above table 4 the highlighted operations are the NVA operations , which consumes extra resources. In this case the NVA's are transportation, bunching activity etc. all the Non-value aided time is due to the transportation & motion waste are eliminated. Second challenge is to remove the bottlenecking activities from the workstations. In this case the on board assembly workstation is the bottleneck workstation in line balancing. Balancing of the work means transferring the same part of the work from fully loaded workstation to the other workstation which is having the less amount of the work.

Non value added activities are eliminated from the assembly line by doing some changes in to the process and layout. Such as compressing the assembly board drawing which helps to reduce the transportation. Another improvement is the providing the gravity chute which helps to eliminate the NVA operation like bunching. And helps to maintain the single piece flow between the workstations.

After eliminating NVA and bottlenecking operations the improved line balancing is shown in table below.

3.4 Assembly Board drawing Modification

Further improvement for the best result is the assembly board modification. Which includes the integrating the two drawings on the same length boards. Which results in to the considerable space saving this helps to improve the output production per board. (Fig.2)

Table 7 Assembly line summery (After)

XXXXXXX-X Assembly Line Summary		
CURRENT PRODUCTION PER SHIFT	750	NOS
PROPOSED PRODUCTION PER SHIFT	900	NOS
CURRENT MANPOWER PER SHIFT	10	NOS
CURRENT ENGAGEMENT	236	MIN
PROPOSED MANPOWER PER SHIFT	7	NOS
PROPOSED ENGAGEMENT	346	MIN
MANPOWER SAVED PER SHIFT	3	NOS

3.5 Workplace layout modifications

- Work table modification to eliminate the NVA: In the sub assembly area the delivery of the parts between two work stations is in form of bunch of 25 quantity. Hence the WIP is more and operator waiting time is also there. To reduce these NVA there is a necessity of the work table modification. Which includes the provision of the gravity chute between the two work centers. Which helps for the single piece flow and reduced operator waiting time.
- Layout modification: Following figure shows original line layout which includes the large assembly stands and two drawings per stand. The area used by the stand is approximately 20*4.8=96 m2.In modified layout the one more sub assembly table is added and because of the board drawing modification assembly stands reduced from four to two. And approximate area now is 15.4*4.8=73.9 m2. (Fig.3 and 4).

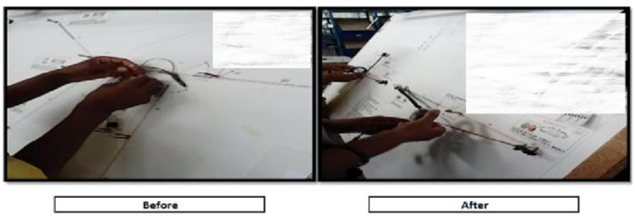

Fig. 2 Assembly Board Drawing Improvement

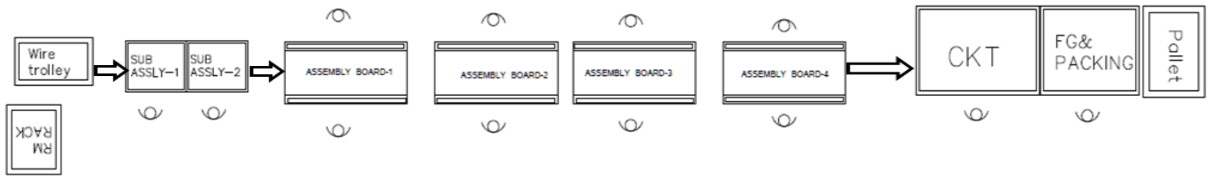

Fig. 3 Line layout (Before)

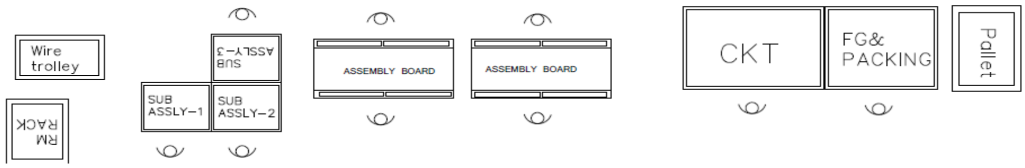

Fig. 4 Line layout (After)

4. Results

Table 8 Result

	Before	After	Benefits / Savings	Benefits/Savings per annum(In INR)
Production /Day (No's)	750	900	150	4,50,000/-
Manpower/Day (No's)	20	14	6	8,64,000/-
Space(m^2)	96	73.9	22.1	-

1) Since there is lot of improvement in workstations by which unnecessary activities of the operator is eliminated.
2) MOST plays vital role to determine the NVA activities associated with various work, balance the entire work layout by identifying the bottlenecks
3) It helped to establish the standard time of 160 sec which could save 11sec per part.
4) This paper gives an idea about the effect of demand on cycle time and productivity improvement by optimizing resources such as manpower and space.
5) The benefits derived as a result of all improvements are summarized in table 8.

References

Mehvish Jamil, Manisha Gupta , Abhishek Saxena & Mr. Vivek Agnihotri, Optimization of Productivity by Work Force Management through Ergonomics and Standardization of Process Activities using M.O.S.T Analysis-A Case Study, Global Journals Inc. (USA), Year 2013.

Kjell B. Zandin, H. B Maynard and Company (1980), MOST® Work Measurement System, Inc. Pittsburgh, Pennsylvania.

R. M. Belokar, Yashveer Dhull, Surender Nain, Sudhir Nain. (2012)'Optimization of Time by Elimination of Unproductive Activities through 'MOST'', International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-1, Issue-1, June 2012.

A. N. M. Karim, H. M. Emrul Kays, A. K. M. N. Amin and M. H. Hasan, Saravanan Tanjong Tuan.(2014)' Improvement of Workflow and Productivity through Application of (MOST)', Proceedings of the 2014 International Conference on Industrial Engineering and Operations Management Bali, Indonesia, Jan7 – 9, 2014.

Prashant Bagal, Shriram Sane and Varsha N. Karandikar, Line Balancing on Wiring Harness Assembly Line: A Case Study, International Journal of Current Engineering and Technology E-ISSN 2277 – 4106, P-ISSN 2347–516