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MOST as a tool to Support the Deployment of New Manufacturing Products

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***Abstract*— *During the process of choosing a new product, the selection of those that are financially viable and economically profitable is crucial. It is essential to consider as important all the elements that influence the cost of a product. At this point of feasibility analysis, the role of process engineering is to analyze the manufacturing process and to predict, with maximum precision, the time required to manufacture a given product, since the manufacturing time directly influences the value of direct labor cost. The purpose of this research is to use MOST (Maynard Operations Sequence Technique), from Predetermined Motion Time System, to estimate the time required to manufacture a new product. This work, classified as an exploratory case study with qualitative and quantitative analyzes, was developed in a multinational industry of the audio sector located in the Manaus Industrial Pole. The analysis of the new product using image and/or sample served as the basis for the choice of assembly sequence, the first step to be developed for the use of MOST. Afterwards, the indices were applied for each activity performed during the manufacturing and finally the standard time of assembly of the product was calculated. The result of this research shows that through MOST it was possible to estimate the standard time of a new product and obtain the labor cost of R$1.82.*

Keywords*— *Maynard Operation Sequence Technique (MOST), Predetermined Motion Time System (PMTS), Standard Time, New product.

I. INTRODUCTION

Due to the globalized market, companies focus on continuous improvements within their production process and tend to reduce their wastes so that they can improve their performance, thus reducing their set-up, loss and cost indexes, which has attracted managers to more production with less [1].

Lifting the cost of a new product is usually done in the planning phase. However, estimating the cost at this stage may contain risks due to lack of accuracy of the data leading to decision making based on the analyst's instinct. Without the correct data the analysis of implementation of a new product can be overestimated, that is, with values above the real cost. Although this is a widely used position, because overestimating is safer than underestimating, this miscalculation can determine the cancellation of the new product implementation [2].

The manufacturing cycle time is one of the most relevant information in the analysis of a product's implementation. Knowledge of the time required to perform a particular task is necessary, among other factors, to meet the production plan, determine performance and establish costs. In the introduction of a new product, if the company uses a technique of Predetermined Motion Time System (PMTS) the process of planning and costing can be carried out with greater assertiveness [3].

The standard time is also used to determinate the resources available for production effectively during the production scheduling process. Provide data for balancing analyzes of the production structure, comparing manufacturing schedules and analyzing capacity planning. It also provides standard cost data, costing of production to be useful in budget calculations during the introduction of new products [4].

The activities performed within the manufacturing are composed of basic movements performed by the operator in order to achieve a determined result. They are movements that resemble processes such as reaching, moving, rotating, pressing, grasping, positioning, releasing, eye movements (revising), trunk, arms and legs, walking. The PMTS techniques propose analyzing each step of the operation, dividing it into basic human movements and computing the time required for each movement, where each has its associated value and time [5].

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Since 1970 the Maynard Operation Sequence Technique (MOST) is one of the most applied in the world. It is five times faster to apply than other traditional PMTS methods [3]. Using MOST it is possible to calculate the time before production starts, resulting in a useful method for product design, tool selection and project development together with production scheduling and control.

II. LITERATURE REVIEW

2.1 Time Study

Frederick W. Taylor is considered the father of the Scientific Administration, because at the end of the 20th century, through his works, he suggested systematizing the concept of productivity. Taylor focused on task management analysis, where he broke down tasks into elementary subtasks and worked extensively to make each of these tasks more efficient. With this, it has developed work methods and processes to obtain higher productivity at the lowest possible cost [6] [7].

The method that Taylor used to develop his study of Scientific Administration consisted in identifying the beginning and end of a production activity, dividing it into elementary activities, measuring with a timer, the time required for each one, and then reassembling it so that the total time for its execution was minimized [7]. Thus, the study of time was born, that is defined as a technique to measure and record the time that the operator takes to execute a certain task under specific conditions, method and rhythm [5].

Knowledge of the time required to perform a given task is directly related to the concept of productivity. For Taylor the improvement of work efficiency would be achieved by analyzing and improving working methods, reducing the time required to perform work and developing working patterns.

Before conducting the Time Study, it is important to ensure that the Motion Study has been performed so that all excess work has been eliminated and also that the total work content is as close as possible to the content of the basic work unit, that is, the minimum work required to perform the task [5].

2.2 Motion Study

The Motion Study is concerned with finding the best method of performing a given task. This study, pioneered by Frank B. Gilbreth and his wife Lilian M. Gilbreth in 1912, began when Frank, after opening his own contractor, noticed that each mason had his own method of doing the work and that two men would never worked equally well. In addition, he noted that they did not always use the same sequence of movements. A bricklayer, for example, used a sequence of moves when he wanted to do the job faster, but he did other moves when he worked slowly, and still others when teaching a person how to lay bricks. From these observations Gilbreth began to develop the best method (standard method) to perform a certain task [8] [9].

The Gilbreth couple extended the concepts of scientific management for the identification, analysis and measurement of the fundamental movements involved in the work. Using a cinematic camera, they began to record the task if they analyze the movements. In this way, they were able to categorize human movements into 17 basic elements or "therbligs", anagram of the name Gilbreth [10] [11] [12].

The therbligs could be plotted on a SIMO (Simultaneous Motion Chart) along with the time each move would take. Then, by examining the graphs, it was possible to determine which therbligs were taking too long and / or which could be eliminated by rearranging the movements. It is worth mentioning the time values associated with each therbligs were not pre-determined values. The Gilbreths believed that with an improved method of work, the shortest cycle time would naturally arise [10].

Understandably, there were those who followed Taylor and his Time Study, and there were those who followed the Gilberth couple and their Motion Study. However, there was a third group interested in using the best of each technique together. From this union of the Time Study and Motion Study came the PMTS [3].

2.3 Standard Time

The time set for the execution of a task or job is called the "Standard Time". This time is obtained by applying techniques that help determine the time that a qualified operator takes to complete a specific task when working at a defined speed (work pace). The various advantages of an organization maintaining a standard time database range from estimating the cost of labor to establishing production capacity, critical factors and influencing productivity [4] [13] [14].

The standard times are influenced by the type of material flow within the company, the nature of the process chosen, the technology used in the production and the characteristics of the activity performed. Even so, the greater the difficulty of measuring time, the greater the human intervention in the activity. Already in automated lines, time measurements vary very little [3].

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To determine the standard time it is necessary to analyze the execution of the activity by a qualified operator. The qualified operator is neither the best nor the worst, but someone who is skillful and can perform activities consistently throughout the work day. He is a motivated operator with the experience and skills to perform work at acceptable levels of quality and quantity in a safe manner [4].

Another factor that must be considered during the measurement of the standard time is the work pace. Work pace is the rate at which the operator is steadily developing his activity for a full day's work. It cannot be too fast or too slow, it should be medium. You should keep this median, since the worker rarely keeps up the same rhythm of work for long hours. At certain times, the worker will perform faster or slower than the normal pace. The normal rhythm represents an ideal standard that the average worker should be able to maintain in the long run [4] [8] [15] [16].

The last two factors that influence the measurement of the standard time are the method and the tolerances. As already described, the concern with the correct definition of the method before performing the measurement is highlighted since the time of Taylor. Tolerances are the addition of a time, often calculated in percentage form, to the measured time referring to the personal needs of the operators like fatigue, waits, breaks besides inevitable small delays [3] [4] [8] [15] [16].

2.4 Predetermined Motion Time System

The PMTS is a system of techniques that use time patterns associated with human movements to define the time required to perform operations. They are job measurement systems to determine workforce performance on an assembly line. Unlike techniques classified as Direct Observation or Estimation, techniques classified as PMTS calculate the time of an operation by deriving predefined time patterns for various movements [17] [18] [19].

PMTS techniques are employed in the construction of standard times at various macro levels, operations, characteristics and products, and form the basis of activities related to industrial engineering and costing procedure. PMTS techniques are mainly used in an industrial environment to analyze the methods of manual operations resulting in the definition of the standard time in which an operator must complete the operation [20].

Typically, PMTS techniques divide the whole operation into basic human movements, also called micro-movements, and classify each of them based on the nature of the movement (ie, movement elements such as ‘understand’, ‘put’ and ‘reach’, and mental functions such as ‘identify’, ‘find’, and ‘decide’) and the condition in which the movement is being performed. The times defined for basic human moves are employed in the sum of the time for an operation at defined levels of performance [19] [21].

Using the PMTS techniques to measure the time of an operation has become a matter of establishing the best basic motion sequence to execute a given task and from the catalog or data table assign the appropriate predetermined time for each movement of that standard sequence. Since the times for all movements are predetermined, it is possible to accurately predict the times of future operations, that is, operations that are not current [3] [8] [20].

The main uses of PMTS techniques can be divided into two classes: Method Evaluation and Standard Time Establishment. Table 1 shows the main reasons for using PMTS techniques divided into two categories suggested by [9].

Numerous techniques have been developed within the PMTS concept. The most used are: Methods of Time Measurement (MTM), o Modular Arrangement of Predetermined Time Standards (MODAPTS), and Maynard Operation Sequence Technique (MOST) [17] [18] [19] [20] [21].

Table 1: Main uses of PMTS

Method Evaluation	Standard Time Establishment
Improvement of existing methods.	Direct use of synthetic times for the establishment of standard times.
Evaluation of proposed methods before production starts.	Compilation of standard data and formulas for specific classes of work in order to make the establishment of standard times faster.
Evaluation of projects of tools, devices and equipment.	
Product design assistance.	Verification of the standards established by time study.
Training of supervisory personnel to guide them in relation to the study of movements and times.	Auditing of standard times.

Source: [9].

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2.5 Maynard Operation Sequence Technique – MOST

MOST is a PMTS technique that allows you to establish the standard time of any manual activity, and some tool operations, using the concept that every operation is formed by fundamental activities combined with each other. For MOST, with the exception of activities that involve "thinking", the purpose of a job is to achieve a goal by moving objects. This is why MOST is a system that concentrates effort in measuring work through the interaction movements between man and object [3] [22].

A standard operation is a sequence of movements, combined with each other, that have certain beginning and end, performed in a workstation. The organization of the movements directly impacts the standard operation time. Each operation is formed by sub operations that can be conceptualized as blocks that fit, that is, they are part of the work developed within the operation [3] [23].

These movements of interaction between man and object follow, almost always, the same sequence. For example, to write a sentence in a notebook using a pen, it is first necessary to 'reach' the pen, then 'pick up' the pen, then 'move' the pen to near the notebook sheet and finally 'position' the tip of the pen on the notebook sheet line. These 'reach', 'pick up', 'move', 'position' moves are common in manual activities and within MOST are identified as sub activities. Each activity of an operation is formed primarily by a sequence of sub activities [3] [23].

In MTM the sequence of movements is determined randomly by the analyst, already in MOST this sequence is fixed. That is, to move an object from one point to another, the operator follows an already defined sequential model of sub activities. However, there are different types of activities according to the behavior of the operator in relation to an object. For example, "loading a carton from one end of the workbench to the other" is different from "pushing the carton from one end of the workbench to the other," both require different efforts and therefore different times [4] [24].

For these type of variations, BasicMOST defines three main Sequence Models: General Move Sequence, for spatial moves of free-form objects in the air, Controlled Move Sequence, for moving objects in contact with surfaces or attached to another object during movement and Tool Use Sequence when the activity is developed using a manual manipulation tool[4] [24]. The main function of Sequence Models is to make the analyst turn his attention to the process by analyzing a structured and standard format. Sequential Models provide a consistent analysis of activities by reducing the omission of sub activities [3].

An analysis with MOST is done by combining several Sequence Models that will ultimately compose a sub operation or an operation directly. That is, hierarchically, the operation is divided into sub operations (this division can be at the discretion of the analyst, because if you prefer you can divide the operation directly into activities). The sub operations are divided into activities, which are classified within the Sequence Models which are then divided into sub activities. Finally, each activity receives a parameter that at the end of the calculations will form the standard time.

2.5.1 BasicMOST

BasicMOST was the first version of the MOST System to be launched and is able to adjust to most of the work operations performed in the industry. While MiniMOST and MaxiMOST have applications in operations made exclusively by certain industries, all companies have some type of operation where BasicMOST is the most logical version to be used [2].

An object can be moved only in two ways: either it is acquired and moves freely to the destination or it is moved in contact with another surface. For these two situations BasicMOST uses two Basic Sequence Models, the General Move and the Controlled Move. When the activity uses a manual manipulation tool, it needs to be analyzed according to a third Sequence Model, Tool Use, which is actually the combination of the two Basics Sequence Models. There is also a fourth Sequence Model is used for heavy object handling activities using, for example, cranes [24].

2.5.1.1 General Move Sequence Model

The Sequential Model of General Moves deals with the spatial displacement of one or more objects that follow an unobstructed path through the air. If the object is in contact, restrained, or adjacent to another object during movement, the General Move Sequence Model is not applicable [2].

The General Move Sequence Model follows a fixed sequence of sub activities identified through the steps described as: REACH with one or two hands at a distance, an object directly or in conjunction with the steps of body movement; GAIN object control manually; MOVE the object at a distance to the positioning point, either directly or in conjunction with body movements; PLACE the object in a temporary or final position;

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RETURN the starting position. This Sequential Model takes the form of a fixed series of letters, called parameters, which represent each sub activity [2].

An activity classified as General Movement follows three distinct phases: GET, PUT, and RETURN. The GET phase describes the actions to reach the object with body movements (if necessary) until the moment in which the control of the object is obtained. Its parameters are 'A' means Action Distance, 'B' stands for Body Motion, and 'G' means Gain Control. The PUT phase describes the action performed to move the object to the other location and has parameters 'A', 'B' and 'P' which means Placement. The last phase, RETURN, simply refers to the return of the operator to the initial position on the workstation its only parameter is 'A' [23].

2.5.1.2 Controlled Move Sequence Model

The Second Sequence Model is called as Controlled Move. Describes the manual movement of objects in a "controlled" path, that is, when moving, the object must follow at least one specific direction in contact or attached to another object. This sequence is also used to analyze activities with manipulation of levers or cranks, push a button or power switch or simply drag an object under a surface [2] [24].

Like the General Move Sequence, the Controlled Move Sequence Model follows a sequence of predetermined sub activities: REACH one or two hands at a distance, an object directly or in conjunction with the body's movement steps; GAIN object control manually; MOVE the object in a controlled and determined path (within reach or with steps), ALLOW a certain time for a machine to carry out its process; ALIGN the object after following the controlled path, or at the end of the machine's processing; RETURN the starting position [2].

The Controlled Move Sequence Model also follows three distinct phases: GET, MOVE or ACTUATE and RETURN. The GET and RETURN phases describe the same sub activities, with the same parameters of the General Move Sequence Model. The big difference is in the MOVE or ACTUATE phase, which describes two types of actions. 'Move' simply means to move an object through a controlled path and 'Actuate' refers to the action of moving a particular object. For this new MOVE/ACTUATE phase, new parameters are established: 'M' stands for Move Controlled, 'X' means Process Time and 'I' means Aligment [23].

2.5.1.3 Tool Use Sequence Model

This model covers activities that use manual tools for actions such as fastening and loosening, for example, in addition to activities involving cutting, surface treatment and measurement. This sequence of movements also includes actions with tools that are not classified as equipment as pencil, to write and marker to mark, and activities classified as information recording. The Use Tool Sequence Model also involves activities performed with mental actions such as reading and inspection [24].

The sequence phases of the Tool Use Sequence Model follows the activities: GET TOOL, PUT TOOL/OBJECT IN PLCE, TOOL ACTION, PUT TOOL/OBJECT ASIDE, and RETURN. The only phase that is common to the other Sequence Models is the 'Return' phase, because it is the return of the operator to the initial position. The GET TOOL phase deals with the action of reaching a tool or object at a certain distance, directly or in conjunction with body movements, so it receives the parameters 'A', 'B' and 'G'. The PUT TOOL phase refers to the action of moving the tool or object at a certain distance to the place where it will be used, directly or in conjunction with body movements, thus receiving the parameters 'A', 'B' and 'P'. The TOOL ACTION phase is the action to apply the tool and its parameter varies according to the type of tool being used: 'F' for fastening tools, 'L' for loosening tools, 'C' for cutting tools, 'S' for surface treatment tools, 'M' for measuring tools, 'R' for tools used to record information, and 'T' for thinking-related actions. Then the other "PUT TOOL" phase is the action of holding the tool, if it is used again, drop it or place it next to it, return the tool to the initial position or move it to another position, also either directly or in conjunction with body movements, to receive the parameters 'A', 'B' and 'P' [2] [23].

2.5.2 Total Time

The result of the MOST operation analysis is the sum of the indices applied to each subactivity multiplied by ten. This result is obtained in TMU (Time Measurement Unit) [23]. A TMU equals 0.00001 hours. Table 2 presents the calculation for TMU conversion in units of conventional times (hours, minutes and seconds).

Table 2: Converting TMU in Conventional Time Units.

TMU	CONVENTIONAL TIME UNITS
1 TMU	0,00001 hours
1 TMU	0,0006 minutes
1 TMU	0,036 seconds

Source: [3].

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The TMU value for each activity assessed under the MOST System is the result of the sum of the sub-activity indices multiplied by ten. This calculation applies to all Sequential Models (General Movement, Controlled Movement, and Tool Usage).

After the analysis result being converted into conventional time units, the so-called normal time is obtained. The standard time is obtained after applying the tolerances (concessions for personal needs, fatigue, flexion, standing work, among others), since MOST analyzes the activities considering an operator with 100% efficiency [25]. According to [26], tolerances have traditionally been determined by adding adequate percentages for each factor in an empirical way. For example, 5% for personal needs, 2 to 3% for short and inevitable delays and 5 to 8% or more for fatigue-induced rest related to light industrial work.

III. MATERIALS AND METHODS

The present research was carried out within the context of a multinational electronics industry, located in Manaus, capital of the state of Amazonas, from January to November 2018. It is classified according to objectives and its procedures as exploratory and study of case, respectively. Exploratory, as it seeks to deepen knowledge on the topics Cost of Manufacturing, Study of times and movements and Synthetic Time Default Systems. It is a case study, since it intends to study a real case seeking to understand the relationship between variables to develop theories. The research uses qualitative and quantitative methods in data collection and analysis. Qualitative, because certain evidences will be obtained through observations and reports, but because it is a study that relates monetary units with units of time will be classified as quantitative [27].

A case study in the area of Production Engineering should follow steps. The theoretical-conceptual frameworks for the work are established, and then, how many and which cases will be studied. Afterwards, one must define the methods and techniques for data collection and analysis. Finally, the protocol that will contain the context of the research, the procedures that will be adopted in the field and the control variables must be elaborated [28].

The research design is the graphical presentation of the activities script that will be developed throughout the research for the elaboration, accomplishment and conclusion of the case study. Figure 1 shows the steps defined for the present case study.

The research begins by reviewing the literature in search of concepts that the author intended to address. After this process, the problem that was the subject of the case study was defined and from that point the profound literature review was begun to understand the problem and the ways of solving it.

The methodology was defined with steps and procedures to be adopted. Then, the research starts with the collection of data and definition of the premises for the application of the BasicMOST tool. It continues with the application of the proposed tool within the company environment. Then, the results are collected, and for the validation of the research proposal, comparative analyzes of these results are made with the methods currently applied by the company. Finally, the conclusions of the study are made, verifying that the objectives have been reached and future studies are being carried out.

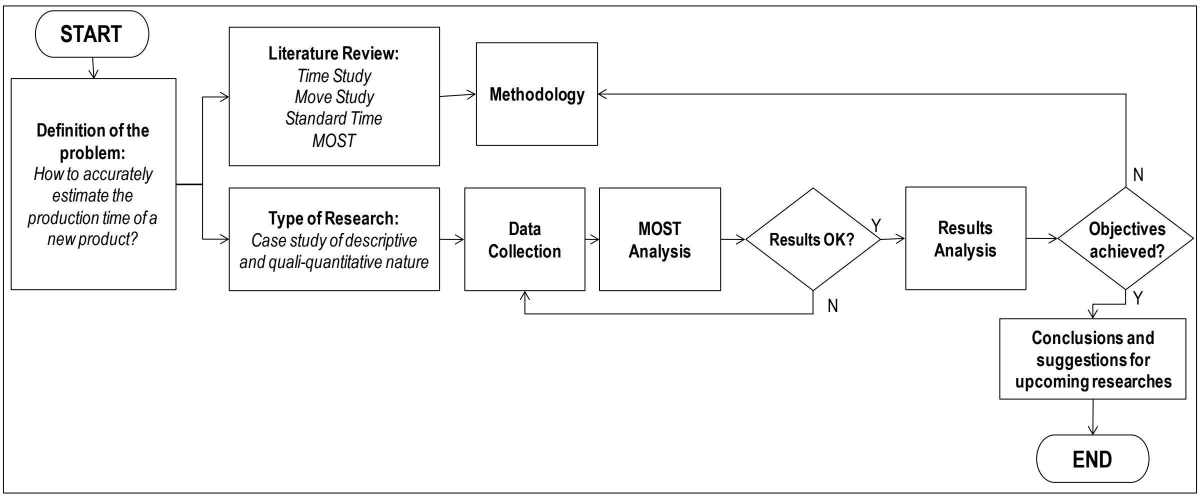

Fig 1: Research Design.
Source: Authors, (2018).

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3.1 Appling BasicMOST

BasicMOST is based on moving objects. The analyst should follow certain guidelines to develop a consistent analysis. You should not skip or change any of them, as a consequence it may result in an incomplete analysis, with erroneous results. The flow of Figure 2 shows all the basic thought processes and decisions that need to be considered to get the BasicMOST analysis.

(1) Determine the start and end of each activity. All have a starting point and end when all activity is performed.

(2) Describing the sequence of movements of each activity is similar to describing a stepwise method.

(3) The analyst should study the activity in order to establish the most effective method of accomplishing the task.

(4) All activities that use tools should be analyzed as Tool Usage.

(5) Use the indexes for the tool described in the table Indexes of the Tool Use Sequence Model. If the tool is not discussed in the Table, use comparison with analog tool or use indexes of other tools such as MiniMOST, MTM-1 and MTM-2.

(6) If the object manipulated during the operation needs to follow a controlled path then the activity should be analyzed as Controlled Movement. If the object is moved freely in the air, use the indexes of the General Movements frame.

(7) Verify that all activities required to perform the operation have been described before finalizing the analysis.

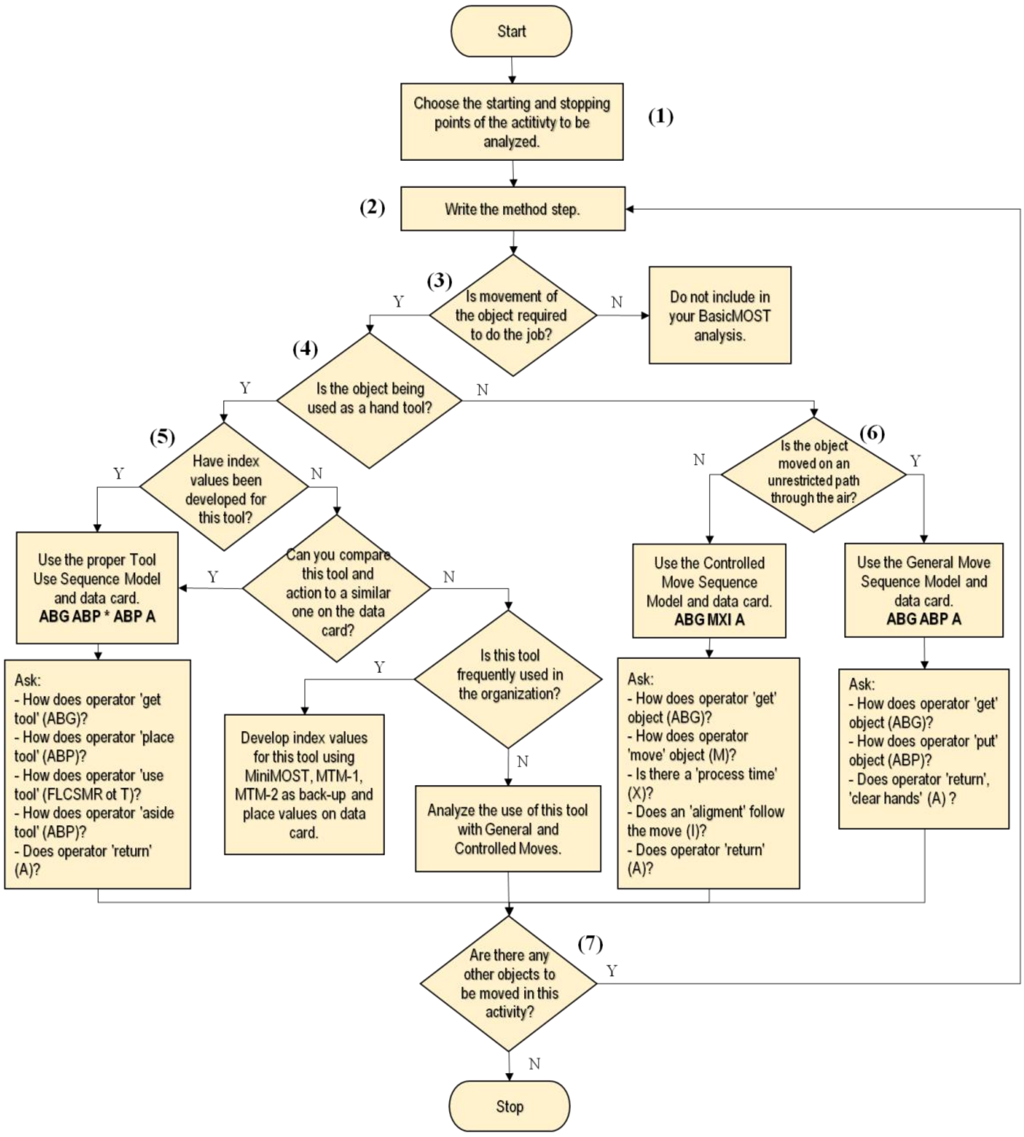

Fig. 2: BasicMOST Analysis Decision Diagram.
Source: [3].

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Following the steps described in the flowchart and answering the questions is fundamental for the effective application of BasicMOST. These responses will help the analyst determine the correct sequential model to be used and the index value for each parameter (sub activity), avoiding ignoring any other objects being moved or analyzing any unnecessary activity.

3.2 Calculating the Total Time Activity

The TMU value for each activity assessed under the MOST System is the result of the sum of the sub-activity indices multiplied by ten. This calculation applies to all Sequential Models (General Move, Controlled Move, and Tool Use). For the example phrase of General Move we have the application of the indices and calculation of the total time demonstrated in Eqs.1:

Pick up a heavy box, bend and place it on pallet.

$$A_3 \quad B_0 \quad G_3 \quad A_1 \quad B_6 \quad P_3 \quad A_0$$

$$(3 + 0 + 3 + 1 + 6 + 3 + 0) \times 10 = 160 \text{ TMU} \qquad (1)$$

This activity takes 160 TMU to be performed, which means, 5.76 seconds.

3.3 BasicMOST Form

To facilitate the application of the MOST indexes, a data insertion form was developed. The document was developed based on the models found in the literature, but with the differential of using the program Microsoft Excel®, whose function of including formulas makes it more practical to obtain the results. Figure 3 shows how you would formulate it, and how it is divided and how it will be filled out.

IV. RESULTS

4.1 Steps for manufacturing a new product

Within the manufacturing industry the case study product will go through three pre-defined steps for all of the company's products: assembly, testing and packaging. The assembly consists of the mechanical union of the parts (raw material) that make up the product. The Test evaluates whether the features of the product meet the specifications and perform the visual inspection of the product. Finally, Packaging is the stage in which the product will be packaged for safe transportation.

Sample analysis, technical specifications, layout definition and assumptions allow the evaluator to list all the actions required to assemble, test and package this case study product, named IWICS6 (In-Wall/In-Ceiling Speakers). For the manufacturing process of this product, a total of 36 activities were described, where 16 were classified as Assembly, 5 activities were classified as Test and 15 as Packing. All these activities are evaluated for the composition of the standard manufacturing time.

BASICMOST ANALYSIS FORM			
PRODUCT:		DATE:	
ID NPI:		ANALYST:	

STEP N°	METHOD STEP DESCRIPTION	BasicMOST Sequence Model	Sequence Models											Fr	TMU
			i	i	i	i	i	i	i	i	i	i	i		
		General Move	A	B	G	A	B	P	A						0
		Controlled Move	A	B	G	M	X	I	A						0
		Tool Use	A	B	G	A	B	P	*	A	B	P	A		0
		Controlled Move	A	B	G	M	X	I	A						0
		Controlled Move	A	B	G	M	X	I	A						0
		Controlled Move	A	B	G	M	X	I	A						0
		<Sequence Model>													0
		<Sequence Model>													0
		<Sequence Model>													0
		<Sequence Model>													0
														Sum	0

Fig. 3: BasicMOST analysis form.
Source: Authors, (2018).

4.2 Definition of types of movements and application of MOST indexes

After inserting the activities, it is necessary to determine the Sequence Model of each one: General Move, Controlled Move and Tool Use, to apply the indexes and frequencies to obtain the normal time of the operation. In the elaborated form, the evaluator chooses between the three options and the sequence of movements (parameters) appears automatically. After this, the

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evaluator determines the indexes for each and the frequency, if it is greater than 1.

In the product packing box two pieces are packaged. This information is relevant, because in the analysis carried out in an initial stage, all the activities were directed to the assembly of only one piece. To convert the result of the analysis into two pieces, it is not correct to multiply the value of all activities by two, since activities classified as Packing are common for both pieces. Thus, only the activities listed from 1 to 25 were multiplied by two (representing the two-piece assembly by adding a Fr2 column to the form). Figure 4 shows the two-part analysis of the first 10 activities. The end result of the normal time was 7600 TMU or 4.56 minutes.

4.3 Parameter Indexing Analysis

Activity analysis shows how the MOST methodology is simple and easy to apply. Activity number 34: "Picking up the FIFO label and paste in the carton" was also classified as General Move. Its description is slightly different, in relation to activities 1 and 5, but it fits perfectly in the phase diagram determined for this Sequential Model, as shown in Table 3.

Table 3: Phases, parameters and, index values of Activity 34

General Move Sequence Model		
Pick up the FIFO label	and paste into carton box	
GET	PUT	RETURN
A_1 B_0 G_3	A_1 B_0 P_6	A_0

Source: Authors, (2018).

The particularity of each activity reflects in the change of applied indexes. For activity 34 the following indices were applied:

FORMULÁRIO DE ANÁLISE BASICMOST			
PRODUCT:	IWICS6	**DATE:**	09/30/2018
ID NPI:	170417	**ANALYST:**	Natália Silva

STEP N°	METHOD STEP DESCRIPTION	BasicMOST Sequence Model	Sequence Models											Fr	TMU	Fr2	Min
			i	*i*	*i*	*i*	*i*	*i*	*i*	*i*	*i*	*i*	*i*				
1	Pick up the plastic frame and position it on the device.	General Move	A 1	B 0	G 1	A 1	B 0	P 1	A 0						40	2	0.048
2	Pick up the EVA and position it in the plastic frame	General Move	A 1	B 0	G 1	A 1	B 0	P 3	A 0						60	2	0.072
3	Pick up the speaker and posiconar on EVA	General Move	A 1	B 0	G 3	A 1	B 0	P 3	A 0						80	2	0.096
4	Pick up the screwdriver and tighten the speaker on the frame	Tool Use	A 1	B 0	G 1	A 0	B 0	P 3	F 3	A 1	B 0	P 1	A 0	4	320	2	0.384
5	Pick up the support brackets and position it on the jig	General Move	A 1	B 0	G 1	A 1	B 0	P 1	A 0					4	160	2	0.192
6	Remove the product from the device and position it on the other jig	General Move	A 0	B 0	G 3	A 1	B 0	P 3	A 0						70	2	0.084
7	Screw the bracket into the frame	Tool Use	A 1	B 0	G 1	A 0	B 0	P 3	F 3	A 1	B 0	P 1	A 0	4	320	2	0.384
8	Rotate 180° the product	Controlled Move	A 0	B 0	G 1	M3	X 0	I 0	A 0						40	2	0.048
9	Apply glue to the towers	Controlled Move	A 1	B 0	G 1	M3	X 0	I 1	A 1					4	280	2	0.336
10	Attach the support bracket on the towers	General Move	A 1	B 0	G 1	A 1	B 0	P 3	A 0					4	240	2	0.288

Fig. 4: BasicMOST Analysis Form for the first 10 activities of the IWICS6.
Source: Authors, (2018).

A_1 - because the object is within reach of the arms.

B_0 - because there was no movement of the body.

G_3 - indicating disengaging or collecting, because although it is a lightweight object (a label), it is likely to be glued to a roll.

A_1 - because the object where the label will be glued is within range of the arms.

B_0 - because there was no movement of the body.

P_6 - which indicates positioning carefully, as there is a marking on the carton where the label should be glued, as shown in Figure 5.

A_0 - because there is no return action to the starting position.

Fig. 5: Application of the FIFO label in the carton.
Source: Authors, (2018).

In the case of activities considered Controlled Move, we can exemplify activity number 29: 'Pick up the tape passer pass the tape to the bottom of the cardboard box'. As discussed in the previous chapter, the activities of this sequential Model are divided into 3 phases: GET, MOVE/ACTUATE, and RETURN. Table 4 shows how activity 8 is divided in relation to the phases of the Controlled Move.

Table 4: Phases, parameters, and index values of Activity 29.

Controlled Move Sequence Model		
Pick up the tape passer	pass the tape to the bottom of the cardboard box	
GET	MOVE/ACTUATE	RETURN
A_1 B_0 G_1	M_3 X_0 I_6	A_1

Source: Authors, (2018).

The GET phase, corresponds to part of the activity "pick up the tape passer", the sub activities will always be A (Action Distance), B (Body Motion) and G (Gain Control) equal to the General Move Sequential Model. Therefore, the analysis of this phase follows the concepts already discussed.

The difference between these two models is in the intermediate phase MOVE/ACTUATE, where the other parameters are: M (Controlled Move), X (Process Time) and I (Alignment). Following the index were applied:

M_3 – because the tape passer will travel a path established by the carton design larger than 30 cm, as shown in Figure 6.
X_0 – because there is no machine process.
I_6 – For the adhesive tape should be aligned with two points with a distance greater than 10 cm.

In the RETURN phase, the analyst chose not to mention, but the ribbon dowel will return to the starting position.

Therefore, this parameter received index 1. Thus, the result in TMU for this activity is demonstrated in Eqs. (2):

$$\underset{A_1}{(1} + \underset{B_0}{0} + \underset{G_1}{1} + \underset{M_3}{3} + \underset{I_0}{0} + \underset{I_6}{6} + \underset{A_0}{0)} \times 10 = 110 \text{ TMU} \qquad (2)$$

Therefore, activity 29 needs 0.066 minutes or 3.96 seconds to be performed.

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Fig. 6: Path traveled by tape passer.
Source: Authors, (2018).

Only three activities were classified within the Tool Use Sequence Model. Two referring to the use of electric clamping tool and one for the inspection action. The division of activity 4 in the phases of the Tool Use Model is presented in Table 5:

Table 5: Phases, parameters, and index values of Activity 4.

Tool Use Sequence Model				
Pick up the screwdriver		and tighten the speaker on the frame		
GET TOOL	PUT TOOL or OBJECT IN PLACE	TOOL ACTION	PUT TOOL or OBJECT ASIDE	RETURN
A_1 B_0 G_1	A_0 B_0 P_3	A_1 F_3	A_1 B_0 P_1	A_0

Source: Authors, (2018).

The TOOL ACTION phase is what differentiates the Tool Use Sequence Model from the other models, and according to the type of tool there is a specific parameter. For the other phases the table is used with the Indexes of the General Move Sequence Model. It is also common to find in this phase the application of partial frequencies, which requires the addition of a parameter Action Distance (A). Therefore, the following index values were applied for Activity 4:

A_1 - the screwdriver is within range of the arms.

A_1 - The screwdriver is within reach of the arms.

B_0 - there were no body movements.

P_1 - place the screwdriver on the side.

A_0 - there was no return to the starting position.

B_0 - there were no body movements.

G_1 - gain control of the screwdriver.

A_0 - zero because the new A index of the Tool Use phase will override this index.

B_0 - there were no body movements.

P_3 - screwdriver positioning receives index 3.

A_1 - the screws are within reach of the arms, with a distance of more than 5 cm, as exemplified in Figure 7.

F_3 - because the diameter of the screw is less than 6mm.

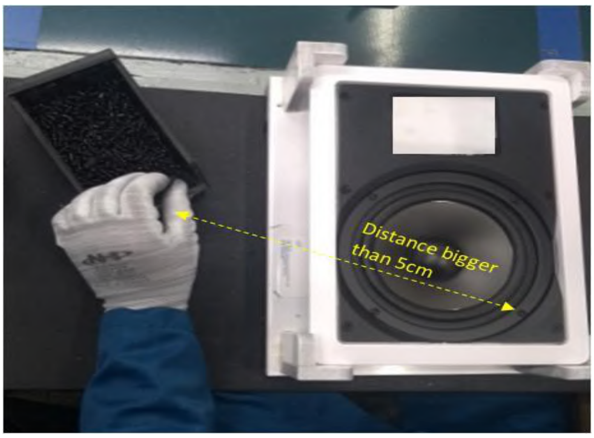

Fig. 7: Screw distance bigger than 5cm.
Source: Authors, (2018).

The calculation result in TMU for Activity 4 should consider the partial frequency that is related to the number of screws to be tightened. Therefore the calculation for this activity is demonstrated in Eqs. (3) below:

A1 B0 G1 A0 B0 (P3 A1 F3) A1 B0 P1 A0 {4}

$$\{1+0+1+0+0+[(3+1+3)\times 4]+1+0+1+0\}\times 10 = 320TMU \quad (3)$$

$$320 \text{ TMU} = 0{,}192 \text{ min} = 11.52 \text{ seconds}$$

At the end of the application of the MOST tool the normal time was equal to 2.616 minutes to realize the final production of the product IWICS6. The standard time is obtained after the application of the tolerances.

4.4 Tolerances and Standard Time.

In the present study, 5% for muscle fatigue, 5% for delays and 5% for special needs will be considered for the calculation of tolerance. Therefore the total value of the PR & D tolerance will be 15%. This percentage applied to the normal time of 4.56 obtained from the MOST analysis yields the standard time in Eqs. (4).

$$\text{Standard Time} = 4{,}56+15\% = 4{,}56*1{,}15 = 5{,}22 \text{ min} \quad (4)$$

Therefore, the standard manufacturing time of the IWICS6 product is 5 minutes and 13 seconds.

4.5 Manufacturing Cost based on MOST Standard Time

The manufacturing cost comprises the sum of the expenses with goods and services applied to the manufacture of a product [25]. In this way, the calculation of the manufacturing cost of the product is given by the sum of the Direct Labor (DL), Direct Materials (DM) and General Manufacturing Expenses (GME) costs, as stated in Eqs. (5) below:

$$\$\text{Manufacturing Cost} = \$DL + \$DM + \$GME \quad (5)$$

With the standard time result obtained from the application of the MOST technique is possible to calculate the cost of the DL by multiplying the standard time by the man/hour rate of the previous month. However, you must convert the default time to the unit of time hours. As the analysis was performed in September 2018, the man-hour rate considered will be the one of August of the same year (R$ 20.93). Therefore the cost of the DL will be according to Eqs. (6).

$$\text{DL Value} = (5.22 \div 60) \times 20.93 = R\$1.82 \quad (6)$$

The sum of the Bill of Material (BOM) items in this product costs R$75.19, and therefore this is the value of DM. The GME attributed to this product is R$23.68. Thus, the calculation of the manufacturing cost of the product is done through Eqs. (7).

$$\$ \text{ IWICS6} = R\$1.82+R\$75.19+R\$23.68 = R\$100.69 \quad (7)$$

V. CONCLUSION

Looking at the impact of manufacturing time on the cost of DL during the process of deploying new products, this study sought to use MOST, PMTS tool, to estimate the total manufacturing time of an audio product manufactured by a multinational electronics industry. Within this purpose, the research was able to identify that the PMTS techniques already have advantages over other methods of standard time measurement, especially when it comes to products that will still be implanted. And the MOST presents the differential of the ease in applying the indexes, since the sequences for each activity are already defined, making the analysis simpler.

Another objective of the study was to define the assumptions and manufacturing steps of the new product, a key factor for the application of MOST, which is a technique for a detailed description of the method to obtain the standard time. The application of the technique resulted in a manufacturing standard time closer to the process reality, without overestimating it, a factor that could jeopardize the viability of the project.

The study presented the formation of the cost of manufacturing for new products and based on this knowledge and using the result of the MOST application, the research showed that the manufacturing time has a direct impact on the cost of manufacturing and therefore it should be analyzed wishing to obtain the lowest time. However, without omitting any activity, and as the results show, MOST met expectations and obtained the lowest cost of DL.

MOST has proved to be an effective technique to estimate manufacturing time of new products, since in addition to imposing the deep analysis of the manufacturing method, the technique allows the analyst, only knowing the product and the means by which it will be manufactured can apply the indices according to each Sequential Model and at the end, after applying the tolerances, obtain the standard time.

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