



**APPLICATION OF VALUE STREAM MAPPING
WITH MODULAR ARRANGEMENT OF
PREDETERMINED TIME STANDARDS TO
REDUCE LEAD TIME: A CASE STUDY IN THE
METAL SECTOR**

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Ömer Abdulaziz KORKMAZ

ABSTRACT

Master Thesis

APPLICATION OF VALUE STREAM MAPPING WITH MODULAR ARRANGEMENT OF PREDETERMINED TIME STANDARDS TO REDUCE LEAD TIME: A CASE STUDY IN THE METAL SECTOR

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Just as producing is necessary for people, production efficiency has become an obligation for companies' sustainability today. Making production better is a never-ending process. Feedback from the system plays a key role. Productivity development is the primary matter preoccupying all factory supervisors. All feedbacks start from improving production area leading to capacity increase, deadline decrease, and profit growth. In the production environment, numerous challenges exist; the primary concern is the ability to discern and recognize these problems. Most production obstacle stations are hidden, so their solutions begin with learning to see them. This thesis works on a real-life case study that deals with unobserved production area problems using Lean Manufacturing techniques. It presents a new model that combines Value Stream Mapping (VSM) and Modular Arrangement of Predetermined Time Standards (MODAPTS), to bring their complementary strengths together.

Much wasted time was noted during the production process. VSM was used to identify the current state by revealing obstacles, and MODAPTS was responsible for time standardization to generate the future state jointly. This study improved lead time by 47% when production time decreased from 36 days to 19 days only. This paper targets proving this combination's value and being a foundation stone on which considerable future research will be built on it.

Key Word : Lean Manufacturing, Value Stream Mapping, Predetermined Motion Time System, MODAPTS, Delivery time.

Science Code : 90617

ÖZET

Yüksek Lisans Tezi

TESLİM SÜRESİNİ AZALTMAK İÇİN MODAPTS İLE DEĞER AKIŞI HARİTALAMANIN UYGULANMASI: METAL SEKTÖRÜNDE VAKA ÇALIŞMASI

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Üretimin insanlar için gerekli oluşu gibi, günümüzde üretim verimliliği de şirketlerin sürdürülebilirliği için zorunlu bir hale gelmiştir. Üretimi iyileştirmek bitmeyen bir süreçtir. Sistemden alınan geri bildirimler önemli bir rol oynamaktadır. Verimliliğin geliştirilmesi, yöneticileri meşgul eden başlıca konudur. Tüm geri bildirimler, kapasitenin artırılmasına, teslimat süresinin azalmasına ve kârın büyümesine yol açan üretim alanının geliştirilmesiyle başlar. Üretim alanında bulunan birçok zorlukla birlikte temel endişe bu problemleri fark edip tanımaktır. Üretimi engelleyici çoğu nokta gizli olduğu için çözümleri de onları görmeyi öğrenmekle başlar. Bu tezin konusu, Yalın Üretim tekniklerini kullanarak gözlemlenmeyen üretim alanı problemlerini ele alan bir gerçek hayat vaka çalışmasıdır. Değer Akışı Haritalama (VSM) ve Önceden Belirlenmiş Zaman Standartlarının Modüler Düzenlemesi (MODAPTS) yöntemlerinin birleşimi sonucu tamamlayıcı güçlerini ortaya çıkaracak

yeni bir model sunulmaktadır. Üretim süreci esnasında çok fazla zaman kaybı gözlemlenmiştir. VSM, engelleri ortaya çıkararak mevcut durumu tanımlamak için kullanılırken MODAPTS, gelecekteki durumu ortaklaşa bir şekilde oluşturma amacıyla zamanın standardize edilmesinden sorumluydu. Çalışma, üretim süresi 36 günden sadece 19 güne düştüğünde teslimat süresini %47 oranında iyileştirmiştir. Bu çalışmanın hedefi bu birleşimin değerini ispatlamak ve gelecekte yapılacak önemli araştırmalar için yapı taşı olmaktır.

Anahtar Sözcükler : Yalın Üretim, Değer Akışı Haritalama, Önceden Belirlenmiş Hareket Zamanı Sistemleri, MODAPTS, Teslimat süresi.

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INDEX OF ABBREVIATIONS

| | |
|----------|---|
| VSM | : Value Stream Mapping |
| MODAPTS | : Modular Arrangement of Predetermined Time Standards |
| MOD | : MODAPTS Measurement Unit |
| PMTS | : Predetermined Motion Time System |
| NVAs | : Non-Value-Added Activities |
| MTM | : Methods Time Measurement |
| MTM-UAS | : Methods Time Measurement Universal Analysis System |
| MOST | : Maynard Operation Sequence Technique |
| FIFO | : First in First out |
| WIP | : Work in Process |
| C/T | : Cycle Time |
| C/O | : Change Over Time |
| %C&A | : The Percentage of Complete and Accurate |
| Ele. No. | : Element Number |
| DESC. | : Description |
| PER. | : Number of Personnels |

CHAPTER 1

INTRODUCTION

Developing productivity is the main aim in the production environment. There are many methodologies to improve production processes. Among them, a portion consists of conventional techniques rooted in classical methodologies, while others encompass novel and contemporary approaches. The classical methods are usually about the general problems that may happen to the workers or/and the machines. On the other hand, some fields, such as Lean Manufacturing, provide many modern techniques, and it builds a new mindset to observe new problems. It makes people learn how to see waste, whether they are materialistic or not, such as wasted time. Using Lean Manufacturing techniques enhances the ability to analyse and solve problems effectively. After observing these micro problems, Lean Manufacturing techniques provide methods to solve them, and sometimes these methods are very simple but with great influence on the entire production system. There are many techniques of Lean Manufacturing, such as Kaizen, 5S, and Value Stream Mapping (VSM), which achieved great success and proved their efficiency. Lean production improves the efficiency of the manufacturing system by applying new activities through its tools to shape new guidance and direction [1]. For facilities that start applying Lean Manufacturing techniques, VSM is highly recommended to start because it is a way to change of seeing the production processes and figure out the real troubles in the system. In this thesis, the VSM technique is applied in the metal sector, specifically in a gas springs factory that currently begins to use Lean Manufacturing methodologies. VSM deals with time; where to see the wasted time, and how to minimise it. According to Patil, Pisal, and Suryavanshi, VSM is an effective tool for decreasing lead time, directly influencing the productivity situation [1]. Therefore, using VSM in this factory benefits for the production processes, explores the hidden reasons for time wasting, and gets rid of them as much as possible.

VSM only shows the current situation regarding the flow in production and indicates at which stations there is a possibility for improvement. After this stage, the question arises of how the progress will be made. Modular Arrangement of Predetermined Time Standards (MODAPTS) assumes a significant role in this context, presenting avenues for seizing improvement opportunities. MODAPTS is a Predetermined Motion Time System (PMTS) tool which applies to standardise the working time of any process. It analyses all the body motions, from the fingers to the entire body movement. It would be an added value for any study or application to determine its working time precisely. Consequently, MODAPTS is used as a supportive method in this study. It is done to determine the actual processing time for each station in the VSM. Thus, the problem addressed in this study becomes a real-world problem. The contribution of the paper is twofold. First, we present a new perspective by combining the unrelated VSM and MODAPST methods. Second, we present step-by-step how to reduce production time by addressing a real problem. In the following sections, the literature review mentions VSM and MODAPTS methods to explain them in detail and provides previous work that has worked on them to prove their competence. Then, the methodology section shows the steps of this application and reveals how VSM and MODAPTS work together in an effective combination. The application is conducted in a gas springs factory and on real data. The results should prove the significance of the Lean manufacturing techniques, especially for VSM methodology as an effective lean tool

CHAPTER 2

METHODS AND LITERATURE REVIEW

The methodology of this study is built on two techniques: VSM and MODAPTS. The main technique is VSM, a Lean Manufacturing tool that supposes to identify wasted time by drawing the whole production process as stations. MODAPTS is analysing the working time of each operator ergonomically to have precise information about the time that all workers spend doing their work individually, so this is the supporting tool for VSM. The following paragraphs will go smoothly deep into each approach to give a full understanding of the final approach and the model of the thesis.

2.1. LEAN MANUFACTURING

Through decades lean manufacturing has proven its efficiency in many studies. It provides solutions to an enormous number of obstacles and improves the performance in the production area and also some of its techniques were able to be applied in office work too. The main idea of lean manufacturing is to reduce waste to the lowest possible percentage. These wastes could be materialistic such as raw materials or nonmaterialistic like time. There are many challenges in the market such as the global competition and the lifecycle of the products that led the firms to rely on lean manufacturing to enhance their productivity [2]. Lean Manufacturing was invented in the factories of Toyota and lean refers to flexibility. It was applied in Toyota Production System, and it seeks to reach the highest efficiency by eliminating the causes of inflexibility in each process [3]. By reducing waste, the costs decrease in parallel leading to revenue increases for the companies. This advantage became essential for the firms to be able to compete in any market. Lean Manufacturing is managing the processes with the lowest cost possible in addition to taking all the

customers' demands into consideration [4]. When some companies started to apply the Lean Manufacturing technique after Toyota, the customers' needs increased because the same products were provided with higher quality and with shorter lead times. That forced many firms to start applying those techniques. The companies that applied the modern techniques of lean manufacturing were the companies that could survive in the market due to their flexibility and quick response to the needs of the customers leading to achieving their satisfaction [5]. All in all, lean manufacturing is like a production ideology or mentality that has many important methods and techniques and using them became a must to be able to survive and compete in today's global market circumstances.

2.1.1. Lean Manufacturing Tools and Techniques

There are many lean manufacturing techniques that had been used by many firms. Some of them are popular and common that often of the factories applying lean production use them and there are uncommon techniques too. It is very significant to have studied a group of tools from the same production philosophy to determine the most suitable choice with the highest economic benefit [6]. Thus, passing through the common lean manufacturing techniques briefly would give a better understanding of the case study. According to a Croatian study, the most commonly used lean manufacturing techniques are VSM, Kaizen, 5S, KPIs, and Standardized Work but the companies which are freshly transferring to the lean system usually tend to start with Kaizen or 5S [7]. Most of the lean manufacturing studies mention the importance and impact of Kaizen and 5S. That shows their importance of being added to this study or similar ones in the same scope. Kaizen is the basic tool of lean manufacturing which is used with other tools. Kai means development and Zen means continues so combined they mean continuous development, and it is about predicting the problems and providing clues to observe, identify, and improve the practice or process [8]. When kaizen became a work habit, it could increase the level of productivity more than expected due to the contribution of employees from all levels. 5S (Sort, Set, Shine, Standardize, Sustain) is also a significant tool. Sort is to separate the essential materials and equipment from the nonessential ones. Set is to put the essential stuff in easy places to get and put smoothly. Shine is to clean the workplace always and regularly.

Standardize is to make standard procedures which should be easy to understand and use them. Sustain is making sure of applying these procedures always and improving them [8]. In order to use 5S effectively, it should be applied as a continuous work culture and habit. Another tool that could be beneficial to start within a production area is VSM due to the fact that it already contains Kaizen as one of its improvement processes. It is detecting hidden problems by mapping the whole production process and uses Kaizen to eliminate them. Therefore, VSM was the most suitable lean manufacturing tool to be used in this study because it improves the production processes from an economic point of view, and it contains Kaizen one of the most common lean manufacturing tools.

2.1.2. Value Stream Mapping (VSM)

The real problems in production areas are often hidden and not seen. VSM expands the horizon and reshapes the way of thinking to see all non-value-added activities. VSM was invented firstly by Taiichi Ohno in 1978 as Muda Classification which means Waste Classification to identify the waste happening in companies. then, it was developed by Taiichi Ohno and Shigeo Shingo in 1980 to be known as VSM that's used to develop and improve companies by reducing wastes [9]. It covers the whole process to make it in the most effective shape as much as possible. VSM was invented in Toyota, Japan. It was identified by Taiichi Ohno, who found it as observing the timeline to take away the non-value-added wastes from the customer sending the order until receiving money [10]. It became a very popular technique that is used in many studies all over the world due to its efficiency in deducting problems.

As mentioned before, Muda means waste and lean manufacturing deals with waste to reduce or eliminate them. There are different types of waste that Lean Manufacturing is interested in. These mudas or wastes are overproduction, inventory, motion, defects, overprocessing, waiting, and transport. Overproduction is considered the most hazardous waste because overstocked items give manufacturers confidence. This sense of trust covers up the problems in production and destroys the possibility of improvement. Inventory is risky deterioration, breaking, burning, etc. As a result, materials may become unusable. In addition, resources that can be spent for more

production are spent on operations such as managing, transporting, protecting and storing stocks. The motions of the workers and machines should be studied, too, because some wrong or unnecessary motions may lead to an increase in production time. Manufacturing defects are one of the common wastes in all production areas. The defects are very costly regarding the repairing cost or the whole cost of the product if the defect is unrepairable and the products will be scraps. Overprocessing is mainly about adding unnecessary features that will not be used or needed in the products. These kinds of activities should be eliminated and focus only on the targeted features requested for the product. Waiting for the part in a production line prevents the flow of production. In addition, while the part is being processed on the machine, it should be ensured that the personnel are busy with another job simultaneously. As a result, part, machine, and personnel waiting times should be reduced to zero. Transport means the movement of materials from one production station to another one. The time and resources used in transporting the materials must be minimized to enhance the workflow on the production line. In this study, VSM and MODAPTS work on inventory, motion, waiting, and transport wastes.

To deal with waste effectively, the meaning and definition of the value should be well understood before any VSM application; the value in Lean Manufacturing is related to all the needed activities to make the requested product. In other words, they are activities that only make changes that the customer wants to the raw material or semi-finished product. So, any activity that interests the customer to consent to pay for leading to producing the final product is a value-adding activity. Rather than that, all the other activities are non-value-added activities (NVAs). However, not all non-value-added activities should be removed or eliminated because some of them are necessary activities. For instance, checking and controlling periodically in the middle of the production processes is not an activity that interests the customers and makes them willing to pay for it; it is a very significant activity to ensure the quality of the final product. The necessary NVAs shouldn't be treated as pure wastes that don't add any value or benefit and destroy the efficiency of the workflow of the production line. Dealing with the necessary NVAs has to be done by ensuring minimizing their spent time as much as possible with keeping the activity itself, which is in the ultimate

interest of the completeness of the product effectively. In this study, the classification of values and activities is done in this way.

VSM Methodology: Applying VSM is not complicated, but it needs to be accurate to come up with real results. It starts with drawing all the processes beginning with receiving the order and ending with delivering the goods. VSM works by drawing the current state that shows the whole processes of production to identify the largest number of wastes to eliminate them in a future state [11]. Basically, it works on developing the delivery time, which is the time from receiving the order from the customer to the end of the shipment process. After that, the wastes and non-value-added activities (NVAs) should be eliminated by a process called Kaizen. Kaizen is the improvement procedure, and it is an ongoing process to develop productivity and enhance the workplace by decreasing hard work and removing waste [12]. Finally, the final status should be drawn too to produce results.

2.1.3. Applying Value Stream Mapping in the Study

VSM starts with selecting the product family. Usually, the product family is chosen after studying all the products and finding out which family passes from most of the production process in the factory. The product family could be one item or a group of items that share the same production processes. Moreover, the cost and price should be considered while choosing the product family and prioritise the products with high costs or prices. The demand for the product is also helping to decide because it is preferable to work on ongoing demanded products. Ultimately, the product family should be chosen wisely to reflect the need of the application in the field.

There are two main parts to VSM. A current state has to be drawn to understand the production processes. The tool that will be used for drawing is Creately which is a diagramming and designing tool developed by Cinergix. A map will be developed in a future state after detecting and reducing the waste as much as possible. At first, there are special symbols to use for drawing a value stream map. These symbols have been identified and globalized since the born of VSM. Having common signs makes the

map readable globally and breaks the barrier of languages. The used symbols for VSM are explained in Figure 2.1 with their shapes in the Creately tool.

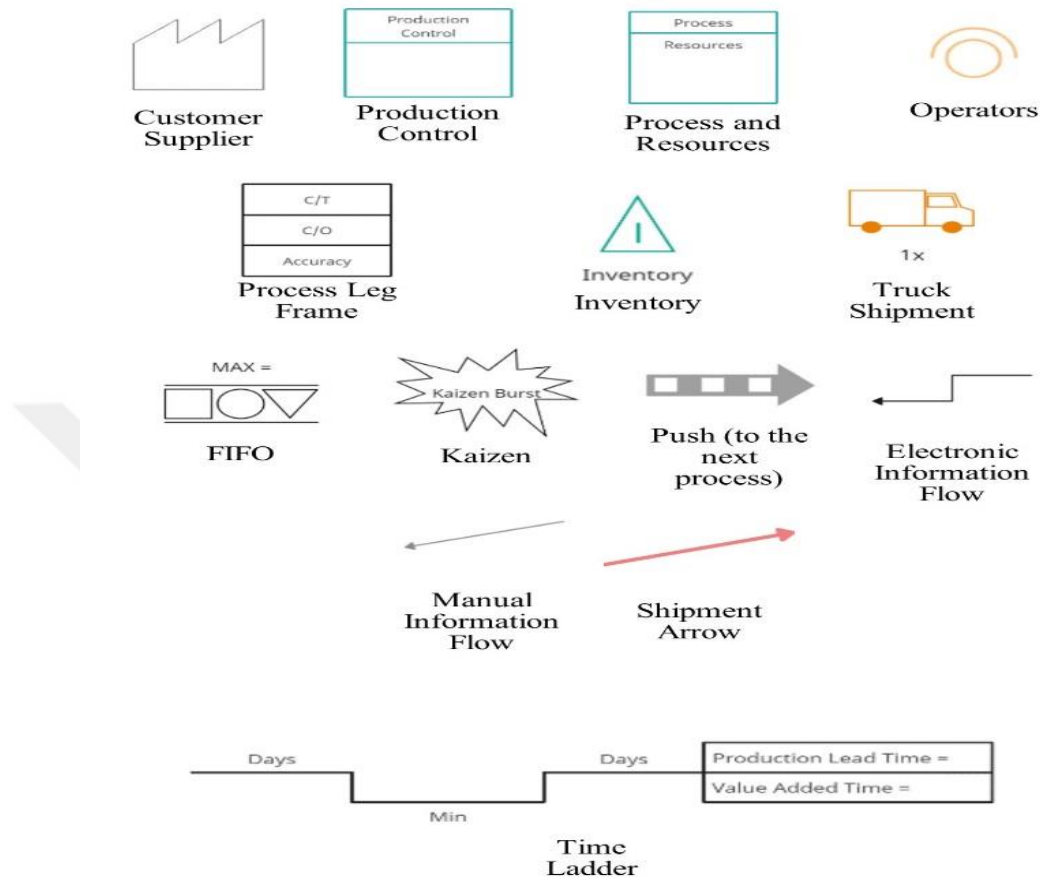


Figure 2.1. VSM symbols

The current map should be drawn in order to know the situation of the production process. The map always starts from the customer in the up-right corner of the page. Then, the production control receives the order information and electronically passes the needed components to the suppliers. The suppliers send the components to the warehouse, which transfers them to the production area and at the same time, the production control gives the orders to the production area manually (sometimes electronically too). After that, the items are pushed from one process to another until complete the finished goods and shipped to the customer. In each process (station) cycle time, change over time, accuracy, and operators' number are identified. Cycle time (C/T) means the time needed to finish one piece in each station, while change over time (C/O) means the time needed to finish a whole order and start another one.

Accuracy is a percentage that shows the efficiency of each machine by calculating the working and stopping time for the machines. The time ladder displays the entire time spent producing the order, including the Work in Process (WIP) inventory. To come up with the production lead time, value-added time, activity ratio, and rolled %C&A (the percentage of complete and accurate). These are the general steps for drawing the current situation map. However, in this study, before drawing the process leg frame and the time ladder, the MODAPTS technique is conducted on each station to calculate working time as a supporting tool for this methodology.

2.2. PREDETERMINED MOTION TIME SYSTEMS (PMTS)

VSM is working on finding the wasted time to improve productivity. Therefore, this study uses predetermined motion time systems (PMTS) as a supporter methodology to produce more accurate results. A study was conducted in Turkey combined VSM with MTM-UAS in the textile sector. MTM-UAS is a PMTS tool that was developed from MTM one of the most famous PMTS tools. After combining VSM and MTM-UAS in the textile factory, improvements occurred in the production lead time and non-value-added activities. The delivery time of the production decreased by 56% and the non-value-added activities by 57% [13]. Time is one of the most important factors in the production system. The production in a shorter time with keeping quality and cost at an accepted level always gives an advantage in the market. It can determine the capability of competition for the companies. So, time plays a serious role in the criteria of customer satisfaction. At the same time, production is a group of very complicated processes, and it is extremely difficult to be able to measure the time of a production process accurately. There are many techniques that have been created to measure the process time such as the stopwatch which is one of the most popular techniques in this field. Nevertheless, the accuracy of the stopwatch and the similar techniques is questionable due to the fact that they measure in seconds and sometimes there is a need for much more smaller measuring unit. From this standpoint, the predetermined motion time systems (PMTS) were created as a more efficient alternative to measure time accurately. The idea of PMTS is to analyse the motions in one or more tasks and there is a specific standard time that was predetermined already for each movement, and the total of these motions in one task will represent the fulfilment time of the task

[14]. Thus, by analysing the motions with small parts of seconds, the accuracy of timing was developed. The high competition in all markets demands a day-by-day evolution, especially in the production areas. It is impossible to improve what you cannot measure so PMTS provides accurate results by the analysis of the motions that can lead to a decrease in the movements so time will be shorter [15]. The detailed motion analysis of PMTS allows the applicators to eliminate the extra motions that add time to fulfil the task without any benefit. Generally, the way of analysing the motions through the PMTS technique is by filming the whole activity via a picture camera that allows seeing the activity in a very slow way to be able to be analysed. While filming, it must be ensured that the atmosphere is natural as the normal situation of the production. To be accurate, the operator who will be filmed while conducting the activity should be experienced and all factors and limitations should be taken into consideration [16]. Being cautious and precise in applying a PMTS analysis is very important because all the results will be built on the outputs of this analysis. In short, PMTS is a way to measure time, which is usually used in production to determine the time of a task or activity more accurately than the classical methods. Eventually, PMTS became more popular because of its many tools and each one of them proved its efficiency in many studies in different fields and all over the world.

2.2.1. PMTS Tools and Techniques

There are many techniques for PMTS and each one of them has its own characteristics. They are all deepened in coding the motions and standardizing the time for each movement. Having many tools and techniques doesn't mean that one is better than the other. However, each tool could be more suitable according to the case and its conditions. Therefore, before conducting a motion time analysis the applicator should study carefully more than one technique to decide which one is more suitable for the studied case. The most popular tools are MTM (Methods Time Measurement), MOST (Maynard Operation Sequence Technique), and MODAPTS (Modular Arrangement of Predetermined Time Standards); MTM and MOST are the often-used tools because of their similarity while the coding of MODAPTS is different [17]. MTM is known for its complexity and difficulty but still, it is the most preferable technique due to its unquestionable accuracy. Maybe the other tools aren't as accurate as MTM, but their

accuracy level could be enough for some activities and tasks. Also, some processes need more flexibility than accuracy. That's why, it is a must to have a basic knowledge at least about these 3 PMTS tools. To begin with, MTM is the original PMTS method, and it is developing day by day until these days. The impressive results of MTM made analysts turn a blind eye to its complexities so for sure it deserves to be explained in all PMTS studies. As a PMTS tool, the motions are coded, and each code is identified with a standard time. There are 4 main variables for MTM which are limbs, the transfer of motion, the manual control, and the affected weight or obstacle [18]. Each task is analysed in a very detailed sheet which makes MTM more complicated. On the other hand, this complexity led to generate many versions of MTM such as MTM1, MTM2, MTM-MEK, and MTM-UAS. Each one of them could be better according to the usage of the analysis. For instance, if the product has a medium time cycle with many repetitions, it is recommended to use MTM-UAS because it is simpler and could find the weaknesses directly with fewer analysing procedures [19]. The other popular tool is MOST which is always compared with MTM due to their similarities that made some researchers make studies just about comparing between these two techniques. MOST also uses coding but its way of analysing the motions is a bit different. What distinguishes MOST is dividing every single operation into smaller sub-operations that would be analysed separately and then combined at the end to come up with the standardized time of the whole operation [20]. A common point also with MTM, some versions were generated from MOST such as basic MOST, mini MOST, and maxi MOST. This was a brief explanation for two of the most popular PMTS tools, that gives a general idea about each one of them and it is important to give them a credit in this study as we use another popular PMTS tool which is MODAPTS. The coding system of MODAPTS is more interactive and direct so it simplifies the analysing process. Thus, owing to the high number of repetitions in the processes for the case study of this thesis, MODAPTS were preferred more than MTM. Choosing between MOST and MODAPTS was challenging but MODAPTS had an advantage because of 2 reasons. Firstly, taking more ergonomic aspects into consideration. Secondly, the harmony between MODAPTS and VSM because of the way MODAPTS identify the non-value-added motions. The following paragraphs will explain all these points related to MODAPTS in very informative details.

2.2.2. Modular Arrangement of Predetermined Time Standards (MODAPTS)

The method used in this study is the MODAPTS technique. MODAPTS is a PMTS from the third generation. Chris Heyde presented MODAPTS in 1966 to provide an accurate and easily applied system that can express the time that any body part takes in any movement starting from the finger movement, which needs the lowest possible amount of energy [21]. There are many similar techniques, such as MTM and MOST, which represent motions by standard times. The standard times are not always the real times; sometimes, they are more or less according to the circumstances. MODAPTS is a technique that gives the physical performance standard time represented as modules, and each movement is calculated through the multiple of the smallest unit in this system which is MOD [22]. MODAPTS is a developed version of MTM that can be used more quickly and gives more accurate results. Ergonomics and action analysis experiences of Heyde were combined in MODAPTS with analysing 21 actions of human bodies to reduce the timing scale to 0.1 seconds to be more efficient [23]. So, creating MODAPTS wasn't only about time measurement through its basic concept but also via taking the human factor into consideration. MODAPTS tries to consider the aspects that aren't considered by other standard PMTSs and fill some of their gaps, so it takes into count human error and studies human performance not only from the systems' approach but also the individual aspects [24]. It is important to choose which PMTS to be used because, as mentioned before, the standard time can be inaccurate according to the circumstances. In this study, MODAPTS was chosen because human factors play a significant role in this case.

2.2.3. Modular Arrangement of Predetermined Time Standards in the Study

MODAPTS is an MPTS method and according to previous studies, it is accurate to be applied in assembly production lines. It gives each movement a special code to be converted to time starting from the finger movement. The coding of the movements in MODAPTS is simple as shown in the Figures 2.2 and 2.3 that had been prepared by the International MODAPTS Association [25].

MODAPTS pocket guide simplifies the coding process. The codes are M, G, and P where M means the movement and after the latter M, a number will be selected according to which part of the body made the move. If the whole arm moved, number 4 is supposed to be chosen so it becomes M4. Each movement has a purpose starting with getting something and then putting it in a different place. For example, getting a screw from a complex area to be assembled in a specific location can be represented as M4G3M4P2. The unit of MODAPTS is MOD which is able to be converted to minutes by multiplying the number of MODs by 0.00215 and to seconds by multiplying by 0.129 so for the previous example there are 13 MODs that make 0.02795 min and 1.677 sec.


RIGHT HAND

LOW HIGH
CONSCIOUS CONSCIOUS
CONTROL CONTROL

| | G0 | G1 | P0 | G3 | P2 | P5 |
|----|----|----|----|----|----|----|
| G0 | 0 | 0 | 0 | 0 | 0 | 0 |
| G1 | 0 | 0 | 0 | 0 | 0 | 0 |
| P0 | 0 | 0 | 0 | 0 | 0 | 0 |
| G3 | 0 | 0 | 0 | X | X | X |
| P2 | 0 | 0 | 0 | X | X | X |
| P5 | 0 | 0 | 0 | X | X | X |

LEFT HAND

HIGH LOW
CONSCIOUS CONSCIOUS
CONTROL CONTROL



MODAPTS[®]

MODular Arrangement
of
Predetermined Time Standards

CAUTION
Do not attempt to use these tables in any way without receiving training from a qualified MODAPTS instructor.

CONVERSIONS

1 MOD = .129 sec.
1 MOD = .00215 min.
1 sec. = 7.75 MODS
1 min. = 465 MODS

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Figure 2.2. MODAPTS pocket guide page 1

| | | |
|---|--|--|
| MOVE M1 Finger 2.5 cm (1") M2 Hand 5 cm (2") M3 Forearm 15 cm (6") M4 Whole arm 30 cm (12") M5 Extended arm 45 cm (18") M7 Trunk 75 cm (30") | READ R2 One word - general reading R3 One word - careful reading R3 Reading up to 3 characters | JUGGLE J2 To gain better control |
| GET G0 Contact, or touch G1 Simple closing of fingers G3 Complex closing of fingers | DECIDE D3 For the unusual case | VOCALIZE V3 For each word spoken |
| PUT P0 To general locations P2 To specific locations P5 To exact locations | EYE CONTROL E2 Eye fixation E2 Eye travel E4 Eye focus | USE -- Back and forth movements No definite start or stop points U.5 Finger motions U1 Hand motions U2 Forearm motions U3 Whole arm motions |
| WALK W5 Per pace W2.96 Per linear foot W7.75 Per meter | NUMBER/COUNT N3 Per item, arranged N6 Per item, disarranged | LOAD FACTOR (effective net weight) L0 < 4.4 lbs (2kg) L1 > 4.4 lbs (2kg) < 13.3 lbs(6kg) Add one MOD for each added 8.8 lbs (4kg) |
| FOOT ACTION F3 15 cm (6") toe travel | BEND AND ARISE B17 Hand goes below knees | HANDWRITE H4 One character in continuous style, one punctuation mark H5 One character in print style, one digit or symbol H6 One character in cursive style, upper case H7 One character in print style, upper case H21 One word in cursive style H26 One word in print style H35 One word in all upper case |
| CRANK C3 Up to 8.9 cm (3.5") C4 Over 8.9 cm (3.5") | SIT AND STAND S30 Production work | |
| | EXTRA FORCE X4 A hesitation (not visible) | |

Figure 2.3. MODAPTS pocket guide page 2

2.3. LITERATURE REVIEW

This section provides very informative studies about the usage of VSM and MODAPTS. Thus, this literature review will be significantly rich with information in different fields such as Ergonomics, Time Standardization & Optimization, and of course Lean Production and manufacturing approaches in several sectors. The studies used in this thesis combined supported the building of the new model that this study works on effectively.

2.3.1. Studies Used VSM

Many studies in different fields and sectors rely on VSM. A review of the Scopus database reveals that the use of VSM has increased significantly only in the last five years. This increase is shown in Figure 2.4.

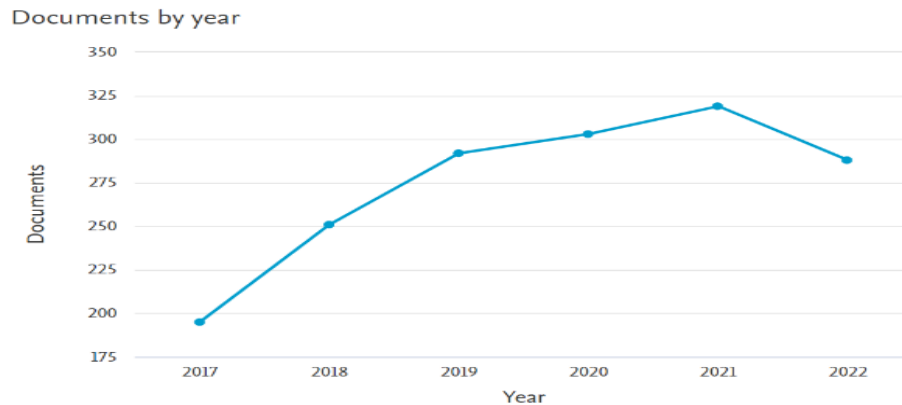


Figure 2.4. Documents by year that used VSM

2.3.1.1. Applying VSM in Different Regions

As mentioned, VSM has become a prevalent Lean Manufacturing technique worldwide. Many countries from different continents are using VSM. It has been applied in many studies that achieved great results. A steel factory in South Africa was suffering from waste and the cost of waste and its removal. After only one year of applying VSM, the waste decreased by 28% and the cost of waste disposal by 45% [26]. These rates are a very high percentage that shows how VSM can benefit any firm. Another study that had also been made in a steel factory in India sought to decrease the deadline for delivering goods. After eliminating NVAs in a steel factory in India, the lead time could be decreased from 33.41h to 14.55h [27]. In Indonesia, a food industry factory is looking for the same and reducing the lead time. The delivery time became 693 min after it was 773 min, and the non-value-added activities decreased from 3.10% to 1.01% [28]. These results have a major impact on the productivity of these factories. An automotive interior parts manufacturer in Bosnia and Herzegovina implemented VSM also to decrease production time. The lead time decreased to 7.4 days from 38.2 days, and the cycle time from 3.48 min to 1.16 min [29]. The improvement in lead time was almost 75%, so an extremely high development was achieved in this study. In short, these studies were from 4 different countries and three different continents, Africa, Asia, and Europe, and they all confirmed the efficiency of VSM.

2.3.1.2. Applying VSM in Different Industries

VSM was used in various industries and on different scales. It can be used with small product industries requiring precise manufacturing processes, such as the lock industry. After applying VSM, the lead time was reduced by 62.74% and the work-in-process inventory by 66.09% [30]. A small-scale heater manufacturer applied VSM too. As a result, the lead time decreased to 11 days from 17.5 days, and the NVAs became 2415 seconds from 3412 seconds [31]. Applying Lean Manufacturing techniques in these small industries are usually complicated. However, the results showed a high level of utility from using VSM. On a bigger scale, a gas stove manufacturer used VSM to reduce the lead time too. It was reduced from 5904.4 seconds to 4805.1 seconds, and the non-value-added from 485.65 seconds to 153.35 seconds [32]. A large-scale beam axle manufacturer applied VSM to increase the productivity of each section. The productivity in units/hr increased from 0.2094 to 0.3459 for section 1, 0.2314 to 0.4714 for section 2, 0.184 to 0.3435 for section 3, 0.115 to 0.3840 for section 4, 0.15 to 0.39 for section 5 [1]. The high increase in productivity rate in each section displays the success of implementing VSM. Even in the food industry, VSM showed a significant effect in finding solutions as a Chinese study presented. Kanban and Supermarket systems were suggested to improve communication in the production area due to the idea of receiving the feedback from the former process directly to keep the flow, and also the FIFO system reduced both the waiting time and the inventories between processes[33]. In brief, VSM proved that it is functional in all scales of production and in different industries, whether for simple products or complicated ones.

2.3.1.3. VSM Impact on Different Fields

This significant evolution in the production processes due to VSM has also had a massive impact on other departments. When there is an improvement in the productivity level, that will lead to a revival in different fields. Capacity improvement is one of the direct impacts of productivity development after applying VSM. A recent study focused on the effectiveness of VSM on capacity. There was a growth in capacity by 86% and a reduction in the workforce by 28% [34]. Minimizing the lead time by

VSM generates a new capacity space for new orders to increase profits or decrease costs. Generally, one of the common challenges that confront VSM is quality control because it is not a production process, but it is essential to complete the process in the right way. However, a developing company implemented VSM on the activity of the quality control department only. The NVAs were figured out as 778 min out of 848 min owing to the movement of the goods from the assembly line to the quality control station and the long time the goods wait until being checked [35]. The future status of this study could decrease the quality control time by 46%, and this percentage proves the capability of VSM to improve quality control too. E-commerce is playing a significant role in all markets nowadays. Between 2019 and 2020, Amazon used VSM on its supply chain process to improve it. A retailer from China who sell to North America was chosen, and after applying VSM to improve the supply chain process, the result was a dramatic sales increase for some goods, such as phone covers at 67% and party decorations at 72%, and without any complaint from customers regarding the delivery process [36]. This study proves the high impact of VSM that goes beyond the production lines and achieves success in different fields. Overall, these applications and their results give credibility for VSM and motivation to conduct it in all fields.

2.3.2. Studies Used MODAPTS

According to the Scopus database, recently, MODAPTS became an interesting topic for researchers in different fields, as shown in Figure 2.5. The larger percentage is for the engineering field. However, the percentage of computer science studies is large, due to the fact that some studies tend to automatize this technique, and this proves its efficiency.

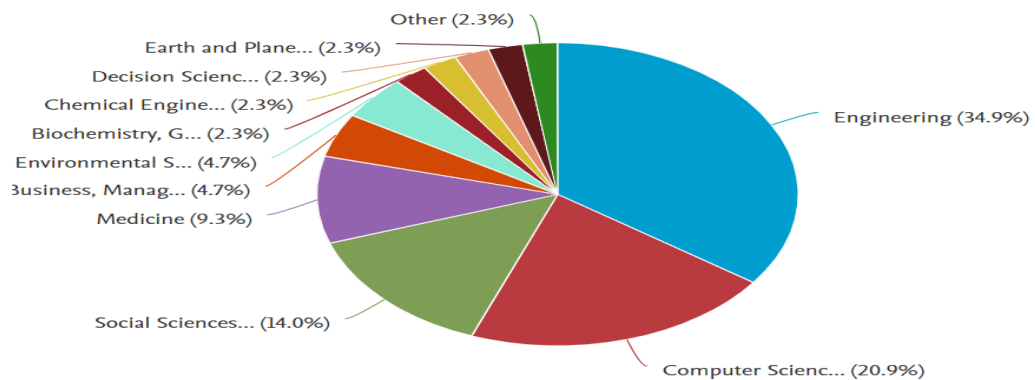


Figure 2.5. Fields that studied MODAPTS in the last 5 years

2.3.2.1. Applying MODAPTS in Different Industries

Many companies started to apply MODAPTS to test their efficiency, and some studies showed excellent results that confirmed the theoretical aspects in a practical way. MODAPTS validated accurate results as an analytical tool in both industrial and commercial companies [37]. An arc welding shop used MODAPTS, and after the application, the satisfaction level was high, and it was suggested for all companies start applying it. MODAPTS standardised the welding time, so the work timing became more rationalized, and welding hours were developed [38]. The production processes can be enhanced a lot by applying MODAPTS. A plastic pipeline manufacturer could achieve an improvement. MODAPTS analysed the motions of working and allowed the firm to identify the bottlenecks and reduce them to reach a productivity improvement of 25.35% [39]. There are other beneficial usages of MODAPTS. A cement packing facility applied it for a different purpose. The time of each operation was standardised with MODAPTS and calculate the working time for each operator was in order to know the workers who are doing a good job and increase productivity accordingly [40]. It is beneficial to have a method to test the performance of the worker because this allows managers and supervisors to be able to reallocate the workers according to their capabilities. An important advantage a warping process shop works on which is the ergonomic part. By using MODAPTS, the workplace had been redesigned to be safer and smoother for working; also, many solutions were found to eliminate the harmful working movements and positions that had been detected by MODAPTS [41]. The safety of the workers and their comfort while working will

directly increase their productivity level, and their tasks will be finished faster and with higher quality. Ultimately, these studies showed the advantages of applying MODAPTS in real-life applications, especially in the production area that this study will focus on to present another implementation in the same field.

2.3.2.2. The Combination of MODAPTS with Different Methods

The flexibility of MODAPTS allows it to be developed to be used for different purposes. Such applications increase the value of the methodology. For example, an electrical devices company used MODAPTS and a design factor technique called DFA to estimate costs in the design stage. MODAPTS is accurate enough to analyse the assembling line movements, and the model combined with DFA saves a lot of effort and time for the product design engineers to estimate the costs while designing the process [42]. Another study that supports this idea; proposed another method for time estimation and the design step for an assembly line built on PMTS. In order to choose the most suitable PMTS, tests were applied on MODAPTS, MTM, and AEM. The difference between actual time and MODAPTS results was a maximum of 9.5%, with MTM results between 13% - 18% and AEM results around 15% [43]. These numbers give credibility to prefer MODAPTS, which outperformed MTM and AEM, which is an assembling evaluation method and also proves its flexibility to be combined with other methodologies to achieve different purposes, such as a study in Korea that was focused on helping the elderly and disabled people. The study was built on the Universal Design (UD) method and principles, which aim to make everything usable and accessible for everyone, including people with disabilities. Also, there is a tool called the Product Performance Programme (PPP) which is used with UD to make sure that products are human-centred design so everyone can use them. The study suggested combining MODAPTS with these tools to have better results. MODAPTS coding and scoring for moving, getting, and putting activities is applicable and useful for designing UD products. That will lead the product design engineers to develop and systemize this model [44]. Thus, MODAPTS can play an important role to serve in evaluating special products, so this increases its value and makes it a great material for more studies. In brief, MODAPTS is a flexible and easy method to be merged with other methods to create new systems with more accurate results either in the Lean

Manufacturing field by dealing with wasted time or in the ergonomic area by highlighting harmful movements for the body.

All the solutions start from realizing and seeing the problems, so the main book of VSM is called Learning to See [45] which was a great guide in this study. This book in addition to the studies that this literature review covered makes a solid ground to start building the system that combines VSM and MODAPTS. All the studies used in this thesis demonstrated the leverage of VSM and MODAPTS compared to their competing techniques because they present real-life examples from different regions such as South Africa, Indonesia, and Bosnia in several different industries. Moreover, they displayed how this combination can be created and used successfully, and how both techniques can complete each other.

2.4. THE COMBINED MODEL OF VSM AND MODAPTS

This study is working on a combination between VSM and MODAPTS, which had been chosen as a supporting method to enhance the accuracy of VSM. MODAPTS was selected due to the common points between it and VSM that would make this combination works effectively. MODAPTS is a technique that evaluates time to decide the best moves for the workers in their workstations by considering the visual connection of the workers with the components or the tools they deal with after filming the station to be analysed [46]. Workstation is a common term between VSM and MODAPTS. They both divide the whole production process into stations and work on them separately, one by one. MODAPTS is used to analyse the process, and by combing process time, a standard cycle time can be estimated so efficiency will be able to be evaluated [47]. So, the cycle time in the VSM can be estimated and standardized by MODAPTS, which improves the entire model. The previously mentioned studies proved the efficiency of MODAPTS as a PMTS method in standardizing time for the assembly lines in the production area. Therefore, building the cycle time of VSM on MODAPTS will give it more credibility. Researchers found that MODAPTS is a valuable method to detect and remove non-value-added activities, which will improve performance, increase productivity, and minimize bottlenecks [48]. Eliminating the NVAs is the main purpose of VSM, which makes MODAPTS

very appropriate for this combination. The results of MODAPTS can clearly show the non-value-added activities that should be minimized in the value stream map. Both VSM and MODAPTS deal with time. VSM seeks to decrease wasted time, and MODAPTS analyse the processing time, and this leads to productivity improvement. For instance, a machine manufacturer used MODAPTS to analyse the assembly line of a packaging machine. MODAPTS were used to find inactive time in each station to be eliminated, and as a result, the productivity level grew to 41.72% [49]. This real-life example proves that there are many intersectional points between MODAPTS and VSM. They both work on time, workstations, and NVAs to develop productivity. To sum up, the mutual aspects between VSM and MODAPTS make them create an integrated system that this paper proves the success and effectiveness of this system.

For this study, a MODAPTS sheet is used as shown in the tables in the application section. A separate sheet was used for each station and each movement was added as an element in the sheet after recording a video for each working station. The movements were coded according to MODAPTS Pocket Guide, and the MODs were calculated and converted to minutes and seconds. There are two parts in the sheet; the first one is for repeated movements that happen while producing the whole order according to the order quantity. The second part is for the non-cyclic elements that are not repeated during the entire production process, such as machine adjustments and some quality control activities. Finally, the sheet contains the standard time to produce one piece and the time to produce the whole order. The time to produce one item can represent the C/T, and the total time for the whole order plus breaks and wasted time generates the C/O time in VSM.

The table of the MODAPTS sheet analyses the workers' movements, so it is also used to identify the non-value-added activities on it. The elements that do not add value were painted in dark grey. Some of these elements cannot be removed or reduced because of their importance, such as quality control activities that are not adding value to production, but they cannot be eliminated, so they were painted light grey. These data were entered in the Process Leg Frame and the Time Ladder of the value stream map to finalize the current status.

The future status was built on the MODAPTS sheet of each station, and the outlooks were gained after completing the analysis for the production processes. The dark grey

areas should be reduced as much as possible to increase efficiency. Moreover, some VSM tools, such as merging two stations, continuous flow, and FIFO was used as well. After that, the future state was drawn, but again before completing the map, a re-MODAPTS step for all stations with their new status was made. VSM was finalized by adding new MODAPTS results to the map as was done in the current status. The final stage was making Time & Quality Value Stream Performance Metric to compare the current status with the future status. The outcomes of this Metric present the efficiency and success of the application. Employing all these tools for both of these techniques should lead to a huge development and prove the success of combining MODAPTS and VSM. The next section of this thesis transforms the methodologies into an applied experience in a gas springs factory.

Table 2.1. Literature review table

| No | Author name(s) | Title | Publisher | Usage |
|----|------------------------|--|--|--|
| 1 | Patil et al. (2021) | Application of value stream mapping to enhance productivity by reducing manufacturing lead time in a manufacturing company: A case study | Journal Of Applied Research and Technology | VSM's efficiency and usage in Beam Axle Industry |
| 2 | Buer et al. (2021) | The complementary effect of lean manufacturing and digitalisation on operational performance | Int J Prod Res | Lean Manufacturing importance |
| 3 | Budianto et al. (2021) | The effect of manufacturing agility competencies on lean manufacturing in increasing operational performance | Uncertain Supply Chain Management | The origin of Lean Manufacturing |
| 4 | Abidin et al. (2022) | Lean impact on manufacturing productivity: A case study of industrialized building system (IBS) manufacturing factory | J Teknol | The main target of Lean Manufacturing |
| 5 | Wassan et al. (2022) | The current status of lean manufacturing in small, medium and large scale manufacturing companies of Karachi, Pakistan | Journal of Applied Engineering Science | The features of Lean Manufacturing |

| | | | | |
|-----------|---------------------------|--|--|---|
| 6 | Díaz-Reza et al. (2022) | Relationship between lean manufacturing tools and their sustainable economic benefits | International Journal of Advanced Manufacturing Technology | Introducing Lean Manufacturing Tools |
| 7 | Leksic et al. (2020) | The impact of using different lean manufacturing tools on waste reduction | Advances in Production Engineering and Management | The most popular Lean Manufacturing Tools |
| 8 | Guzel & Asiabi (2022) | Increasing productivity of furniture factory with lean manufacturing techniques (case study) | Tehnicki Glasnik | Brief explanations for Kaizen and 5S |
| 9 | Salwin et al. (2021) | Using value stream mapping to eliminate waste: A case study of a steel pipe manufacturer | Energies | VSM's history |
| 10 | Romero & Arce (2017) | Applying value stream mapping in manufacturing: A systematic literature review | IFAC Papers OnLine | VSM's history |
| 11 | Kale & Parikh (2019) | Lean implementation in a manufacturing industry through value stream mapping | International Journal of Engineering and Advanced Technology | VSM methodology |
| 12 | Jasti et al. (2020) | An application of value stream mapping in auto-ancillary industry: A case study | TQM Journal | Kaizen meaning |
| 13 | Demirci & Gündüz (2020) | Combined application proposal of value stream mapping (VSM) and methods time measurement universal analysis system (MTM-UAS) methods in textile industry | Endüstri Mühendisliği | A combination of VSM and a PMTS tool in a study from Turkey |
| 14 | León-Duarte et al. (2019) | A software tool for the calculation of time standards by means of predetermined motion time systems and motion sensing technology | Advances in Intelligent Systems and Computing | The definition of PMTS |

| | | | | |
|-----------|------------------------------|---|--|-------------------------------|
| 15 | Mondal & Jana (2022) | Application of predetermined motion and time system in sewing automat to enhance the productivity and operator utilisation | Research Journal of Textile and Apparel | The main target of PMTS |
| 16 | Angel et al. (2022) | Developing an AR based tool for teaching motion analysis on assembly tasks | Institute of Electrical and Electronics Engineers Inc | Conducting PMTS |
| 17 | Viharos & Bán (2020) | Comprehensive comparison of MTM and BasicMOST, as the most widely applied PMTS analysis methods | International Measurement Confederation, IMEKO | Introducing PMTS Tools |
| 18 | Engineering & Sumarmi (2019) | Measurement of standard time work with the predetermined motion time system method at the production department in PT | The Asian Institute of Research Engineering and Technology Quarterly Reviews | MTM explanation |
| 19 | Bellarbi et al. (2019) | Towards method time measurement identification using virtual reality and gesture recognition | IEEE | MTM versions |
| 20 | Kumar et al. (2020) | Productivity enhancement of assembly line by using Maynard operation sequence technique after identification of lean wastages | International Journal of Productivity and Quality Management | MOST explanation |
| 21 | Genaidy et al. (1990) | Computerized predetermined motion-time systems in manufacturing industries | Computers and Industrial Engineering | History of MODAPTS |
| 22 | Wygant et al. (1993) | Combining ergonomics and work measurement for job analysis | Computers And Industrial Engineering | MODAPTS technique explanation |
| 23 | Hu (2021) | Research on the application of mod method, the core technology of industrial engineering | IOP Science | MODAPTS technique explanation |

| | | | | |
|----|---|---|---|--|
| 24 | Chan et al. (2017) | Subjective estimates of times for assembly work | International Journal of Industrial Ergonomics | Advantage of MODAPTS |
| 25 | International MODAPTS Association (2018) | MODAPTS pocket guide | Eisbrenner Productivity Group | Explaining the codes of MODAPTS |
| 26 | Schoeman et al. (2021) | Value stream mapping as a supporting management tool to identify the flow of industrial waste: A case study | Sustainability, Switzerland | Presenting a study from South Africa |
| 27 | Sudhakara et al. (2020) | Management of non-value-added activities to minimize lead time using value stream mapping in the steel industry | Acta Montanistica Slovaca | Presenting a study from India |
| 28 | Zahrotun & Taufiq. (2018) | Lean manufacturing: waste reduction using value stream mapping | EDP Sciences | Presenting a study from Indonesia |
| 29 | Yüksel & Uzunović (2019) | Application of value stream mapping in a manufacturing firm in Bosnia and Herzegovina | Yönetim Ve Ekonomi: Celal Bayar Üniversitesi İktisadi Ve İdari Bilimler Fakültesi Dergisi | Presenting a study from Bosnia and Herzegovina |
| 30 | Parab & Shirodkar (2019) | Value stream mapping: A case study of lock industry | AIP Publishing | Using VSM in Lock Industry |
| 31 | Zahraee et al. (2020) | Lean manufacturing analysis of a heater industry based on value stream mapping and computer simulation | Procedia Manufacturing | Using VSM in Heater Industry |
| 32 | Hernadewita & Rohimah (2018) | Lean manufacturing implementation using value stream mapping to | International Journal of Mechanical | Using VSM in Gas Stove Industry |

| | | | | |
|----|-------------------------------|---|---|---|
| | | eliminate seven waste in painting process | and Production Engineering Research and Development | |
| 33 | Liu et al. (2020) | Applying value stream mapping in an unbalanced production line: A case study of a Chinese food processing enterprise | Quality Engineering | Using VSM in Food Industry |
| 34 | Dinesh et al. (2019) | Capacity enhancement through value stream mapping and line balancing technique in compressor assembly line | International Journal of Innovative Technology and Exploring Engineering | VSM impact on capacity growing |
| 35 | Ikatrinasari & Kosasih (2018) | Improving quality control process through value stream mapping | International Journal of Engineering and Technology | VSM impact on quality control |
| 36 | Qin & Liu (2022) | Application of value stream mapping in e-commerce: A case study on an Amazon Retailer | Sustainability, Switzerland | VSM impact on e-commerce |
| 37 | Chen et al. (2020) | A maintenance time estimation method based on virtual simulation and improved modular arrangement of predetermined time standards | International Journal Of Industrial Ergonomics | Th efficiency of MODAPTS |
| 38 | Ma et al. (2014) | Arc welding working hours based on MODAPTS | Trans Tech Publications | MODAPTS advantages in the production area |
| 39 | Xu et al. (2013) | The discussion on the application of MODAPTS about improving the pipeline of plastic enterprise | Proceedings of 20th Int. Conf. on Industrial Engineering and Engineering Management | MODAPTS advantages in the production area |

| | | | | |
|----|---------------------------------|---|--|--|
| 40 | Erliana and Abdullah (2018) | Application of the MODAPTS method with innovative solutions in the cement packing process | Inter. Journal of Engineering and Technology | MODAPTS advantages in the production area |
| 41 | Šabarić et al. (2013) | Application of the MODAPTS method with innovative solutions in the warping process | Fibres And Textiles in Eastern Europe | MODAPTS advantages in the production area |
| 42 | Cho et al. (2014) | Time estimation method for manual assembly using MODAPTS technique in the product design stage | International Journal of Production Research | MODAPTS combination with other methods |
| 43 | Cho & Park (2014) | Motion-based method for estimating time required to attach self-adhesive insulators | CAD Computer Aided Design | MODAPTS combination with other methods & comparison with MTM and AEM |
| 44 | Park (2014) | Design evaluation method for universal product development | Trans Tech Publications | MODAPTS combination with other methods |
| 45 | Rother & Shook (1999) | Learning to see | Lean Enterprise Institute | Mentioning the main book in VSM |
| 46 | Assef et al. (2018) | Confrontation between techniques of time measurement | Journal of Manufacturing Technology Management | Common points between VSM and MODAPTS |
| 47 | Stewart & Athinarayana n (2000) | MODAPTS and human data simulation | SAE International | Common points between VSM and MODAPTS |
| 48 | RAJ et al. (2021) | Productivity improvement of an automotive assembly line using modular arrangement of predetermined time standards (MODAPTS) | I-Manager's Journal on Future Engineering and Technology | Common points between VSM and MODAPTS |

| | | | | |
|-----------|----------------------|--|------|---|
| 49 | Sun et al. (2009) | Study on work improvement in a packaging machine manufacturing company | IEEE | Common points between VSM and MODAPTS |
|-----------|----------------------|--|------|---|

All the studies used in this thesis contributed significantly to complete the model. As Table 2.1 shows each study had a role to explain and clarify a topic either about VSM or MODAPTS. Also, the real-life examples in some studies approved the efficiency of the techniques. Moreover, some studies are used to support the idea of the harmony of both techniques, and they can be combined into one model. The new model of the combination of VSM and MODAPTS is what differentiates this thesis from the other studies used in the methodology or the literature review. This model can be considered as the added value and the new contribution of the study, which gathered the substance of the studies to shape and introduce the combination of VSM and MODAPTS in one model. Hence, this thesis provides a new and different contribution to support either VSM and MODAPTS techniques separately or combined.

CHAPTER 3

APPLICATION IN THE METAL SECTOR

This study is going to be conducted in the metal sector, which means the industries of shaping metal materials to make useful goods. It is a real-life case study that was applied in a gas springs factory by the Production Planning Engineer who is responsible for this field in the workplace and under the supervision of the Planning Manager. The application aims to approve and support the studies in the literature review and add to them through its touchable results. The application will go through some sections. Firstly, a brief about the company. Then, VSM and MODAPTS are applied separately. After that, combining them in one model for both the current status and future status. This model leads to very accurate and realistic results which have a great value for the applied field and the research field.

3.1. COMPANY INFORMATION

The application was made in the Global Gas Springs factory which is a multinational (Turkish – French – German) enterprise in Tekirdag - Turkey. The factory specializes in gas springs and their own end fittings and spare parts with more than 25 years of experience in that field. The company was established in 2003 in Istanbul and in 2019 it moved to Tekirdag for a bigger facility while keeping the branch in Istanbul for selling purposes. The enterprise is interested in all the industries related to the gas springs such as automotive, medical, defence, and more. The main competing area of the factory is France, Germany, England, and the Netherlands with more than 85% of exporting rate all over the world. The staffing of the factory exceeds 100 people with 15 office employees (5 of them are Engineers) and the ability of contact with Turkish, English, French, German, Portuguese, and Arabic. In the gas springs factory, there are many processes for shaping and reshaping metals to be more beneficial components.

Gas springs are products that help to lift heavy items dynamically and hydraulically by the support of the gas and oil inside of them.

3.2. VSM APPLICATION FOR CURRENT STATE

There are many types of gas springs, and they go through different processes. Thus, to apply VSM, there is a need to identify a specific product or a product family that shares the same production processes and goes through the same manufacturing stations. In this study, the gas springs used for Double Decker Bicycle Racks whose orders come as 4000 pcs/order were chosen for a couple of reasons. Firstly, they pass through 81% of all production processes in the factory. Also, they are in second place for the highest orders prices, which means one of the most profitable goods for the firm. Lastly, there is a dramatic increase in demand as the following chart in Figure 3.1 displays.

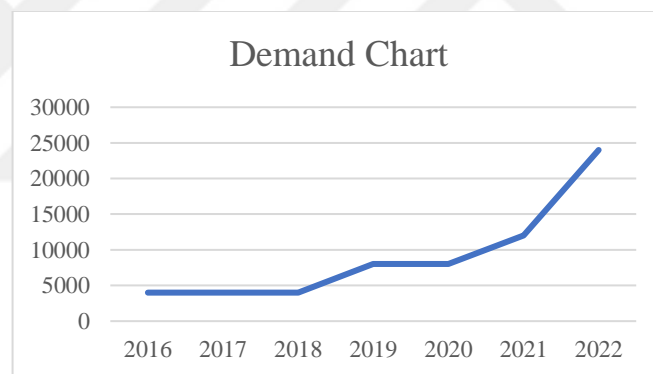


Figure 3.1. The demand increase for the chosen product

The current situation started by getting the order from the customer and verifying the delivery time of receiving the missing components from the suppliers. Then, analyse the workstations that the product goes through. There were 13 stations that were studied, which are rod cutting, rod shaping, tube cutting, tube chamfering, pistons assembling, riveting, end plug assembling, oil filling, rolling & closing, gas filling, painting, end fitting assembling, and packaging. After studying them, they all have been presented in the pre-current status of VSM as shown in Figure 3.2.

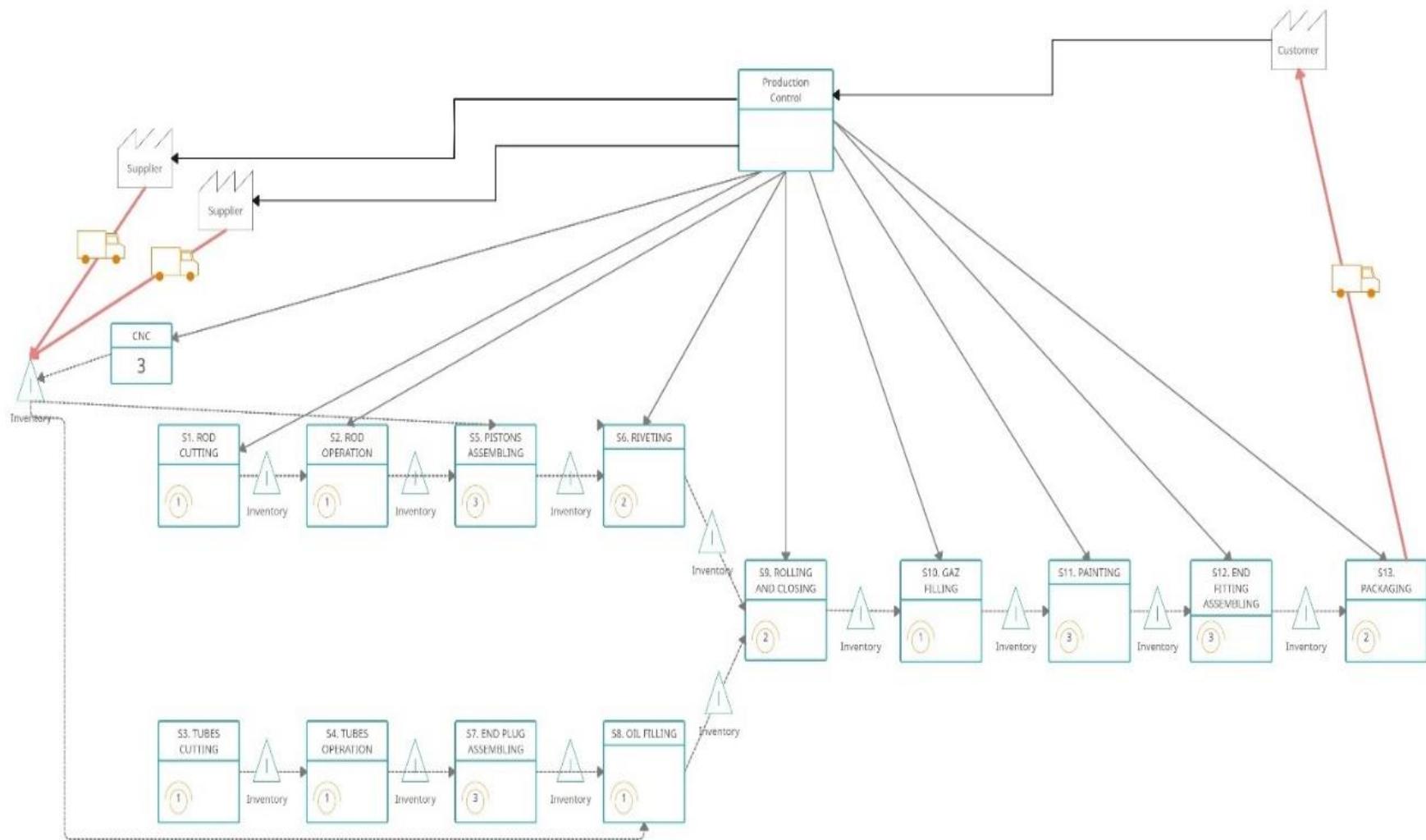


Figure 3.2. The pre-current state of VSM

3.3. MODAPTS APPLICATION

MODAPTS were applied on each station separately, and the non-value-added activities were indicated in the tables. The tables below show the 13 MODAPTS tables for the 13 stations of this study in their current state. Each motion has a unique MODAPTS code representing the distance or the way that any part of the body moves in letters and numbers that can be converted to time. For instance, The MODAPT study performed at Station 1 is presented in Table 4.1. The ninth move in the table is getting the rod, so its code is M5G1, M for movement, five because the body moved with the whole arm, G for getting the rod, and one because the rod is not in a complex place. The total MODs for this motion is six and to get minutes, we multiply five by 0.00215 and for seconds, we multiply by 0.129. The frequency means how many times this motion is repeated in the whole order, and the next column is for the number of persons or operators conducting this activity. Then, to get the total MODs, minutes, and seconds, we multiply them by the frequency and divide them by the number of persons. Table 3.1 is the MODAPTS table for station 1 where an operator is responsible for cutting the rods.

Table 3.1. MODAPTS table for station 1

| <u>STATION NAME</u> | | <u>STATION NUMBER</u> | | | | | | | | | |
|---------------------|-----------------------------------|-----------------------|---------------|-------|---------|---------|-------|------|------------|---------------|---------------|
| RODS CUTTING | | 1 | | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MODS | MINUTES | SECONDS | FREQ. | PER. | Total MODS | Total MINUTES | Total SECONDS |
| 1 | Get the cutter | RH | M4G1S30 | 35 | 0.075 | 4.515 | 160 | 1 | 5600 | 12.04 | 722.4 |
| | | LH | | | | | | | | | |
| 2 | Put the cutter on the rod's cover | RH | M4P5 | 9 | 0.019 | 1.161 | 160 | 1 | 1440 | 3.096 | 185.76 |
| | | LH | | | | | | | | | |
| 3 | Cut the cover | RH | W23.25X4 | 27.25 | 0.059 | 3.515 | 160 | 1 | 4360 | 9.374 | 562.44 |
| | | LH | | | | | | | | | |
| 4 | Get a part of the cover out | RH | M4G1 | 5 | 0.011 | 0.645 | 160 | 1 | 800 | 1.72 | 103.2 |
| | | LH | | | | | | | | | |
| 5 | Take the part of the cover out | RH | M4P0 | 4 | 0.009 | 0.516 | 160 | 1 | 640 | 1.376 | 82.56 |
| | | LH | | | | | | | | | |

| | | | | | | | | | | | |
|---------------------|--------------------------------|----|-----------|-------|---------|---------|------|---|------------|---------------|---------------|
| 6 | Go back to the machine | RH | W23.25S30 | 53.25 | 0.114 | 6.869 | 160 | 1 | 8520 | 18.318 | 1099.08 |
| | | LH | | | | | | | | | |
| 7 | Get another part of the cover | RH | M4G1 | 5 | 0.011 | 0.645 | 160 | 1 | 800 | 1.72 | 103.2 |
| | | LH | | | | | | | | | |
| 8 | Take the part of the cover out | RH | M4P0 | 4 | 0.009 | 0.516 | 160 | 1 | 640 | 1.376 | 82.56 |
| | | LH | | | | | | | | | |
| 9 | Get the rod | RH | M5G1 | 6 | 0.013 | 0.774 | 4000 | 1 | 24000 | 51.6 | 3096 |
| | | LH | | | | | | | | | |
| 10 | Put the rod in the machine | RH | M5P5 | 10 | 0.022 | 1.29 | 4000 | 1 | 40000 | 86 | 5160 |
| | | LH | | | | | | | | | |
| 11 | Foot press | RH | F3 | 3 | 0.006 | 0.387 | 4000 | 1 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 12 | Get the cut rod | RH | M3G1 | 4 | 0.009 | 0.516 | 4000 | 1 | 16000 | 34.4 | 2064 |
| | | LH | | | | | | | | | |
| 13 | Put the cut rods in the box | RH | M5P2 | 7 | 0.015 | 0.903 | 4000 | 1 | 28000 | 60.2 | 3612 |
| | | LH | | | | | | | | | |
| 14 | Check the rods | RH | | | 0.2 | 12 | 320 | 1 | | 64 | 3840 |
| | | LH | | | | | | | | | |
| NON-CYCLIC ELEMENTS | | | | | | | | | | | |
| 1 | Adjusting the machine | RH | | | 3.58 | 214.8 | 1 | 1 | | 3.58 | 3.58 |
| | | LH | | | | | | | | | |
| 2 | Get the compass | RH | M5G1 | 5 | 0.011 | 0.645 | 2 | 1 | 10 | 0.022 | 1.29 |
| | | LH | | | | | | | | | |
| 3 | Put the compass on the rod | RH | M5P5E4 | 14 | 0.03 | 1.806 | 2 | 1 | 28 | 0.06 | 3.612 |
| | | LH | | | | | | | | | |
| 4 | Put the compass back | RH | M5P2 | 7 | 0.015 | 0.903 | 2 | 1 | 14 | 0.03 | 1.806 |
| | | LH | | | | | | | | | |
| TOTAL | | | | MODS | MINUTES | SECONDS | | | Total MODS | Total MINUTES | Total SECONDS |
| | | | | 198.5 | 4.207 | 252.407 | | | 142852 | 374.712 | 22271.488 |

Table 3.2 shows the MODAPTS analysis for station 2 where an operator is machining both sides of the rods, one for the piston side and the other for the thread.

Table 3.2. MODAPTS table for station 2

| STATION NAME | | STATION NUMBER | | | | | | | | | |
|---------------------|--|----------------|---------------|------|---------|---------|-------|------|------------|---------------|---------------|
| RODS OPERATION | | 2 | | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MODS | MINUTES | SECONDS | FREQ. | PER. | Total MODS | Total MINUTES | Total SECONDS |
| 1 | Get the rods from the box | RH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 1 | 20000 | 43 | 2580 |
| | | LH | | | | | | | | | |
| 2 | Put the rod in the machine for piston side operation | RH | W5M4P5 | 14 | 0.03 | 1.806 | 4000 | 1 | 56000 | 120.4 | 7224 |
| | | LH | | | | | | | | | |
| 3 | Press the first button | RH | M4G0X4 | 8 | 0.017 | 1.032 | 4000 | 1 | 32000 | 68.8 | 4128 |
| | | LH | | | | | | | | | |
| 4 | Press the second button | RH | M3G0X4 | 7 | 0.015 | 0.903 | 4000 | 1 | 28000 | 60.2 | 3612 |
| | | LH | | | | | | | | | |
| 5 | Machining time | RH | | | 0.3 | 18 | 4000 | 1 | | 1200 | 72000 |
| | | LH | | | | | | | | | |
| 6 | Get the rod from the machine | RH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 1 | 28000 | 60.2 | 3612 |
| | | LH | | | | | | | | | |
| 7 | Put the rod in the box | RH | W5M4P2 | 11 | 0.024 | 1.419 | 4000 | 1 | 44000 | 94.6 | 5676 |
| | | LH | | | | | | | | | |
| 8 | Get the rods from the box | RH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 1 | 20000 | 43 | 2580 |
| | | LH | | | | | | | | | |
| 9 | Put the rod in the machine for thread side operation | RH | W5M4P5 | 14 | 0.03 | 1.806 | 4000 | 1 | 56000 | 120.4 | 7224 |
| | | LH | | | | | | | | | |
| 10 | Press the first button | RH | M4G0X4 | 8 | 0.017 | 1.032 | 4000 | 1 | 32000 | 68.8 | 4128 |
| | | LH | | | | | | | | | |
| 11 | Press the second button | RH | M3G0X4 | 7 | 0.015 | 0.903 | 4000 | 1 | 28000 | 60.2 | 3612 |
| | | LH | | | | | | | | | |
| 12 | Machining time | RH | | | 0.51 | 30.6 | 4000 | 1 | | 2040 | 122400 |
| | | LH | | | | | | | | | |
| 13 | Get the rod from the machine | RH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 1 | 28000 | 60.2 | 3612 |
| | | LH | | | | | | | | | |
| 14 | Put the rod in the box | RH | W5M4P2 | 11 | 0.024 | 1.419 | 4000 | 1 | 44000 | 94.6 | 5676 |
| | | LH | | | | | | | | | |
| NON-CYCLIC ELEMENTS | | | | | | | | | | | |
| 1 | Adjusting the machine | RH | | | 10 | 600 | 1 | 1 | | 10 | 600 |
| | | LH | | | | | | | | | |

| | | | | | | | | | | | |
|-------|---------------------------------------|----|--------|------|---------|---------|-----|---|------------|---------------|---------------|
| | for piston side | | | | | | | | | | |
| 2 | Get the compass | RH | M5G1 | 6 | 0.013 | 0.774 | 400 | 1 | 2400 | 5.16 | 309.6 |
| | | LH | | | | | | | | | |
| 3 | Put the compass on the rod | RH | M5P5E4 | 14 | 0.03 | 1.806 | 400 | 1 | 5600 | 12.04 | 722.4 |
| | | LH | | | | | | | | | |
| 4 | Put the compass back | RH | M5P2 | 7 | 0.015 | 0.903 | 400 | 1 | 2800 | 6.02 | 361.2 |
| | | LH | | | | | | | | | |
| 7 | Adjusting the machine for thread side | RH | | | 15 | 900 | 1 | 1 | | 15 | 900 |
| | | LH | | | | | | | | | |
| TOTAL | | | | MODS | MINUTES | SECONDS | | | Total MODS | Total MINUTES | Total SECONDS |
| | | | | 131 | 26.092 | 1565.5 | | | 426800 | 4182.62 | 250957.2 |

Table 3.3 displays the MODAPTS sheet for station 3 where the tubes are cut by one operator.

Table 3.3. MODAPTS table for station 3

| STATION NAME | | STATION NUMBER | | | | | | | | | |
|---------------|--------------------------------------|----------------|---------------|-------|---------|---------|-------|------|------------|---------------|---------------|
| TUBES CUTTING | | 3 | | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MODS | MINUTES | SECONDS | FREQ. | PER. | Total MODS | Total MINUTES | Total SECONDS |
| 1 | Get the tubes from the shelves | RH | M7G3 | 10 | 0.022 | 1.29 | 20 | 1 | 200 | 0.43 | 25.8 |
| | | LH | | | | | | | | | |
| 2 | Pull the tubes | RH | M7W14.16L8 | 29.16 | 0.063 | 3.762 | 20 | 1 | 583.2 | 1.254 | 75.233 |
| | | LH | | | | | | | | | |
| 3 | Put the tubes on the shoulders | RH | M5P2L8 | 15 | 0.032 | 1.935 | 20 | 1 | 300 | 0.645 | 38.7 |
| | | LH | | | | | | | | | |
| 4 | Walk to the cutting machine | RH | W47.2L8 | 55.2 | 0.119 | 7.121 | 20 | 1 | 1104 | 2.374 | 142.416 |
| | | LH | | | | | | | | | |
| 5 | Get the tubes from the shoulders | RH | | | | | | | | | |
| | | LH | M5G1 | 6 | 0.013 | 0.774 | 20 | 1 | 120 | 0.258 | 15.48 |
| 6 | Put the tubes in the machine | RH | M7P5L8 | 20 | 0.043 | 2.58 | 20 | 1 | 400 | 0.86 | 51.6 |
| | | LH | | | | | | | | | |
| 7 | Hold the hanger of the machine cover | RH | M4G1 | 5 | 0.011 | 0.645 | 40 | 1 | 200 | 0.43 | 25.8 |
| | | LH | | | | | | | | | |
| 8 | | RH | M5P0 | 5 | 0.011 | 0.645 | 40 | 1 | 200 | 0.43 | 25.8 |

| | | | | | | | | | | | |
|---------------------|---------------------------------|----|----------|--------|---------|---------|------|---|------------|---------------|---------------|
| | Pull up the machine cover | LH | | | | | | | | | |
| 9 | Get 2 tubes from the feeder | RH | M7G3 | 10 | 0.022 | 1.29 | 40 | 1 | 400 | 0.86 | 51.6 |
| | | LH | | | | | | | | | |
| 10 | Feed the machine with the tubes | RH | M7P5L4U3 | 19 | 0.041 | 2.451 | 40 | 1 | 760 | 1.634 | 98.04 |
| | | LH | | | | | | | | | |
| 11 | Press the button | RH | W5M4G0 | 9 | 0.019 | 1.161 | 40 | 1 | 360 | 0.774 | 46.44 |
| | | LH | | | | | | | | | |
| 12 | Machining time | RH | | | 0.3 | 18 | 2000 | 1 | | 600 | 36000 |
| | | LH | | | | | | | | | |
| 13 | Get the tubes from the machine | RH | M7G3L2M7 | 19 | 0.041 | 2.451 | 400 | 1 | 7600 | 16.34 | 980.4 |
| | | LH | | | | | | | | | |
| 14 | Put them on the wheel | RH | W5M5P5L2 | 17 | 0.037 | 2.193 | 400 | 1 | 6800 | 14.62 | 877.2 |
| | | LH | | | | | | | | | |
| NON-CYCLIC ELEMENTS | | | | | | | | | | | |
| 1 | Adjusting the machine | RH | | | 15 | 900 | 1 | 1 | | 15 | 900 |
| | | LH | | | | | | | | | |
| TOTAL | | | | MODS | MINUTES | SECONDS | | | Total MODS | Total MINUTES | Total SECONDS |
| | | | | 219.36 | 15.772 | 946.297 | | | 19027.2 | 655.908 | 39354.509 |

Table 3.4 represents the MODAPTS motion analysis for the operator during the chamfering process.

Table 3.4. MODAPTS table for station 4

| STATION NAME | | STATION NUMBER | | | | | | | | | |
|-----------------|------------------------------------|----------------|----------------|-------|---------|---------|-------|------|------------|---------------|---------------|
| TUBES OPERATION | | 4 | | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MOD S | MINUTES | SECONDS | FREQ. | PER. | Total MODS | Total MINUTES | Total SECONDS |
| 1 | Get the tubes from the wheel | RH | M7G3L2M 7 | 19 | 0.041 | 2.451 | 800 | 1 | 15200 | 32.68 | 1960.8 |
| | | LH | | | | | | | | | |
| 2 | Put them in the chamfering machine | RH | W5M5P5L2 | 17 | 0.037 | 2.193 | 800 | 1 | 13600 | 29.24 | 1754.4 |
| | | LH | | | | | | | | | |
| 3 | Chamfering time | RH | | | 0.083 | 5 | 8000 | 1 | | 666.667 | 40000 |
| | | LH | | | | | | | | | |
| 4 | | RH | B17M4G1L 11 | 33 | 0.071 | 4.257 | 160 | 1 | 5280 | 11.352 | 681.12 |

| | | | | | | | | | | | |
|---------------------|-------------------------|----|---------------|---------|----------|-------|-----|---|------------|---------------|---------------|
| | Get the chamfered tubes | LH | | | | | | | | | |
| 5 | Put them on the wheel | RH | W5M5P5L1 1 | 26 | 0.056 | 3.354 | 160 | 1 | 4160 | 8.944 | 536.64 |
| | | LH | | | | | | | | | |
| NON-CYCLIC ELEMENTS | | | | | | | | | | | |
| 1 | Adjusting the machine | RH | | | 30 | 1800 | | 1 | | 30 | 1800 |
| | | LH | | | | | | | | | |
| TOTAL | | | | | | | | | | | |
| | | | MODS | MINUTES | SECONDS | | | | Total MODS | Total MINUTES | Total SECONDS |
| | | | 95 | 30.288 | 1817.255 | | | | 38240 | 778.883 | 46732.96 |

Table 3.5 shows the MODAPTS table of the assembling of the pistons and their components such as orings and washers together done by 3 operators.

Table 3.5. MODAPTS table for station 5

| STATION NAME | | | STATION NUMBER | | | | | | | | |
|--------------------|---------------------------------------|------|----------------|------|---------|---------|-------|------|-------------|---------------|---------------|
| PISTONS ASSEMBLING | | | 5 | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MODS | MINUTES | SECONDS | FREQ. | PER. | Total MODS | Total MINUTES | Total SECONDS |
| 1 | Get the guiding | RH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.3 3 | 20.067 | 1204 |
| | Get Oring no 1 | LH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.3 3 | 20.067 | 1204 |
| 2 | Assemble the guiding with Oring no 1 | RH | M4P5 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 3 | Put it on the table | RH | M3P0 | 3 | 0.006 | 0.387 | 4000 | 3 | 4000 | 8.6 | 516 |
| | | LH | | | | | | | | | |
| 4 | Get the front guiding | RH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.3 3 | 20.067 | 1204 |
| | Get the seals | LH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.3 3 | 20.067 | 1204 |
| 5 | Assemble the front guiding with seals | RH | M3P2X4 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 6 | Get glow | RH | M7G0 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.3 3 | 20.067 | 1204 |
| | | LH | | | | | | | | | |
| 7 | Put on output of 5 | RH | M7P0 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.3 3 | 20.067 | 1204 |
| | | LH | | | | | | | | | |

| | | | | | | | | | | | |
|----|----------------------------------|----|--------|----|-------|-------|-------|---|---------|--------|------|
| 8 | Spread the glow | RH | M2P0 | 2 | 0.004 | 0.258 | 20000 | 3 | 13333.3 | 28.667 | 1720 |
| | | LH | | | | | | | | | |
| 9 | Clean hand | RH | M7G0 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.3 | 20.067 | 1204 |
| | | LH | | | | | | | | | |
| 10 | Clean hand | RH | M2 | 2 | 0.004 | 0.258 | 8000 | 3 | 5333.3 | 11.467 | 688 |
| | | LH | | | | | | | | | |
| 11 | Get output of 3 | RH | M7G1 | 8 | 0.017 | 1.032 | 4000 | 3 | 10666.7 | 22.933 | 1376 |
| | | LH | | | | | | | | | |
| 12 | Put output of 3 on output of 7 | RH | P2 | 2 | 0.004 | 0.258 | 4000 | 3 | 2666.6 | 5.733 | 344 |
| | | LH | M5P0 | 5 | 0.011 | 0.645 | 4000 | 3 | 6666.6 | 14.333 | 860 |
| 13 | centralize the machine and press | RH | M4U2F3 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 14 | Pressing time | RH | | | 0.05 | 3 | 4000 | 3 | | 66.667 | 4000 |
| | | LH | | | | | | | | | |
| 15 | Get Oring no 2 | RH | M7G3 | 10 | 0.021 | 1.29 | 4000 | 3 | 13333.3 | 28.667 | 1720 |
| | | LH | M4P0 | 4 | 0.009 | 0.516 | 4000 | 3 | 5333.3 | 11.467 | 688 |
| 16 | Put on output 14 | RH | M7P5 | 12 | 0.026 | 1.548 | 4000 | 3 | 16000 | 34.4 | 2064 |
| | | LH | | | | | | | | | |
| 17 | Get the rods | RH | W5M7G1 | 13 | 0.028 | 1.677 | 4000 | 3 | 17333.3 | 37.267 | 2236 |
| | | LH | BOTH | | | | | | | | |
| 18 | Assemble them | RH | M4P5 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 19 | Put on the table | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 |
| | | LH | | | | | | | | | |
| 20 | Get the washer no 1 and lift it | RH | M4G3M3 | 10 | 0.022 | 1.29 | 4000 | 3 | 13333.3 | 28.667 | 1720 |
| | | LH | M3G1 | 4 | 0.009 | 0.516 | 4000 | 3 | 5333.3 | 11.467 | 688 |
| 21 | Put the washer no 1 on the rod | RH | | | | | | | | | |
| | | LH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 |
| 22 | Get the piston no 1 | RH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.3 | 20.067 | 1204 |
| | | LH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.3 | 20.067 | 1204 |
| 23 | Get Oring no 3 | RH | M4P5 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |

| | | | | | | | | | | | |
|---------------------|--|----|--------|------|---------|---------|------|---|------------|---------------|---------------|
| | Assemble the piston no 1 with Oring no 3 | LH | | | | | | | | | |
| | | RH | | | | | | | | | |
| 24 | Put output 23 on the rod | LH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 |
| | Get the washer no 2 and lift it | RH | M4G3M3 | 10 | 0.022 | 1.29 | 4000 | 3 | 13333.3 | 28.667 | 1720 |
| 25 | Get the washer no 2 from the right hand | LH | M3G1 | 4 | 0.009 | 0.516 | 4000 | 3 | 5333.3 | 11.467 | 688 |
| | | RH | | | | | | | | | |
| 26 | Put the washer no 2 on the rod | LH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 |
| | Get the piston no 2 | RH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.3 | 20.067 | 1204 |
| 27 | Get Oring no 4 | LH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.3 | 20.067 | 1204 |
| | Assemble the piston no 2 with Oring no 4 | RH | M4P5 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| 28 | | LH | | | | | | | | | |
| | | RH | | | | | | | | | |
| 29 | Put output 28 on the rod | LH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 |
| NON-CYCLIC ELEMENTS | | | | | | | | | | | |
| TOTAL | | | | MODS | MINUTES | SECONDS | | | Total MODS | Total MINUTES | Total SECONDS |
| | | | | 152 | 0.588 | 35.25 | | | 346666.7 | 812 | 48720 |

Table 3.6 is the MODAPTS table for the riveting process in station 6 where 2 operators press the assembled pistons from station 5 on top of the machined rods from station 2.

Table 3.6. MODAPTS table for station 6

| STATION NAME | | STATION NUMBER | | | | | | | | | |
|--------------|-------------|----------------|---------------|------|---------|---------|-------|------|------------|---------------|---------------|
| RIVETING | | 6 | | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MODS | MINUTES | SECONDS | FREQ. | PER. | Total MODS | Total MINUTES | Total SECONDS |
| | | RH | | | | | | | | | |
| 1 | Get the rod | LH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 2 | 10000 | 21.5 | 1290 |

| | | | | | | | | | | | |
|---------------------|------------------------|----|--------|------|---------|---------|------|---|------------|---------------|---------------|
| 2 | Juggling | RH | | | | | | | | | |
| | | LH | J2 | 2 | 0.004 | 0.258 | 4000 | 2 | 4000 | 8.6 | 516 |
| 3 | Put in the machine | RH | M3P2 | 5 | 0.011 | 0.645 | 4000 | 2 | 10000 | 21.5 | 1290 |
| | | LH | | | | | | | | | |
| 4 | Foot press | RH | F3 | 3 | 0.006 | 0.387 | 4000 | 2 | 6000 | 12.9 | 774 |
| | | LH | | | | | | | | | |
| 5 | Pressing time | RH | | | 0.25 | 15 | 4000 | 2 | | 1000 | 60000 |
| | | LH | | | | | | | | | |
| 6 | Get the rod back | RH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 2 | 10000 | 21.5 | 1290 |
| | | LH | | | | | | | | | |
| 7 | Control | RH | M4 | 4 | 0.009 | 0.516 | 4000 | 2 | 8000 | 17.2 | 1032 |
| | | LH | M2G1X4 | 7 | 0.015 | 0.903 | 4000 | 2 | 14000 | 30.1 | 1806 |
| 8 | Put on table | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 2 | 12000 | 25.8 | 1548 |
| | | LH | | | | | 4000 | 2 | | | |
| NON-CYCLIC ELEMENTS | | | | | | | | | | | |
| 1 | Adjust the machine | RH | M4G3C4 | 11 | 0.024 | 1.419 | 3 | 1 | 33 | 0.071 | 4.257 |
| | | LH | M4G3C4 | 11 | 0.024 | 1.419 | 3 | 1 | 33 | 0.071 | 4.257 |
| 2 | Put the mold back | RH | M4P5 | 9 | 0.019 | 1.161 | 3 | 1 | 27 | 0.058 | 3.483 |
| | | LH | | | | | | | | | |
| 3 | Check the rod position | RH | M4G1E4 | 9 | 0.019 | 1.161 | 3 | 1 | 27 | 0.058 | 3.483 |
| | | LH | M4G1E4 | 9 | 0.019 | 1.161 | 3 | 1 | 27 | 0.058 | 3.483 |
| 4 | Put the rod back | RH | M4P2 | 6 | 0.013 | 0.774 | 3 | 1 | 18 | 0.039 | 2.322 |
| | | LH | | | | | | | | | |
| TOTAL | | | | MODS | MINUTES | SECONDS | | | Total MODS | Total MINUTES | Total SECONDS |
| | | | | 92 | 0.448 | 26.868 | | | 74165 | 1159.455 | 69567.285 |

Table 3.7 represents the MODAPTS table for station 7 where the end plugs and their components such as rings and valves are combined and assembled which is very similar to station 5 but additionally, at the end of the process the end plugs are assembled to the chamfered tubes from station 4.

Table 3.7. MODAPTS table for station 7

| STATION NAME | | STATION NUMBER | | | | | | | | | |
|---------------------|-------|----------------|---------------|------|---------|---------|-------|------|------------|---------------|---------------|
| END PLUG ASSEMBLING | | 7 | | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MODS | MINUTES | SECONDS | FREQ. | PER. | Total MODS | Total MINUTES | Total SECONDS |

| | | | | | | | | | | | |
|----|---|----|----------|----|-------|-------|------|---|-------------|--------|-------|
| 1 | Get the end plug | RH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.3 | 20.067 | 1204 |
| | Get Oring no 1 | LH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.3 | 20.067 | 1204 |
| 2 | Assemble the guiding with Oring no 1 | RH | M4P5 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 3 | Get another Oring no 1 | RH | | | | | | | | | |
| | | LH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.3 3 | 20.067 | 1204 |
| 4 | Assemble the guiding with the second Oring no 1 | RH | M4P5 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 5 | Put the end plug on its place | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 |
| | | LH | | | | | | | | | |
| 6 | Get the Oring no 2 | RH | M4G3 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 |
| | | LH | | | | | | | | | |
| 7 | Put the Oring no 2 | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 |
| | | LH | | | | | | | | | |
| 8 | Get a squeezer | RH | M4G1 | 5 | 0.011 | 0.645 | 1 | 3 | 1.667 | 0.004 | 0.215 |
| | | LH | | | | | | | | | |
| 9 | Press the parts | RH | M4P2J2X4 | 12 | 0.026 | 1.548 | 4000 | 3 | 16000 | 34.4 | 2064 |
| | | LH | | | | | | | | | |
| 10 | Put the pen back | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 |
| | | LH | | | | | | | | | |
| 11 | Get the bobbin | RH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.3 | 20.067 | 1204 |
| | | LH | | | | | | | | | |
| 12 | Put the bobbin | RH | M4P5 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 13 | Get the valve | RH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.3 | 20.067 | 1204 |
| | | LH | | | | | | | | | |
| 14 | Put the valve | RH | M4P5 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 15 | Get the holder | RH | M4G1 | 5 | 0.011 | 0.645 | 1 | 3 | 1.667 | 0.004 | 0.215 |
| | | LH | | | | | | | | | |
| 16 | Get the metal ring | RH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.3 | 20.067 | 1204 |
| | | LH | | | | | | | | | |
| 17 | Put in the holder | RH | M3P2 | 5 | 0.011 | 0.645 | 4000 | 3 | 6666.7 | 14.333 | 860 |
| | | LH | | | | | | | | | |
| 18 | Put the metal ring | RH | M4P5X4 | 13 | 0.028 | 1.677 | 4000 | 3 | 17333. 3 | 37.267 | 2236 |
| | | LH | | | | | | | | | |

| | | | | | | | | | | | |
|---------------------|--|----|----------|----|---------|-------|------|---|--------|--------|--------|
| 19 | Get a squeezer | RH | M4G1 | 1 | 0.002 | 0.129 | 4000 | 3 | 1333.3 | 2.867 | 172 |
| | | LH | | | | | | | | | |
| 20 | Press the parts | RH | M4P2J2X4 | 12 | 0.026 | 1.548 | 4000 | 3 | 16000 | 34.4 | 2064 |
| | | LH | | | | | | | | | |
| 21 | Transfer to closing machine | RH | W5L2 | 7 | 0.015 | 0.903 | 75 | 1 | 525 | 1.129 | 67.725 |
| | | LH | | | | | | | | | |
| 22 | Get the tube | RH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 3 | 6666.7 | 14.333 | 860 |
| | | LH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 3 | 6666.7 | 14.333 | 860 |
| 23 | Put the end plug in the tube (The other assembling with machining time) | RH | M3P2X4 | 9 | 0.019 | 1.161 | 1 | 1 | 9 | 0.019 | 1.161 |
| | | LH | | | | | | | | | |
| 24 | Put in the machine | RH | M7P5U2 | 14 | 0.03 | 1.806 | 4000 | 2 | 28000 | 60.2 | 3612 |
| | | LH | | | | | | | | | |
| 25 | Foot press | RH | F5 | 5 | 0.011 | 0.645 | 4000 | 2 | 10000 | 21.5 | 1290 |
| | | LH | | | | | | | | | |
| 26 | Pressing time | RH | | | 0.133 | 8 | 4000 | 2 | | 266.66 | 16000 |
| | | LH | | | | | | | | | |
| 27 | Get out the tube | RH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 2 | 10000 | 21.5 | 1290 |
| | | LH | | | | | | | | | |
| 28 | Check | RH | M4E4 | 8 | 0.017 | 1.032 | 4000 | 2 | 16000 | 34.4 | 2064 |
| | | LH | | | | | | | | | |
| 29 | Put the tube | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 2 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| NON-CYCLIC ELEMENTS | | | | | | | | | | | |
| 1 | Reach the bags | RH | M4G3 | 7 | 0.015 | 0.903 | 5 | 1 | 35 | 0.075 | 4.515 |
| | | LH | | | | | | | | | |
| 2 | Open the bags | RH | M2P2X4 | 8 | 0.017 | 1.032 | 5 | 1 | 40 | 0.086 | 5.16 |
| | | LH | | | | | | | | | |
| 3 | Put the bags down | RH | M2P2 | 4 | 0.009 | 0.516 | 5 | 1 | 20 | 0.043 | 2.58 |
| | | LH | | | | | | | | | |
| 4 | Recheck with holder (10%) | RH | M4G1 | 5 | 0.011 | 0.645 | 400 | 3 | 666.67 | 1.433 | 86 |
| | | LH | M4P5 | 9 | 0.01935 | 1.161 | 400 | 3 | 1200 | 2.58 | 154.8 |
| 5 | In the closing machine Check the plug dimension by compass | RH | M4G1 | 4 | 0.009 | 0.516 | 1 | 1 | 4 | 0.009 | 0.516 |
| | | LH | | | | | | | | | |
| 6 | Using the compass | RH | M4P2E4 | 10 | 0.022 | 1.29 | 1 | 1 | 10 | 0.022 | 1.29 |
| | | LH | | | | | | | | | |
| 7 | Get the tube Put the plug inside | RH | M4G1 | 5 | 0.011 | 0.645 | 1 | 1 | 5 | 0.011 | 0.645 |
| | | LH | M3P2X4 | 9 | 0.019 | 1.161 | 1 | 1 | 9 | 0.019 | 1.161 |

| | | | | | | | | | | | |
|-------|----------------------|----|--------|------|---------|---------|---|---|------------|---------------|---------------|
| 8 | Check with compass | RH | M7P5E4 | 16 | 0.034 | 2.064 | 1 | 1 | 16 | 0.034 | 2.064 |
| | | LH | | | | | | | | | |
| 9 | Leave compass | RH | M4P2 | 6 | 0.013 | 0.774 | 1 | 1 | 6 | 0.013 | 0.774 |
| | | LH | | | | | | | | | |
| 10 | Get pen | RH | M4G1 | 5 | 0.011 | 0.645 | 1 | 1 | 5 | 0.011 | 0.645 |
| | | LH | | | | | | | | | |
| 11 | Sign the right place | RH | M4P2H4 | 10 | 0.022 | 1.29 | 1 | 1 | 10 | 0.022 | 1.29 |
| | | LH | | | | | | | | | |
| 12 | Leave the pen | RH | M4P2 | 6 | 0.013 | 0.774 | 1 | 1 | 6 | 0.013 | 0.774 |
| | | LH | | | | | | | | | |
| 13 | Get the tube | RH | M2G0 | 2 | 0.004 | 0.258 | 1 | 1 | 2 | 0.004 | 0.258 |
| | | LH | | | | | | | | | |
| 14 | Put in the machine | RH | M4P5 | 9 | 0.019 | 1.161 | 1 | 1 | 9 | 0.019 | 1.161 |
| | | LH | | | | | | | | | |
| 15 | Adjusting | RH | | | 1.417 | 85 | 1 | 1 | | 1.417 | 85 |
| | | LH | | | | | | | | | |
| TOTAL | | | | MODS | MINUTES | SECONDS | | | Total MODS | Total MINUTES | Total SECONDS |
| | | | | 334 | 2.268 | 136.086 | | | 285247.67 | 881.359 | 52881.949 |

Table 3.8 is the MODAPTS sheet for station 8 where one operator is responsible for filling the oil in the tubes after assembling the end plugs in station 7.

Table 3.8. MODAPTS table for station 8

| STATION NAME | | STATION NUMBER | | | | | | | | | |
|---------------------|----------------------------|----------------|---------------|-------|---------|---------|--------|------|-------------|---------------|---------------|
| OIL FILLING | | 8 | | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MOD S | MINUTES | SECONDS | FREQ . | PER. | Total MOD S | Total MINUTES | Total SECONDS |
| 1 | Get the tube | RH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 1 | 20000 | 43 | 2580 |
| | | LH | | | | | | | | | |
| 2 | Put in the filling machine | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 1 | 24000 | 51.6 | 3096 |
| | | LH | | | | | | | | | |
| 3 | Press button | RH | M3U0.5 | 3.5 | 0.008 | 0.452 | 4000 | 1 | 14000 | 30.1 | 1806 |
| | | LH | | | | | | | | | |
| 4 | Filling time | RH | | | 0.033 | 2 | 4000 | 1 | | 133.32 | 8000 |
| | | LH | | | | | | | | | |
| 5 | Put the tube back | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 1 | 24000 | 51.6 | 3096 |
| | | LH | | | | | | | | | |
| NON-CYCLIC ELEMENTS | | | | | | | | | | | |

| | | | | | | | | |
|-------|----------------------------|----|-------|---------|---------|------------|---------------|---------------|
| 1 | Adjust the filling machine | RH | 0.167 | 10 | 1 | 1 | 0.167 | 10 |
| | | LH | | | | | | |
| TOTAL | | | MODS | MINUTES | SECONDS | Total MODS | Total MINUTES | Total SECONDS |
| | | | 20.5 | 0.244 | 14.645 | 82000 | 309.787 | 18588 |

Table 3.9 shows the MODAPTS motion analysis for combining the output of stations 6 and 8 in station 9 where the rods and tubes are assembled in the rolling and closing machines by 2 operators.

Table 3.9. MODAPTS table for station 9

| STATION NAME | | STATION NUMBER | | | | | | | | | |
|---------------------|------------------------------------|----------------|---------------|------|---------|---------|-------|------|------------|---------------|---------------|
| ROLLING AND CLOSING | | 9 | | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MODS | MINUTES | SECONDS | FREQ. | PER. | Total MODS | Total MINUTES | Total SECONDS |
| 1 | Get the installation tool | RH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 2 | 10000 | 21.5 | 1290 |
| | | LH | | | | | | | | | |
| 2 | Put the tool in its place | RH | M4P0 | 4 | 0.009 | 0.516 | 4000 | 2 | 8000 | 17.2 | 1032 |
| | | LH | | | | | | | | | |
| 3 | Get the tube | RH | | | | | | | | | |
| | | LH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 2 | 10000 | 21.5 | 1290 |
| 4 | Put the tube in installation place | RH | | | | | | | | | |
| | | LH | M4P0 | 4 | 0.009 | 0.516 | 4000 | 2 | 8000 | 17.2 | 1032 |
| 5 | Install on the tube | RH | M3P2 | 5 | 0.011 | 0.645 | 4000 | 2 | 10000 | 21.5 | 1290 |
| | | LH | | | | | | | | | |
| 6 | Get the rod | RH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 2 | 10000 | 21.5 | 1290 |
| | | LH | | | | | | | | | |
| 7 | Put the rod in the tube | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 2 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 8 | Move to the pressing machine | RH | M2G0 | 2 | 0.004 | 0.258 | 4000 | 2 | 4000 | 8.6 | 516 |
| | | LH | | | | | | | | | |
| 9 | Foot press | RH | F3 | 3 | 0.006 | 0.387 | 4000 | 2 | 6000 | 12.9 | 774 |
| | | LH | | | | | | | | | |
| 10 | Pressing time | RH | | | 0.033 | 2 | 4000 | 2 | | 66.6 | 4000 |
| | | LH | | | | | | | | | |
| 11 | Put the assembled part back | RH | | | | | | | | | |
| | | LH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 2 | 12000 | 25.8 | 1548 |

| | | | | | | | | | | | |
|---------------------|---|----|---------|------|-------|-------|------|---|-------|--------|--------|
| 12 | Transfer to rolling and closing machine | RH | W23.5L2 | 25.5 | 0.055 | 3.29 | 200 | 2 | 2550 | 5.483 | 328.95 |
| | | LH | | | | | | | | | |
| 13 | Get the gas spring | RH | M4G1 | 5 | 0.011 | 0.645 | 2 | 2 | 5 | 0.011 | 0.645 |
| | | LH | | | | | | | | | |
| 14 | Put the gas spring in the machine | RH | M4P2U2 | 8 | 0.017 | 1.032 | 8000 | 2 | 32000 | 68.8 | 4128 |
| | | LH | | | | | | | | | |
| 15 | Foot press | RH | F3 | 3 | 0.006 | 0.387 | 8000 | 2 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 16 | Machining time (get the next one while machining) | RH | | | 0.133 | 8 | 8000 | 2 | | 533.32 | 32000 |
| | | LH | | | | | | | | | |
| 17 | Get the gas spring from the machine | RH | M4G1 | 5 | 0.011 | 0.645 | 8000 | 2 | 20000 | 43 | 2580 |
| | | LH | | | | | | | | | |
| 18 | Put the gas spring back | RH | M4P2 | 6 | 0.013 | 0.774 | 8000 | 2 | 24000 | 51.6 | 3096 |
| | | LH | | | | | | | | | |
| 19 | Get the gas spring for second rolling | RH | M4G1 | 5 | 0.011 | 0.645 | 8000 | 2 | 20000 | 43 | 2580 |
| | | LH | | | | | | | | | |
| 20 | Put in the machine | RH | M4P2U2 | 8 | 0.017 | 1.032 | 8000 | 2 | 32000 | 68.8 | 4128 |
| | | LH | | | | | | | | | |
| NON-CYCLIC ELEMENTS | | | | | | | | | | | |
| 1 | Adjust the assembling machine | RH | | | 3.7 | 222 | 2 | 2 | | 3.7 | 222 |
| | | LH | | | | | | | | | |
| 2 | In the closing machine Check the plug dimension by compass | RH | M4G1 | 4 | 0.009 | 0.516 | 2 | 2 | 4 | 0.009 | 0.516 |
| | | LH | | | | | | | | | |
| 3 | Using the compass | RH | M4P2E4 | 10 | 0.022 | 1.29 | 2 | 2 | 10 | 0.022 | 1.29 |
| | | LH | | | | | | | | | |
| 4 | Get the tube Put the plug inside | RH | M4G1 | 5 | 0.011 | 0.645 | 2 | 2 | 5 | 0.011 | 0.645 |
| | | LH | M3P2X4 | 9 | 0.019 | 1.161 | 2 | 2 | 9 | 0.019 | 1.161 |
| 5 | Check with compass | RH | M7P5E4 | 16 | 0.034 | 2.064 | 2 | 2 | 16 | 0.034 | 2.064 |
| | | LH | | | | | | | | | |
| 6 | Leave compass | RH | M4P2 | 6 | 0.013 | 0.774 | 2 | 2 | 6 | 0.013 | 0.774 |
| | | LH | | | | | | | | | |
| 7 | Get pen | RH | M4G1 | 5 | 0.011 | 0.645 | 2 | 2 | 5 | 0.011 | 0.645 |
| | | LH | | | | | | | | | |
| 8 | Sign the right place | RH | M4P2H4 | 10 | 0.022 | 1.29 | 2 | 2 | 10 | 0.022 | 1.29 |
| | | LH | | | | | | | | | |
| 9 | Leave the pen | RH | M4P2 | 6 | 0.013 | 0.774 | 2 | 2 | 6 | 0.013 | 0.774 |
| | | LH | | | | | | | | | |
| 10 | Get the tube | RH | M2G0 | 2 | 0.004 | 0.258 | 2 | 2 | 2 | 0.004 | 0.258 |

| | | LH | | | | | | | | | |
|----|--------------------|----|------|-------|-------|---------|---------|---|------------|---------------|---------------|
| 11 | Put in the machine | RH | M4P5 | 9 | 0.019 | 1.161 | 2 | 2 | 9 | 0.019 | 1.161 |
| | | LH | | | | | | | | | |
| 12 | Adjusting | RH | | | 2.833 | 170 | 2 | 2 | | 2.833 | 170 |
| | | LH | | | | | | | | | |
| | | | | TOTAL | MODS | MINUTES | SECONDS | | Total MODS | Total MINUTES | Total SECONDS |
| | | | | | 192.5 | 7.114 | 426.833 | | 232637 | 1106.623 | 66402.173 |

Table 3.10 is the MODAPTS table for the gas charging process in station 10 which is done by one operator.

Table 3.10. MODAPTS table for station 10

| STATION NAME | | STATION NUMBER | | | | | | | | | |
|---------------------|---|----------------|---------------|------|---------|---------|-------|------|------------|---------------|---------------|
| GAS FILLING | | 10 | | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MODS | MINUTES | SECONDS | FREQ. | PER. | Total MODS | Total MINUTES | Total SECONDS |
| 1 | Get the first gas spring | RH | M7G1 | 8 | 0.017 | 1.032 | 1 | 1 | 8 | 0.017 | 1.032 |
| | | LH | | | | | | | | | |
| 2 | Put in the machine | RH | M7P2J2 | 11 | 0.024 | 1.419 | 1 | 1 | 11 | 0.024 | 1.419 |
| | | LH | | | | | | | | | |
| 3 | Press the button | RH | M3G0X4 | 7 | 0.015 | 0.903 | 4000 | 1 | 28000 | 60.2 | 3612 |
| | | LH | | | | | | | | | |
| 4 | Filling time (get the next one while filling) | RH | | | 0.167 | 10 | 4000 | 1 | | 666.68 | 40000.8 |
| | | LH | | | | | | | | | |
| 5 | Take the filled gas spring | RH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 1 | 20000 | 43 | 2580 |
| | | LH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 1 | 24000 | 51.6 | 3096 |
| 6 | Put the next one | RH | M7P2 | 9 | 0.019 | 1.161 | 4000 | 1 | 36000 | 77.4 | 4644 |
| | | LH | | | | | | | | | |
| NON-CYCLIC ELEMENTS | | | | | | | | | | | |
| 1 | Get the mold of the machine | RH | M4G1C4 | 9 | 0.019 | 1.161 | 1 | 1 | 9 | 0.019 | 1.161 |
| | | LH | M4G1C4 | 9 | 0.019 | 1.161 | 1 | 1 | 9 | 0.019 | 1.161 |
| 2 | Pull the mold | RH | M4G0 | 4 | 0.009 | 0.516 | 1 | 1 | 4 | 0.009 | 0.516 |
| | | LH | M4G0 | 4 | 0.009 | 0.516 | 1 | 1 | 4 | 0.009 | 0.516 |
| 3 | Put on the table | RH | M7P2 | 9 | 0.019 | 1.161 | 1 | 1 | 9 | 0.019 | 1.161 |
| | | LH | M7P2 | 9 | 0.019 | 1.161 | 1 | 1 | 9 | 0.019 | 1.161 |

| | | | | | | | | | | | |
|-------|--------------------------------|----|--------|------|---------|---------|---|---|------------|---------------|---------------|
| 4 | Get the upper part | RH | M3G1 | 4 | 0.009 | 0.516 | 1 | 1 | 4 | 0.009 | 0.516 |
| | Get the new mold | LH | M3G1 | 4 | 0.009 | 0.516 | 1 | 1 | 4 | 0.009 | 0.516 |
| 5 | Put the upper part | RH | M7P5 | 12 | 0.026 | 1.548 | 1 | 1 | 12 | 0.026 | 1.548 |
| | Put the new mold | LH | M7P5C4 | 16 | 0.034 | 2.064 | 1 | 1 | 16 | 0.034 | 2.064 |
| 6 | Adjust the mold in the machine | RH | | | 3.167 | 190 | 1 | 1 | | 3.167 | 190 |
| | | LH | | | | | | | | | |
| TOTAL | | | | MODS | MINUTES | SECONDS | | | Total MODS | Total MINUTES | Total SECONDS |
| | | | | 126 | 3.604 | 216.254 | | | 108099 | 902.26 | 54135.571 |

Table 3.11 is the MODAPTS analysis for the motions of the operators in station 11 to feed the painting robot in the painting room.

Table 3.11. MODAPTS table for station 11

| STATION NAME | | STATION NUMBER | | | | | | | | | |
|--------------|-------------------------------------|----------------|---------------|-------|---------|---------|-------|------|------------|---------------|---------------|
| PAINTING | | 11 | | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MODS | MINUTES | SECONDS | FREQ. | PER. | Total MODS | Total MINUTES | Total SECONDS |
| 1 | Get the gas springs | RH | M4G3 | 7 | 0.015 | 0.903 | 800 | 1 | 5600 | 12.04 | 722.4 |
| | | LH | | | | | | | | | |
| 2 | Go to the pool | RH | W2.36 | 2.36 | 0.005 | 0.304 | 800 | 1 | 1888 | 4.059 | 243.552 |
| | | LH | | | | | | | | | |
| 3 | Put the gas springs in the water | RH | M7P2 | 9 | 0.019 | 1.161 | 800 | 1 | 7200 | 15.48 | 928.8 |
| | | LH | | | | | | | | | |
| 4 | Washing time | RH | | | 0.167 | 10 | 800 | 1 | | 133.336 | 8000.16 |
| | | LH | | | | | | | | | |
| 5 | Pull the gas spring | RH | M7G1U6 | 14 | 0.03 | 1.806 | 800 | 1 | 11200 | 24.08 | 1444.8 |
| | | LH | | | | | | | | | |
| 6 | Put the gas spring in the next pool | RH | W2.36M7P2 | 11.36 | 0.024 | 1.465 | 800 | 1 | 9088 | 19.539 | 1172.352 |
| | | LH | | | | | | | | | |
| 7 | Washing time | RH | | | 0.167 | 10 | 800 | 1 | | 133.336 | 8000.16 |
| | | LH | | | | | | | | | |
| 8 | Pull the gas spring | RH | M7G1U6 | 14 | 0.03 | 1.806 | 800 | 1 | 11200 | 24.08 | 1444.8 |
| | | LH | | | | | | | | | |
| 9 | Put them back | RH | W2.36M5P2 | 9.36 | 0.02 | 1.207 | 800 | 1 | 7488 | 16.099 | 965.952 |
| | | LH | | | | | | | | | |

| | | | | | | | | | | | |
|---------------------|--------------------------------------|----|---------------|-------|-------|-------|------|---|----------|--------|---------|
| 10 | Get the gas springs | RH | M7G1 | 8 | 0.017 | 1.032 | 4000 | 3 | 10666.67 | 22.933 | 1376 |
| | | LH | | | | | | | | | |
| 11 | Hang the gas springs | RH | M7P2J2C4 | 15 | 0.032 | 1.935 | 4000 | 3 | 20000 | 43 | 2580 |
| | | LH | | | | | | | | | |
| 12 | Get the rod protection cover | RH | M7G3 | 10 | 0.022 | 1.29 | 4000 | 3 | 13333.33 | 28.667 | 1720 |
| | | LH | | | | | | | | | |
| 13 | Put the covers on rods | RH | M7P5J2 | 14 | 0.03 | 1.806 | 4000 | 3 | 18666.67 | 40.133 | 2408 |
| | | LH | | | | | | | | | |
| 14 | Get a rag | RH | W2.36M7G 1 | 10.36 | 0.022 | 1.336 | 3 | 3 | 10.36 | 0.022 | 1.336 |
| | | LH | | | | | | | | | |
| 15 | Wipe the tubes | RH | M4P2J2U3 | 11 | 0.024 | 1.419 | 4000 | 3 | 14666.67 | 31.533 | 1892 |
| | | LH | | | | | | | | | |
| 16 | Get the rod covers after painting | RH | W2.36M4G 1 | 7.36 | 0.016 | 0.949 | 4000 | 3 | 9813.33 | 21.099 | 1265.92 |
| | | LH | | | | | | | | | |
| 17 | Take the cover off and put them away | RH | M5P2 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 |
| | | LH | | | | | | | | | |
| 18 | Get the gas springs | RH | M7G1J2C4 | 14 | 0.03 | 1.806 | 4000 | 3 | 18666.67 | 40.133 | 2408 |
| | | LH | | | | | | | | | |
| 19 | Take the gas spring off | RH | M7P2 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| NON-CYCLIC ELEMENTS | | | | | | | | | | | |
| 1 | Hold the water pool | RH | M5G1 | 6 | 0.013 | 0.774 | 1 | 1 | 6 | 0.013 | 0.774 |
| | | LH | | | | | | | | | |
| 2 | Open the water pool | RH | M7P0 | 7 | 0.015 | 0.903 | 1 | 1 | 7 | 0.015 | 0.903 |
| | | LH | | | | | | | | | |
| 3 | Get the gloves | RH | W2.36M7G 1 | 10.36 | 0.022 | 1.336 | 1 | 1 | 10.36 | 0.022 | 1.336 |
| | | LH | W2.36M7G 1 | 10.36 | 0.022 | 1.336 | 1 | 1 | 10.36 | 0.022 | 1.336 |
| 4 | Wear the gloves | RH | M2P5 | 7 | 0.015 | 0.903 | 1 | 1 | 7 | 0.015 | 0.903 |
| | | LH | M2P5 | 7 | 0.015 | 0.903 | 1 | 1 | 7 | 0.015 | 0.903 |
| 5 | Go to the gas springs | RH | W2.36 | 2.36 | 0.005 | 0.304 | 1 | 1 | 2.36 | 0.005 | 0.304 |
| | | LH | | | | | | | | | |
| 6 | Get the air gun | RH | M4G3 | 7 | 0.015 | 0.903 | 1 | 1 | 7 | 0.015 | 0.903 |
| | | LH | M4G0X4 | 8 | 0.017 | 1.032 | 1 | 1 | 8 | 0.017 | 1.032 |
| 7 | Drying time | RH | | | 10 | 600 | 1 | 1 | | 10 | 600 |
| | | LH | | | | | | | | | |
| 8 | Transfer to the painting room | RH | W38.75 | 38.75 | 0.083 | 4.999 | 1 | 1 | 38.75 | 0.083 | 4.999 |
| | | LH | | | | | | | | | |
| 9 | | RH | | | 120 | 7200 | 1 | 1 | | 120 | 7200 |

| | | | | | | | | | | | |
|------------------|----|-------|--------|---------|----------|--|--|---------------|------------------|------------------|--|
| Painting time | LH | | | | | | | | | | |
| | | TOTAL | MODS | MINUTES | SECONDS | | | Total MODS | Total MINUTES | Total SECONDS | |
| | | | 276.63 | 130.928 | 7855.686 | | | 180924.857 | 785.66 | 47139.62 | |

Table 3.12 displays the MODAPTS table of station 12 where 3 operators assemble the end fittings on the two sides of the gas springs.

Table 3.12. MODAPTS table for station 12

| STATION NAME | | | STATION NUMBER | | | | | | | | |
|------------------------|--------------------------------------|------|----------------|------|---------|---------|-------|------|------------|---------------|---------------|
| END FITTING ASSEMBLING | | | 12 | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MODS | MINUTES | SECONDS | FREQ. | PER. | Total MODS | Total MINUTES | Total SECONDS |
| 1 | Get the gas springs from the trolley | RH | M7G1 | 8 | 0.017 | 1.032 | 800 | 3 | 2133.333 | 4.587 | 275.2 |
| | | LH | | | | | | | | | |
| 2 | Put the gas spring on the table | RH | M7P2 | 9 | 0.019 | 1.161 | 800 | 3 | 2400 | 5.16 | 309.6 |
| | | LH | | | | | | | | | |
| 3 | Get the gas spring | RH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 3 | 6666.667 | 14.333 | 860 |
| | | LH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.333 | 20.067 | 1204 |
| 4 | Assemble the fork | RH | M4P2C4 | 10 | 0.022 | 1.29 | 4000 | 3 | 13333.333 | 28.667 | 1720 |
| | | LH | | | | | | | | | |
| 5 | Switch the gas spring | RH | M2 | 2 | 0.004 | 0.258 | 4000 | 3 | 2666.667 | 5.733 | 344 |
| | | LH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.333 | 20.067 | 1204 |
| 6 | Assemble the joint | RH | M4P2C4 | 10 | 0.022 | 1.29 | 4000 | 3 | 13333.333 | 28.667 | 1720 |
| | | LH | | | | | | | | | |
| 7 | Put the gas spring back | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 |
| | | LH | | | | | | | | | |
| 8 | Get the gas spring again | RH | | 5 | 0.011 | 0.645 | 4000 | 2 | 10000 | 21.5 | 1290 |
| | | LH | M4G1 | | | | | | | | |
| 9 | Put the fork in the director tool | RH | | 9 | 0.019 | 1.161 | 4000 | 2 | 18000 | 38.7 | 2322 |
| | | LH | M4P5 | | | | | | | | |
| 10 | Get a holder | RH | M4G1 | 5 | 0.011 | 0.645 | 1 | 1 | 5 | 0.011 | 0.645 |
| | | LH | | | | | | | | | |
| 11 | Put the holder on the joint | RH | M7P2J2C4 | 15 | 0.032 | 1.935 | 4000 | 2 | 30000 | 64.5 | 3870 |
| | | LH | | | | | | | | | |

| | | | | | | | | | | | |
|---------------------|--------------------|----|-------|------|---------|---------|------|---|------------|---------------|---------------|
| 12 | Get the gas spring | RH | | | | | | | | | |
| | | LH | M1G0 | 1 | 0.002 | 0.129 | 4000 | 2 | 2000 | 4.3 | 258 |
| 13 | Put on the table | RH | | | | | | | | | |
| | | LH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 2 | 12000 | 25.8 | 1548 |
| NON-CYCLIC ELEMENTS | | | | | | | | | | | |
| | | | TOTAL | MODS | MINUTES | SECONDS | | | Total MODS | Total MINUTES | Total SECONDS |
| | | | | 105 | 0.226 | 13.545 | | | 139205 | 299.291 | 17957.445 |

Table 3.13 shows the MODAPTS table of the last station number 13 where 3 workers pack the gas springs in their boxes and put them in the shipment parcels.

Table 3.13. MODAPTS table for station 13

| STATION NAME | | STATION NUMBER | | | | | | | | | |
|--------------|---------------------------------|----------------|---------------|------|---------|---------|-------|------|------------|---------------|---------------|
| PACKAGING | | 13 | | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MODS | MINUTES | SECONDS | FREQ. | PER. | Total MODS | Total MINUTES | Total SECONDS |
| 1 | Get the gas spring | RH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 3 | 6666.667 | 14.333 | 860 |
| | Get the plastic bag | LH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.333 | 20.067 | 1204 |
| 2 | Put the gas spring in the bag | RH | M4P5J2 | 11 | 0.024 | 1.419 | 4000 | 3 | 14666.67 | 31.533 | 1892 |
| | | LH | | | | | | | | | |
| 3 | Put the gas spring on the table | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 |
| | | LH | | | | | | | | | |
| 4 | Open a box | RH | | | 0.3 | 18 | 160 | 2 | | 24 | 1440 |
| | | LH | | | | | | | | | |
| 5 | Get the gas springs (5 pcs) | RH | M4G3 | 7 | 0.015 | 0.903 | 800 | 2 | 2800 | 6.02 | 361.2 |
| | | LH | | | | | | | | | |
| 6 | Put in the box | RH | M7P5 | 12 | 0.026 | 1.548 | 800 | 2 | 4800 | 10.32 | 619.2 |
| | | LH | | | | | | | | | |
| 7 | Close the box | RH | | | 0.183 | 11 | 160 | 2 | | 14.666 | 880 |
| | | LH | | | | | | | | | |
| 8 | Get the box | RH | M4G3L3 | 10 | 0.022 | 1.29 | 160 | 2 | 800 | 1.72 | 103.2 |

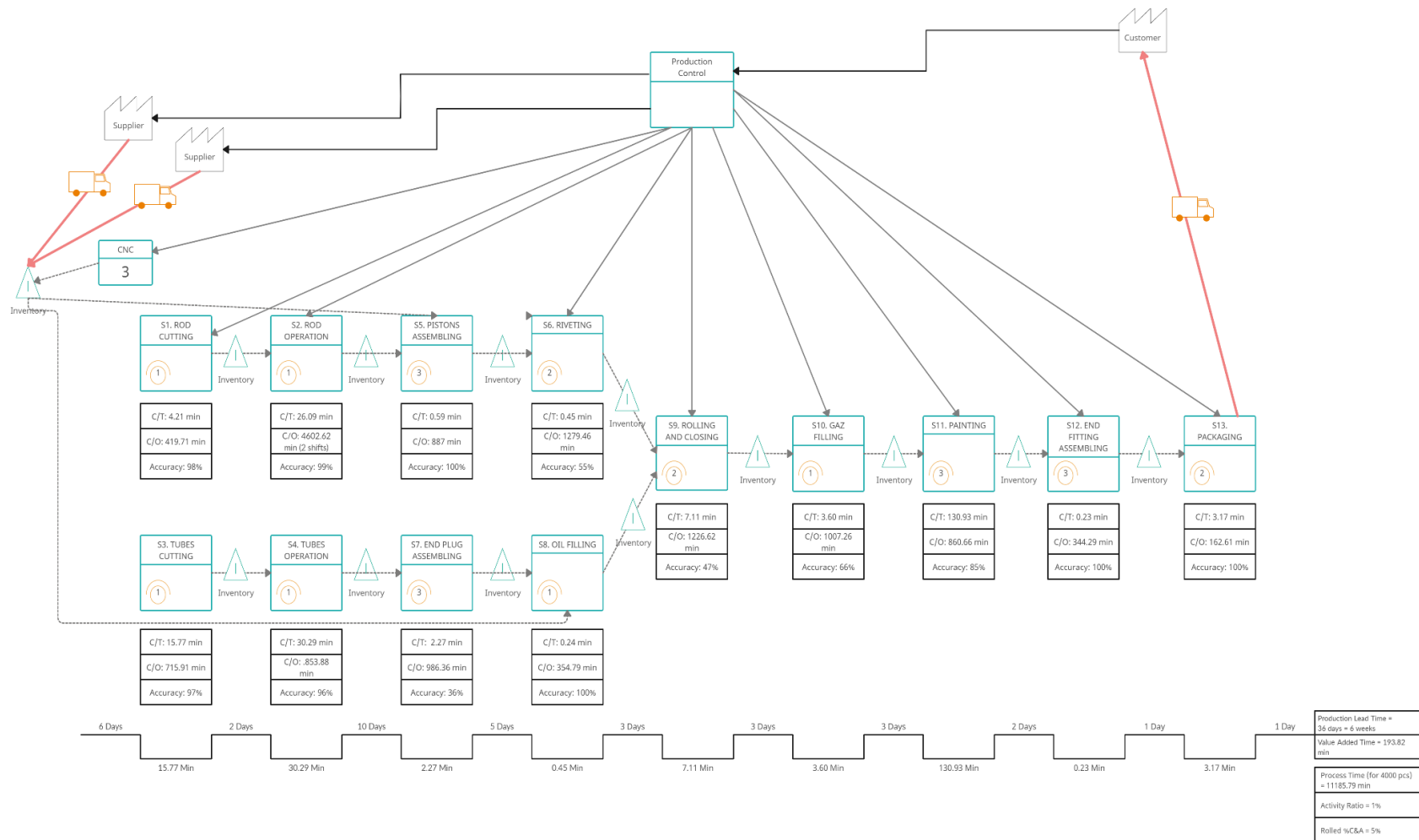


Figure 3.3. The current state of VSM

3.4.1. VSM Development Tools

After eliminating unnecessary activities, the first technique applied in this case is merging the stations to decrease stocking items in the production area. There are some factors to conduct a successful merging. To begin with, the cycle time C/T should be checked for each station, and there must be a kind of harmony between the stations planned to be merged. Table 3.14 shows the cycle time of each station.

Table 3.14. C/T for the stations

| Station No | C/T (min) |
|------------|-----------|
| 1 | 4.207 |
| 2 | 26.092 |
| 3 | 15.772 |
| 4 | 30.288 |
| 5 | 0.588 |
| 6 | 0.448 |
| 7 | 2.268 |
| 8 | 0.244 |
| 9 | 7.114 |
| 10 | 3.604 |
| 11 | 130.928 |
| 12 | 0.226 |
| 13 | 3.174 |

Another factor is the physical place of each station. The stations that would be merged should be close to each other or movable to be connected, shaping a new merged station. Lastly, the purpose of the merge is to serve the workflow, so after checking the suitability of C/T and station location or its mobility, the sequence of the stations should be taken into consideration to ensure that the flow of the processes would be improved with the applied merging of stations. The stations that had been merged are 3&4 (tube cutting & tube chamfering), 5&6 (pistons assembling & riveting), 7&8 (end plug assembling & oil filling), and 12&13 (end fitting assembling & packaging). All

of those stations were working as isolated islands; then they became working as a continuous flow by connecting the machines, such as the merging of stations 3&4 or by linking the assembling tables as done with the other merging situations. The number of stations had decreased from 13 stations to only nine stations. In addition, to apply the merge effectively, the working table of the first five stations had been rearranged to make a continuous flow to achieve the goal of the merge. Moreover, instead of WIP inventory between stations, the FIFO technique was applied in three different areas to reduce the production lead time and to be dynamic as Figure 3.4 displays.



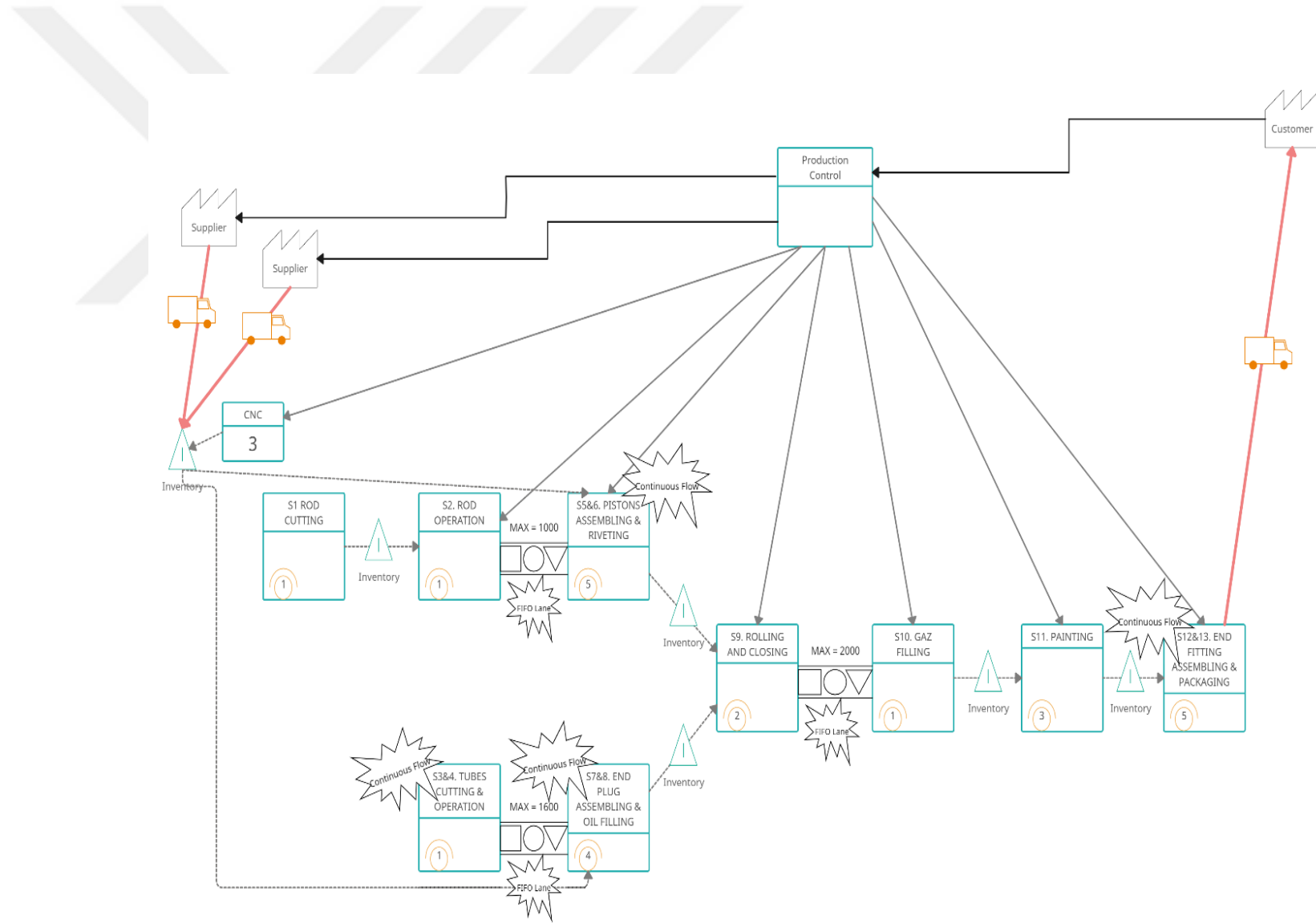


Figure 3.4. The pre-future state of VSM

3.4.2. Re-MODAPTS

As happened with the current status, a re-MODAPTS analysis was obtained for the stations with their new formation to come up with the future state of this study. The following tables shows the MODAPTS tables of the re-MODAPTS process.

Table 3.15 shows the Re-MODAPTS table for station 1 after eliminating 3 of the non-value-added activities.

Table 3.15. Re-MODAPTS table for station 1

| STATION NAME | | STATION NUMBER | | | | | | | | | |
|--------------|-----------------------------------|----------------|---------------|-------|---------|---------|-------|------|------------|---------------|---------------|
| RODS CUTTING | | 1 | | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MODS | MINUTES | SECONDS | FREQ. | PER. | Total MODS | Total MINUTES | Total SECONDS |
| 1 | Get the cutter (cut 10 by 10 pcs) | RH | M4G1S30 | 35 | 0.075 | 4.515 | 16 | 1 | 560 | 1.204 | 72.24 |
| | | LH | | | | | | | | | |
| 2 | Put the cutter on the rod's cover | RH | M4P5 | 9 | 0.019 | 1.161 | 160 | 1 | 1440 | 3.096 | 185.76 |
| | | LH | | | | | | | | | |
| 3 | Cut the cover | RH | W23.25X4 | 27.25 | 0.059 | 3.515 | 160 | 1 | 4360 | 9.374 | 562.44 |
| | | LH | | | | | | | | | |
| 4 | Get a part of the cover out | RH | M4G1 | 5 | 0.011 | 0.645 | 160 | 1 | 800 | 1.72 | 103.2 |
| | | LH | | | | | | | | | |
| 5 | Take the part of the cover out | RH | M4P0 | 4 | 0.009 | 0.516 | 160 | 1 | 640 | 1.376 | 82.56 |
| | | LH | | | | | | | | | |
| 6 | Go back to the machine | RH | W23.25S30 | 53.25 | 0.114 | 6.869 | 16 | 1 | 852 | 1.832 | 109.908 |
| | | LH | | | | | | | | | |
| 7 | Get another part of the cover | RH | M4G1 | 5 | 0.011 | 0.645 | 160 | 1 | 800 | 1.72 | 103.2 |
| | | LH | | | | | | | | | |
| 8 | Take the part of the cover out | RH | M4P0 | 4 | 0.009 | 0.516 | 160 | 1 | 640 | 1.376 | 82.56 |
| | | LH | | | | | | | | | |
| 9 | Get the rod | RH | M5G1 | 6 | 0.013 | 0.774 | 4000 | 1 | 24000 | 51.6 | 3096 |
| | | LH | | | | | | | | | |
| 10 | Put the rod in the machine | RH | M5P5 | 10 | 0.022 | 1.29 | 4000 | 1 | 40000 | 86 | 5160 |
| | | LH | | | | | | | | | |
| 11 | Foot press | RH | F3 | 3 | 0.006 | 0.387 | 4000 | 1 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 12 | Get the cut rod | RH | M3G1 | 4 | 0.009 | 0.516 | 4000 | 1 | 16000 | 34.4 | 2064 |

| | | LH | | | | | | | | | |
|---------------------|--|----|--------|-------|---------|---------|-----|---|------------|---------------|---------------|
| 13 | Put the cut rods in the box (put 5 by 5) | RH | M5P2 | 7 | 0.015 | 0.903 | 800 | 1 | 5600 | 12.04 | 722.4 |
| | | LH | | | | | | | | | |
| 14 | Check the rods | RH | | | 0.2 | 12 | 320 | 1 | | 64 | 3840 |
| | | LH | | | | | | | | | |
| NON-CYCLIC ELEMENTS | | | | | | | | | | | |
| 1 | Adjusting the machine | RH | | | 3.58 | 214.8 | 1 | 1 | | 3.58 | 3.58 |
| | | LH | | | | | | | | | |
| 2 | Get the compass | RH | M5G1 | 5 | 0.011 | 0.645 | 2 | 1 | 10 | 0.022 | 1.29 |
| | | LH | | | | | | | | | |
| 3 | Put the compass on the rod | RH | M5P5E4 | 14 | 0.03 | 1.806 | 2 | 1 | 28 | 0.06 | 3.612 |
| | | LH | | | | | | | | | |
| 4 | Put the compass back | RH | M5P2 | 7 | 0.015 | 0.903 | 2 | 1 | 14 | 0.03 | 1.806 |
| | | LH | | | | | | | | | |
| TOTAL | | | | MODS | MINUTES | SECONDS | | | Total MODS | Total MINUTES | Total SECONDS |
| | | | | 198.5 | 4.207 | 252.407 | | | 107744 | 299.23 | 17742.556 |

Table 3.16 is the Re-MODAPTS table for station 2 where 2 non-value-added activities were deducted.

Table 3.16. Re-MODAPTS table for station 2

| <u>STATION NAME</u> | | <u>STATION NUMBER</u> | | | | | | | | | |
|---------------------|--|-----------------------|---------------|------|---------|---------|-------|------|------------|---------------|---------------|
| RODS OPERATION | | 2 | | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MODS | MINUTES | SECONDS | FREQ. | PER. | Total MODS | Total MINUTES | Total SECONDS |
| 1 | Get the rods from the box | RH | M4G1 | 5 | 0.011 | 0.645 | 1 | 1 | 5 | 0.011 | 0.645 |
| | | LH | | | | | | | | | |
| 2 | Put the rod in the machine for piston side operation | RH | W5M4P5 | 14 | 0.03 | 1.806 | 4000 | 1 | 56000 | 120.4 | 7224 |
| | | LH | | | | | | | | | |
| 3 | Press the first button | RH | M4G0X4 | 8 | 0.017 | 1.032 | 4000 | 1 | 32000 | 68.8 | 4128 |
| | | LH | | | | | | | | | |
| 4 | Press the second button | RH | M3G0X4 | 7 | 0.015 | 0.903 | 4000 | 1 | 28000 | 60.2 | 3612 |
| | | LH | | | | | | | | | |
| 5 | Machining time (get the next one) | RH | | | 0.3 | 18 | 4000 | 1 | | 1200 | 72000 |
| | | LH | | | | | | | | | |

| | | | | | | | | | | | |
|---------------------|--|----|--------|------|---------|---------|------|---|------------|---------------|---------------|
| | while machining) | | | | | | | | | | |
| 6 | Get the rod from the machine | RH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 1 | 28000 | 60.2 | 3612 |
| | | LH | | | | | | | | | |
| 7 | Put the rod in the box | RH | W5M4P2 | 11 | 0.024 | 1.419 | 4000 | 1 | 44000 | 94.6 | 5676 |
| | | LH | | | | | | | | | |
| 8 | Get the rods from the box | RH | M4G1 | 5 | 0.011 | 0.645 | 1 | 1 | 5 | 0.011 | 0.645 |
| | | LH | | | | | | | | | |
| 9 | Put the rod in the machine for thread side operation | RH | W5M4P5 | 14 | 0.03 | 1.806 | 4000 | 1 | 56000 | 120.4 | 7224 |
| | | LH | | | | | | | | | |
| 10 | Press the first button | RH | M4G0X4 | 8 | 0.017 | 1.032 | 4000 | 1 | 32000 | 68.8 | 4128 |
| | | LH | | | | | | | | | |
| 11 | Press the second button | RH | M3G0X4 | 7 | 0.015 | 0.903 | 4000 | 1 | 28000 | 60.2 | 3612 |
| | | LH | | | | | | | | | |
| 12 | Machining time (get the next one while machining) | RH | | | 0.51 | 30.6 | 4000 | 1 | | 2040 | 122400 |
| | | LH | | | | | | | | | |
| 13 | Get the rod from the machine | RH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 1 | 28000 | 60.2 | 3612 |
| | | LH | | | | | | | | | |
| 14 | Put the rod in the box | RH | W5M4P2 | 11 | 0.024 | 1.419 | 4000 | 1 | 44000 | 94.6 | 5676 |
| | | LH | | | | | | | | | |
| NON-CYCLIC ELEMENTS | | | | | | | | | | | |
| 1 | Adjusting the machine for piston side | RH | | | 10 | 600 | 1 | 1 | | 10 | 600 |
| | | LH | | | | | | | | | |
| 2 | Get the compass | RH | M5G1 | 6 | 0.013 | 0.774 | 400 | 1 | 2400 | 5.16 | 309.6 |
| | | LH | | | | | | | | | |
| 3 | Put the compass on the rod | RH | M5P5E4 | 14 | 0.03 | 1.806 | 400 | 1 | 5600 | 12.04 | 722.4 |
| | | LH | | | | | | | | | |
| 4 | Put the compass back | RH | M5P2 | 7 | 0.015 | 0.903 | 400 | 1 | 2800 | 6.02 | 361.2 |
| | | LH | | | | | | | | | |
| 7 | Adjusting the machine for thread side | RH | | | 15 | 900 | 1 | 1 | | 15 | 900 |
| | | LH | | | | | | | | | |
| TOTAL | | | | MODS | MINUTES | SECONDS | | | Total MODS | Total MINUTES | Total SECONDS |
| | | | | 131 | 26.092 | 1565.5 | | | 386810 | 4096.642 | 245798.49 |

Table 3.17 represents the Re-MODAPTS table of the merge of stations 3 and 4 with the elimination of 5 non-value-added activities.

Table 3.17. Re-MODAPTS table for station 3&4

| STATION NAME | | | STATION NUMBER | | | | | | | | |
|---------------------------|---|------|----------------|-------|---------|---------|-------|------|------------|---------------|---------------|
| TUBES CUTTING & OPERATION | | | 3&4 | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MODS | MINUTES | SECONDS | FREQ. | PER. | Total MODS | Total MINUTES | Total SECONDS |
| 1 | Get the tubes from the shelves | RH | M7G3 | 10 | 0.022 | 1.29 | 20 | 1 | 200 | 0.43 | 25.8 |
| | | LH | | | | | | | | | |
| 2 | Pull the tubes | RH | M7W14.16L8 | 29.16 | 0.063 | 3.762 | 20 | 1 | 583.2 | 1.254 | 75.233 |
| | | LH | | | | | | | | | |
| 3 | Put the tubes on the shoulders | RH | M5P2L8 | 15 | 0.03225 | 1.935 | 20 | 1 | 300 | 0.645 | 38.7 |
| | | LH | | | | | | | | | |
| 4 | Walk to the cutting machine | RH | W23.6L8 | 31.6 | 0.068 | 4.076 | 20 | 1 | 632 | 1.359 | 81.528 |
| | | LH | | | | | | | | | |
| 5 | Get the tubes from the shoulders | RH | | | | | | | | | |
| | | LH | M5G1 | 6 | 0.013 | 0.774 | 20 | 1 | 120 | 0.258 | 15.48 |
| 6 | Put the tubes in the machine | RH | M7P5L8 | 20 | 0.043 | 2.58 | 20 | 1 | 400 | 0.86 | 51.6 |
| | | LH | | | | | | | | | |
| 7 | Hold the hanger of the machine cover | RH | M4G1 | 5 | 0.011 | 0.645 | 40 | 1 | 200 | 0.43 | 25.8 |
| | | LH | | | | | | | | | |
| 8 | Pull up the machine cover | RH | M5P0 | 5 | 0.011 | 0.645 | 40 | 1 | 200 | 0.43 | 25.8 |
| | | LH | | | | | | | | | |
| 9 | Get 2 tubes from the feeder | RH | M7G3 | 10 | 0.022 | 1.29 | 1 | 1 | 10 | 0.022 | 1.29 |
| | | LH | | | | | | | | | |
| 10 | Feed the machine with the tubes | RH | M7P5L4U3 | 19 | 0.041 | 2.451 | 1 | 1 | 19 | 0.041 | 2.451 |
| | | LH | | | | | | | | | |
| 11 | Press the button | RH | W5M4G0 | 9 | 0.019 | 1.161 | 40 | 1 | 360 | 0.774 | 46.44 |
| | | LH | | | | | | | | | |
| 12 | Machining time (get the next 2 while machining) | RH | | | 0.3 | 18 | 2000 | 1 | | 600 | 36000 |
| | | LH | | | | | | | | | |
| 13 | Get the tubes from the machine | RH | M7G3L2M7 | 19 | 0.041 | 2.451 | 400 | 1 | 7600 | 16.34 | 980.4 |
| | | LH | | | | | | | | | |
| 14 | Put them in the chamfering machine | RH | W5M5P5L2 | 17 | 0.037 | 2.193 | 800 | 1 | 13600 | 29.24 | 1754.4 |
| | | LH | | | | | | | | | |

| | | | | | | | | | | | |
|---------------------|----------------------------------|----|----------------|--------|---------|----------|-----|------------|---------------|---------------|--------|
| 15 | Chamfering time | RH | | 0.083 | 5 | 8000 | 1 | 666.667 | 40000 | | |
| | | LH | | | | | | | | | |
| 16 | Get the chamfered tubes | RH | B17M4G1L 11 | 33 | 0.071 | 4.257 | 160 | 1 | 5280 | 11.352 | 681.12 |
| | | LH | | | | | | | | | |
| 17 | Put them on the wheel | RH | W5M5P5L1 1 | 26 | 0.056 | 3.354 | 160 | 1 | 4160 | 8.944 | 536.64 |
| | | LH | | | | | | | | | |
| NON-CYCLIC ELEMENTS | | | | | | | | | | | |
| 1 | Adjusting the cutting machine | RH | | 15 | 900 | 1 | 1 | 15 | 900 | | |
| | | LH | | | | | | | | | |
| 2 | Adjusting the chamfering machine | RH | | 30 | 1800 | 1 | 1 | 30 | 1800 | | |
| | | LH | | | | | | | | | |
| TOTAL | | | | | | | | | | | |
| | | | | MODS | MINUTES | SECONDS | | Total MODS | Total MINUTES | Total SECONDS | |
| | | | | 254.76 | 45.931 | 2755.864 | | 33664.2 | 1384.045 | 83042.682 | |

Table 3.18 is the Re-MODAPTS table of the combination of stations 5 and 6 in addition to decrease the non-value-added activities to 5 out of 7.

Table 3.18. Re-MODAPTS table for station 5&6

| STATION NAME | | STATION NUMBER | | | | | | | | | |
|-------------------------------|---------------------------------------|----------------|---------------|------|---------|---------|-------|------|------------|---------------|---------------|
| PISTONS ASSEMBLING & RIVETING | | 5&6 | | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MODS | MINUTES | SECONDS | FREQ. | PER. | Total MODS | Total MINUTES | Total SECONDS |
| 1 | Get the guiding | RH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 |
| | Get Oring no 1 | LH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 |
| 2 | Assemble the guiding with Oring no 1 | RH | M4P5 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 3 | Put it on the table | RH | M3P0 | 3 | 0.006 | 0.387 | 4000 | 3 | 4000 | 8.6 | 516 |
| | | LH | | | | | | | | | |
| 4 | Get the front guiding | RH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 |
| | Get the seals | LH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 |
| 5 | Assemble the front guiding with seals | RH | M3P2X4 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 6 | Get glow | RH | M7G0 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 |
| | | LH | | | | | | | | | |
| 7 | | RH | M7P0 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 |

| | | | | | | | | | | | |
|----|--|----|--------|----|-------|-------|-------|---|---------|--------|------|
| | Put on output of 5 | LH | | | | | | | | | |
| | | RH | M2P0 | 2 | 0.004 | 0.258 | 20000 | 3 | 13333.3 | 28.667 | 1720 |
| 8 | Spread the glow | LH | | | | | | | | | |
| | | RH | M7G0 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 |
| 9 | Clean hand | LH | | | | | | | | | |
| | | RH | M2 | 2 | 0.004 | 0.258 | 8000 | 3 | 5333.33 | 11.467 | 688 |
| 10 | Clean hand | LH | | | | | | | | | |
| | | RH | M7G1 | 8 | 0.017 | 1.032 | 4000 | 3 | 10666.7 | 22.933 | 1376 |
| 11 | Get output of 3 | LH | | | | | | | | | |
| | Put output of 3 on output of 7 | RH | P2 | 2 | 0.004 | 0.258 | 4000 | 3 | 2666.67 | 5.733 | 344 |
| 12 | Put output of 7 under press machine | LH | M5P0 | 5 | 0.011 | 0.645 | 4000 | 3 | 6666.67 | 14.333 | 860 |
| | Centralize the machine and press | RH | M4U2F3 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| 13 | Pressing time | LH | | | | | | | | | |
| | | RH | | | 0.05 | 3 | 4000 | 3 | | 66.667 | 4000 |
| 14 | Get Oring no 2 | RH | M7G3 | 10 | 0.022 | 1.29 | 4000 | 3 | 13333.3 | 28.667 | 1720 |
| 15 | Get output 14 | LH | M4P0 | 4 | 0.009 | 0.516 | 4000 | 3 | 5333.33 | 11.467 | 688 |
| | Put on output 14 | RH | M7P5 | 12 | 0.026 | 1.548 | 4000 | 3 | 16000 | 34.4 | 2064 |
| 16 | Get the rods | RH | M7G1 | 8 | 0.017 | 1.032 | 4000 | 3 | 10666.7 | 22.933 | 1376 |
| 17 | Get output 16 | LH | BOTH | | | | | | | | |
| | Assemble them | RH | M4P5 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| 18 | Put on the table | LH | | | | | | | | | |
| | | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 |
| 19 | Get the washer no 1 and lift it | RH | M4G3M3 | 10 | 0.022 | 1.29 | 4000 | 3 | 13333.3 | 28.667 | 1720 |
| 20 | Get the washer no 1 from the right hand | LH | M3G1 | 4 | 0.009 | 0.516 | 4000 | 3 | 5333.33 | 11.467 | 688 |
| | Put the washer no 1 on the rod | RH | | | | | | | | | |
| 21 | | LH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 |
| | Get the piston no 1 | RH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 |
| 22 | Get Oring no 3 | LH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 |
| | Assemble the piston no 1 with Oring no 3 | RH | M4P5 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| 23 | Put output 23 on the rod | LH | | | | | | | | | |
| | | RH | | | | | | | | | |
| 24 | | LH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 |

| | | | | | | | | | | | |
|---------------------|--|----|--------|----|-------|-------|------|---|---------|--------|-------|
| 25 | Get the washer no 2 and lift it | RH | M4G3M3 | 10 | 0.022 | 1.29 | 4000 | 3 | 13333.3 | 28.667 | 1720 |
| | Get the washer no 2 from the right hand | LH | M3G1 | 4 | 0.009 | 0.516 | 4000 | 3 | 5333.33 | 11.467 | 688 |
| 26 | Put the washer no 2 on the rod | RH | | | | | | | | | |
| | | LH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 |
| 27 | Get the piston no 2 | RH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 |
| | Get Oring no 4 | LH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 |
| 28 | Assemble the piston no 2 with Oring no 4 | RH | M4P5 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 29 | Put output 28 on the rod | RH | | | | | | | | | |
| | | LH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 |
| 30 | Get the rod | RH | | | | | | | | | |
| | | LH | M4G1 | 5 | 0.011 | 0.645 | 1 | 2 | 2.5 | 0.005 | 0.323 |
| 31 | Juggling | RH | | | | | | | | | |
| | | LH | J2 | 2 | 0.004 | 0.258 | 4000 | 2 | 4000 | 8.6 | 516 |
| 32 | Put in the machine | RH | M3P2 | 5 | 0.011 | 0.645 | 4000 | 2 | 10000 | 21.5 | 1290 |
| | | LH | | | | | 4000 | 2 | | | |
| 33 | Foot press | RH | F3 | 3 | 0.006 | 0.387 | 4000 | 2 | 6000 | 12.9 | 774 |
| | | LH | | | | | 4000 | 2 | | | |
| 34 | Pressing time (get the next one while machining) | RH | | | 0.25 | 15 | 4000 | 2 | | 1000 | 60000 |
| | | LH | | | | | 4000 | 2 | | | |
| 35 | Get the rod back | RH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 2 | 10000 | 21.5 | 1290 |
| | | LH | | | | | 4000 | 2 | | | |
| 36 | Control | RH | M4 | 4 | 0.009 | 0.516 | 4000 | 2 | 8000 | 17.2 | 1032 |
| | | LH | M2G1X4 | 7 | 0.015 | 0.903 | 4000 | 2 | 14000 | 30.1 | 1806 |
| 37 | Put on table | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 2 | 12000 | 25.8 | 1548 |
| | | LH | | | | | 4000 | 2 | | | |
| NON-CYCLIC ELEMENTS | | | | | | | | | | | |
| 1 | Adjust the machine | RH | M4G3C4 | 11 | 0.024 | 1.419 | 3 | 1 | 33 | 0.071 | 4.257 |
| | Get the mold | LH | M4G3C4 | 11 | 0.024 | 1.419 | 3 | 1 | 33 | 0.071 | 4.257 |
| 2 | Put the mold back | RH | M4P5 | 9 | 0.019 | 1.161 | 3 | 1 | 27 | 0.058 | 3.483 |
| | | LH | | | | | | | | | |
| 3 | Check the rod position | RH | M4G1E4 | 9 | 0.019 | 1.161 | 3 | 1 | 27 | 0.058 | 3.483 |
| | | LH | M4G1E4 | 9 | 0.019 | 1.161 | 3 | 1 | 27 | 0.058 | 3.483 |
| 4 | Put the rod back | RH | M4P2 | 6 | 0.013 | 0.774 | 3 | 1 | 18 | 0.039 | 2.322 |
| | | LH | | | | | | | | | |

| | | | MODS | MINUTES | SECONDS | Total MODS | Total MINUTES | Total SECONDS |
|-------|--|--|------|---------|---------|---------------|------------------|------------------|
| TOTAL | | | 337 | 1.025 | 61.473 | 404167.5 | 1935.627 | 116137.608 |

Table 3.19 shows merged station that gathered stations 7 and 8 into one.

Table 3.19. Re-MODAPTS table for station 7&8

| STATION NAME | | STATION NUMBER | | | | | | | | | |
|--|---|----------------|---------------|-------|---------|---------|-------|------|------------|---------------|---------------|
| S7&8 END PLUG ASSEMBLING & OIL FILLING | | 7&8 | | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MOD S | MINUTES | SECONDS | FREQ. | PER. | Total MODS | Total MINUTES | Total SECONDS |
| 1 | Get the end plug | RH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 |
| | Get Oring no 1 | LH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 |
| 2 | Assemble the guiding with Oring no 1 | RH | M4P5 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 3 | Get another Oring no 1 | RH | | | | | | | | | |
| | | LH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 |
| 4 | Assemble the guiding with the second Oring no 1 | RH | M4P5 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 5 | Put the end plug on its place | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 |
| | | LH | | | | | | | | | |
| 6 | Get the Oring no 2 | RH | M4G3 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 |
| | | LH | | | | | | | | | |
| 7 | Put the Oring no 2 | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 |
| | | LH | | | | | | | | | |
| 8 | Get a squeezer | RH | M4G1 | 5 | 0.011 | 0.645 | 1 | 3 | 1.667 | 0.004 | 0.215 |
| | | LH | | | | | | | | | |
| 9 | Press the parts | RH | M4P2J2X4 | 12 | 0.026 | 1.548 | 4000 | 3 | 16000 | 34.4 | 2064 |
| | | LH | | | | | | | | | |
| 10 | Put the pen back | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 |
| | | LH | | | | | | | | | |
| 11 | | RH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 |

| | | | | | | | | | | | |
|----|--|----|----------|----|-------|-------|------|---|---------|--------|--------|
| | Get the bobbin | LH | | | | | | | | | |
| 12 | Put the bobbin | RH | M4P5 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 13 | Get the valve | RH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 |
| | | LH | | | | | | | | | |
| 14 | Put the valve | RH | M4P5 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 15 | Get the holder | RH | M4G1 | 5 | 0.011 | 0.645 | 1 | 3 | 1.667 | 0.004 | 0.215 |
| | | LH | | | | | | | | | |
| 16 | Get the metal ring | RH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 |
| | | LH | | | | | | | | | |
| 17 | Put in the holder | RH | M3P2 | 5 | 0.011 | 0.645 | 4000 | 3 | 6666.67 | 14.333 | 860 |
| | | LH | | | | | | | | | |
| 18 | Put the metal ring | RH | M4P5X4 | 13 | 0.028 | 1.677 | 4000 | 3 | 17333.3 | 37.267 | 2236 |
| | | LH | | | | | | | | | |
| 19 | Get a squeezer | RH | M4G1 | 1 | 0.002 | 0.129 | 4000 | 3 | 1333.33 | 2.867 | 172 |
| | | LH | | | | | | | | | |
| 20 | Press the parts | RH | M4P2J2X4 | 12 | 0.026 | 1.548 | 4000 | 3 | 16000 | 34.4 | 2064 |
| | | LH | | | | | | | | | |
| 21 | Transfer to closing machine | RH | W5L2 | 7 | 0.015 | 0.903 | 75 | 1 | 525 | 1.129 | 67.725 |
| | | LH | | | | | | | | | |
| 22 | Get the tube | RH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 3 | 6666.67 | 14.333 | 860 |
| | Get the end plug | LH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 3 | 6666.67 | 14.333 | 860 |
| 23 | Put the end plug in the tube (The other assembling with machining time) | RH | M3P2X4 | 9 | 0.019 | 1.161 | 1 | 1 | 9 | 0.019 | 1.161 |
| | | LH | | | | | | | | | |
| 24 | Put in the machine | RH | M7P5U2 | 14 | 0.03 | 1.806 | 4000 | 2 | 28000 | 60.2 | 3612 |
| | | LH | | | | | | | | | |
| 25 | Foot press | RH | F5 | 5 | 0.011 | 0.645 | 4000 | 2 | 10000 | 21.5 | 1290 |
| | | LH | | | | | | | | | |
| 26 | Pressing time | RH | | | 0.133 | 8 | 4000 | 2 | | 266.66 | 16000 |
| | | LH | | | | | | | | | |
| 27 | Get out the tube | RH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 2 | 10000 | 21.5 | 1290 |
| | | LH | | | | | | | | | |
| 28 | Check | RH | M4E4 | 8 | 0.017 | 1.032 | 4000 | 2 | 16000 | 34.4 | 2064 |
| | | LH | | | | | | | | | |
| 29 | Put the tube | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 2 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 30 | Get the tube | RH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 1 | 20000 | 43 | 2580 |
| | | LH | | | | | | | | | |
| 31 | | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 1 | 24000 | 51.6 | 3096 |

| | | | | | | | | | | | |
|---------------------|-------------------------------------|----|--------|-----|-------|-------|------|---|---------|--------|-------|
| | Put in the filling machine | LH | | | | | | | | | |
| 32 | Press button | RH | M3U0.5 | 3.5 | 0.008 | 0.452 | 4000 | 1 | 14000 | 30.1 | 1806 |
| | | LH | | | | | | | | | |
| 33 | Filling time | RH | | | 0.033 | 2 | 4000 | 1 | | 133.32 | 8000 |
| | | LH | | | | | | | | | |
| 34 | Put the tube back | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 1 | 24000 | 51.6 | 3096 |
| | | LH | | | | | | | | | |
| NON-CYCLIC ELEMENTS | | | | | | | | | | | |
| 1 | Reach the bags | RH | M4G3 | 7 | 0.015 | 0.903 | 5 | 1 | 35 | 0.075 | 4.515 |
| | | LH | | | | | | | | | |
| 2 | Open the bags | RH | M2P2X4 | 8 | 0.017 | 1.032 | 5 | 1 | 40 | 0.086 | 5.16 |
| | | LH | | | | | | | | | |
| 3 | Put the bags down | RH | M2P2 | 4 | 0.009 | 0.516 | 5 | 1 | 20 | 0.043 | 2.58 |
| | | LH | | | | | | | | | |
| 4 | Recheck with holder (10%) | RH | M4G1 | 5 | 0.011 | 0.645 | 400 | 3 | 666.667 | 1.433 | 86 |
| | | LH | M4P5 | 9 | 0.019 | 1.161 | 400 | 3 | 1200 | 2.58 | 154.8 |
| 5 | In the closing machine | RH | M4G1 | 4 | 0.009 | 0.516 | 1 | 1 | 4 | 0.009 | 0.516 |
| | Check the plug dimension by compass | LH | | | | | | | | | |
| 6 | Using the compass | RH | M4P2E4 | 10 | 0.022 | 1.29 | 1 | 1 | 10 | 0.022 | 1.29 |
| | | LH | | | | | | | | | |
| 7 | Get the tube | RH | M4G1 | 5 | 0.011 | 0.645 | 1 | 1 | 5 | 0.011 | 0.645 |
| | Put the plug inside | LH | M3P2X4 | 9 | 0.019 | 1.161 | 1 | 1 | 9 | 0.019 | 1.161 |
| 8 | Check with compass | RH | M7P5E4 | 16 | 0.034 | 2.064 | 1 | 1 | 16 | 0.034 | 2.064 |
| | | LH | | | | | | | | | |
| 9 | Leave compass | RH | M4P2 | 6 | 0.013 | 0.774 | 1 | 1 | 6 | 0.013 | 0.774 |
| | | LH | | | | | | | | | |
| 10 | Get pen | RH | M4G1 | 5 | 0.011 | 0.645 | 1 | 1 | 5 | 0.011 | 0.645 |
| | | LH | | | | | | | | | |
| 11 | Sign the right place | RH | M4P2H4 | 10 | 0.022 | 1.29 | 1 | 1 | 10 | 0.022 | 1.29 |
| | | LH | | | | | | | | | |
| 12 | Leave the pen | RH | M4P2 | 6 | 0.013 | 0.774 | 1 | 1 | 6 | 0.013 | 0.774 |
| | | LH | | | | | | | | | |
| 13 | Get the tube | RH | M2G0 | 2 | 0.004 | 0.258 | 1 | 1 | 2 | 0.004 | 0.258 |
| | | LH | | | | | | | | | |
| 14 | Put in the machine | RH | M4P5 | 9 | 0.019 | 1.161 | 1 | 1 | 9 | 0.019 | 1.161 |
| | | LH | | | | | | | | | |
| 15 | Adjust the assembling machine | RH | | | 1.417 | 85 | 1 | 1 | | 1.417 | 85 |
| | | LH | | | | | | | | | |

| | | | | | | | | | | |
|-------|----------------------------|----|-------|---------|---------|---|---|------------|---------------|---------------|
| 16 | Adjust the filling machine | RH | | 0.167 | 10 | 1 | 1 | | 0.167 | 10 |
| | | LH | | | | | | | | |
| TOTAL | | | MODS | MINUTES | SECONDS | | | Total MODS | Total MINUTES | Total SECONDS |
| | | | 354.5 | 2.512 | 150.731 | | | 367247.667 | 1191.146 | 71469.949 |

Table 3.20 is the Re-MODAPTS sheet for station 9 where no change occurred due to the importance of the existence of the non-value-added activities of this process.

Table 3.20. Re-MODAPTS table for station 9

| STATION NAME | | | STATION NUMBER | | | | | | | | |
|---------------------|------------------------------------|------|----------------|------|---------|---------|-------|------|------------|---------------|---------------|
| ROLLING AND CLOSING | | | 9 | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MODS | MINUTES | SECONDS | FREQ. | PER. | Total MODS | Total MINUTES | Total SECONDS |
| 1 | Get the installation tool | RH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 2 | 10000 | 21.5 | 1290 |
| | | LH | | | | | | | | | |
| 2 | Put the tool in its place | RH | M4P0 | 4 | 0.009 | 0.516 | 4000 | 2 | 8000 | 17.2 | 1032 |
| | | LH | | | | | | | | | |
| 3 | Get the tube | RH | | | | | | | | | |
| | | LH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 2 | 10000 | 21.5 | 1290 |
| 4 | Put the tube in installation place | RH | | | | | | | | | |
| | | LH | M4P0 | 4 | 0.009 | 0.516 | 4000 | 2 | 8000 | 17.2 | 1032 |
| 5 | Install on the tube | RH | M3P2 | 5 | 0.011 | 0.645 | 4000 | 2 | 10000 | 21.5 | 1290 |
| | | LH | | | | | | | | | |
| 6 | Get the rod | RH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 2 | 10000 | 21.5 | 1290 |
| | | LH | | | | | | | | | |
| 7 | Put the rod in the tube | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 2 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 8 | Move to the pressing machine | RH | M2G0 | 2 | 0.004 | 0.258 | 4000 | 2 | 4000 | 8.6 | 516 |
| | | LH | | | | | | | | | |
| 9 | Foot press | RH | F3 | 3 | 0.006 | 0.387 | 4000 | 2 | 6000 | 12.9 | 774 |
| | | LH | | | | | | | | | |
| 10 | Pressing time | RH | | | 0.0333 | 2 | 4000 | 2 | | 66.6 | 4000 |
| | | LH | | | | | | | | | |
| 11 | Put the assembled part back | RH | | | | | | | | | |
| | | LH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 2 | 12000 | 25.8 | 1548 |
| 12 | Transfer to rolling and | RH | W23.5L2 | 25.5 | 0.055 | 3.29 | 200 | 2 | 2550 | 5.483 | 328.95 |
| | | LH | | | | | | | | | |

| | | | | | | | | | | | |
|---------------------|---|----|--------|----|-------|-------|------|---|-------|--------|-------|
| | closing machine | | | | | | | | | | |
| 13 | Get the gas spring | RH | M4G1 | 5 | 0.011 | 0.645 | 2 | 2 | 5 | 0.011 | 0.645 |
| | | LH | | | | | | | | | |
| 14 | Put the gas spring in the machine | RH | M4P2U2 | 8 | 0.017 | 1.032 | 8000 | 2 | 32000 | 68.8 | 4128 |
| | | LH | | | | | | | | | |
| 15 | Foot press | RH | F3 | 3 | 0.006 | 0.387 | 8000 | 2 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| 16 | Machining time (get the next one while machining) | RH | | | 0.133 | 8 | 8000 | 2 | | 533.32 | 32000 |
| | | LH | | | | | | | | | |
| 17 | Get the gas spring from the machine | RH | M4G1 | 5 | 0.011 | 0.645 | 8000 | 2 | 20000 | 43 | 2580 |
| | | LH | | | | | | | | | |
| 18 | Put the gas spring back | RH | M4P2 | 6 | 0.013 | 0.774 | 8000 | 2 | 24000 | 51.6 | 3096 |
| | | LH | | | | | | | | | |
| 19 | Get the gas spring for second rolling | RH | M4G1 | 5 | 0.011 | 0.645 | 8000 | 2 | 20000 | 43 | 2580 |
| | | LH | | | | | | | | | |
| 20 | Put in the machine | RH | M4P2U2 | 8 | 0.017 | 1.032 | 8000 | 2 | 32000 | 68.8 | 4128 |
| | | LH | | | | | | | | | |
| NON-CYCLIC ELEMENTS | | | | | | | | | | | |
| 1 | Adjust the assembling machine | RH | | | 3.7 | 222 | 2 | 2 | | 3.7 | 222 |
| | | LH | | | | | | | | | |
| 2 | In the closing machine Check the plug dimension by compass | RH | M4G1 | 4 | 0.009 | 0.516 | 2 | 2 | 4 | 0.009 | 0.516 |
| | | LH | | | | | | | | | |
| 3 | Using the compass | RH | M4P2E4 | 10 | 0.022 | 1.29 | 2 | 2 | 10 | 0.022 | 1.29 |
| | | LH | | | | | | | | | |
| 4 | Get the tube Put the plug inside | RH | M4G1 | 5 | 0.011 | 0.645 | 2 | 2 | 5 | 0.011 | 0.645 |
| | | LH | M3P2X4 | 9 | 0.019 | 1.161 | 2 | 2 | 9 | 0.019 | 1.161 |
| 5 | Check with compass | RH | M7P5E4 | 16 | 0.034 | 2.064 | 2 | 2 | 16 | 0.034 | 2.064 |
| | | LH | | | | | | | | | |
| 6 | Leave compass | RH | M4P2 | 6 | 0.013 | 0.774 | 2 | 2 | 6 | 0.013 | 0.774 |
| | | LH | | | | | | | | | |
| 7 | Get pen | RH | M4G1 | 5 | 0.011 | 0.645 | 2 | 2 | 5 | 0.011 | 0.645 |
| | | LH | | | | | | | | | |
| 8 | Sign the right place | RH | M4P2H4 | 10 | 0.022 | 1.29 | 2 | 2 | 10 | 0.022 | 1.29 |
| | | LH | | | | | | | | | |
| 9 | Leave the pen | RH | M4P2 | 6 | 0.013 | 0.774 | 2 | 2 | 6 | 0.013 | 0.774 |
| | | LH | | | | | | | | | |
| 10 | Get the tube | RH | M2G0 | 2 | 0.004 | 0.258 | 2 | 2 | 2 | 0.004 | 0.258 |

| | | LH | | | | | | | | | |
|-------|--------------------|----|------|-------|---------|---------|---|---|------------|---------------|---------------|
| 11 | Put in the machine | RH | M4P5 | 9 | 0.019 | 1.161 | 2 | 2 | 9 | 0.019 | 1.161 |
| | | LH | | | | | | | | | |
| 12 | Adjusting | RH | | 2.833 | 170 | | 2 | 2 | 2.833 | 170 | |
| | | LH | | | | | | | | | |
| TOTAL | | | | MODS | MINUTES | SECONDS | | | Total MODS | Total MINUTES | Total SECONDS |
| | | | | 192.5 | 7.114 | 426.833 | | | 232637 | 1106.623 | 66402.173 |

Table 3.21 represents the RE-MODAPTS table of station 10 which also remained the same because it already had only one non-value-added activity that is important for the process.

Table 3.21. Re-MODAPTS table for station 10

| <u>STATION NAME</u> | | <u>STATION NUMBER</u> | | | | | | | | | |
|---------------------|---|-----------------------|---------------|------|---------|---------|-------|------|------------|---------------|---------------|
| GAS FILLING | | 10 | | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MODS | MINUTES | SECONDS | FREQ. | PER. | Total MODS | Total MINUTES | Total SECONDS |
| 1 | Get the first gas spring | RH | M7G1 | 8 | 0.017 | 1.032 | 1 | 1 | 8 | 0.017 | 1.032 |
| | | LH | | | | | | | | | |
| 2 | Put in the machine | RH | M7P2J2 | 11 | 0.024 | 1.419 | 1 | 1 | 11 | 0.024 | 1.419 |
| | | LH | | | | | | | | | |
| 3 | Press the button | RH | M3G0X4 | 7 | 0.015 | 0.903 | 4000 | 1 | 28000 | 60.2 | 3612 |
| | | LH | | | | | | | | | |
| 4 | Filling time (get the next one while filling) | RH | | | 0.167 | 10 | 4000 | 1 | | 666.68 | 40000.8 |
| | | LH | | | | | | | | | |
| 5 | Take the filled gas spring | RH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 1 | 20000 | 43 | 2580 |
| | | LH | | | | | | | | | |
| 6 | Put the next one | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 1 | 24000 | 51.6 | 3096 |
| | | LH | | | | | | | | | |
| 6 | Put the filled gas spring | RH | M7P2 | 9 | 0.019 | 1.161 | 4000 | 1 | 36000 | 77.4 | 4644 |
| | | LH | | | | | | | | | |
| NON-CYCLIC ELEMENTS | | | | | | | | | | | |
| 1 | Get the mold of the machine | RH | M4G1C4 | 9 | 0.019 | 1.161 | 1 | 1 | 9 | 0.019 | 1.161 |
| | | LH | | | | | | | | | |
| 2 | Pull the mold | RH | M4G0 | 4 | 0.009 | 0.516 | 1 | 1 | 4 | 0.009 | 0.516 |
| | | LH | | | | | | | | | |
| 3 | Put on the table | RH | M7P2 | 9 | 0.019 | 1.161 | 1 | 1 | 9 | 0.019 | 1.161 |
| | | LH | | | | | | | | | |

| | | | | | | | | | | | |
|-------|--------------------------------|----|--------|----|-------|-------|---------|---|------------|---------------|---------------|
| 4 | Get the upper part | RH | M3G1 | 4 | 0.009 | 0.516 | 1 | 1 | 4 | 0.009 | 0.516 |
| | Get the new mold | LH | M3G1 | 4 | 0.009 | 0.516 | 1 | 1 | 4 | 0.009 | 0.516 |
| 5 | Put the upper part | RH | M7P5 | 12 | 0.026 | 1.548 | 1 | 1 | 12 | 0.026 | 1.548 |
| | Put the new mold | LH | M7P5C4 | 16 | 0.034 | 2.064 | 1 | 1 | 16 | 0.034 | 2.064 |
| 6 | Adjust the mold in the machine | RH | | | 3.167 | 190 | 1 | 1 | | 3.167 | 190 |
| | | LH | | | | | | | | | |
| TOTAL | | | | | | | | | Total MODS | Total MINUTES | Total SECONDS |
| | | | | | 126 | 3.604 | 216.254 | | 108099 | 902.26 | 54135.571 |

Table 3.22 displays the Re-MODAPTS table of station 11 and similarly to stations 9 and 10, it had no modification owing to its reliance on a semi-automated system.

Table 3.22. Re-MODAPTS table for station 11

| STATION NAME | | STATION NUMBER | | | | | | | | | | |
|--------------|-------------------------------------|----------------|---------------|-------|---------|---------|-------|------|------------|---------------|---------------|--|
| PAINTING | | 11 | | | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MOD S | MINUTES | SECONDS | FREQ. | PER. | Total MODS | Total MINUTES | Total SECONDS | |
| 1 | Get the gas springs | RH | M4G3 | 7 | 0.015 | 0.903 | 800 | 1 | 5600 | 12.04 | 722.4 | |
| | | LH | | | | | | | | | | |
| 2 | Go to the pool | RH | W2.36 | 2.36 | 0.005 | 0.304 | 800 | 1 | 1888 | 4.059 | 243.552 | |
| | | LH | | | | | | | | | | |
| 3 | Put the gas springs in the water | RH | M7P2 | 9 | 0.019 | 1.161 | 800 | 1 | 7200 | 15.48 | 928.8 | |
| | | LH | | | | | | | | | | |
| 4 | Washing time | RH | | | 0.167 | 10 | 800 | 1 | | 133.336 | 8000.16 | |
| | | LH | | | | | | | | | | |
| 5 | Pull the gas spring | RH | M7G1U6 | 14 | 0.03 | 1.806 | 800 | 1 | 11200 | 24.08 | 1444.8 | |
| | | LH | | | | | | | | | | |
| 6 | Put the gas spring in the next pool | RH | W2.36M7P2 | 11.36 | 0.024 | 1.465 | 800 | 1 | 9088 | 19.539 | 1172.352 | |
| | | LH | | | | | | | | | | |
| 7 | Washing time | RH | | | 0.167 | 10 | 800 | 1 | | 133.336 | 8000.16 | |
| | | LH | | | | | | | | | | |
| 8 | Pull the gas springs | RH | M7G1U6 | 14 | 0.03 | 1.806 | 800 | 1 | 11200 | 24.08 | 1444.8 | |
| | | LH | | | | | | | | | | |
| 9 | Put them back | RH | W2.36M5P2 | 9.36 | 0.02 | 1.207 | 800 | 1 | 7488 | 16.099 | 965.952 | |
| | | LH | | | | | | | | | | |

| | | | | | | | | | | | |
|---------------------|--------------------------------------|----|---------------|-------|--------|-------|------|---|---------|---------|---------|
| 10 | Get the gas springs | RH | M7G1 | 8 | 0.0172 | 1.032 | 4000 | 3 | 10666.7 | 22.933 | 1376 |
| | | LH | | | | | | | | | |
| 11 | Hang the gas springs | RH | M7P2J2C4 | 15 | 0.032 | 1.935 | 4000 | 3 | 20000 | 43 | 2580 |
| | | LH | | | | | | | | | |
| 12 | Get the rod protection cover | RH | M7G3 | 10 | 0.022 | 1.29 | 4000 | 3 | 13333.3 | 28.667 | 1720 |
| | | LH | | | | | | | | | |
| 13 | Put the covers on rods | RH | M7P5J2 | 14 | 0.03 | 1.806 | 4000 | 3 | 18666.7 | 40.133 | 2408 |
| | | LH | | | | | | | | | |
| 14 | Get a rag | RH | W2.36M7G 1 | 10.36 | 0.022 | 1.336 | 3 | 3 | 10.36 | 0.022 | 1.336 |
| | | LH | | | | | | | | | |
| 15 | Wipe the tubes | RH | M4P2J2U3 | 11 | 0.0237 | 1.419 | 4000 | 3 | 14666.7 | 31.533 | 1892 |
| | | LH | | | | | | | | | |
| 16 | Get the rod covers after painting | RH | W2.36M4G 1 | 7.36 | 0.016 | 0.949 | 4000 | 3 | 9813.33 | 21.099 | 1265.92 |
| | | LH | | | | | | | | | |
| 17 | Take the cover off and put them away | RH | M5P2 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 |
| | | LH | | | | | | | | | |
| 18 | Get the gas springs | RH | M7G1J2C4 | 14 | 0.03 | 1.806 | 4000 | 3 | 18666.7 | 40.1333 | 2408 |
| | | LH | | | | | | | | | |
| 19 | Take the gas spring off | RH | M7P2 | 9 | 0.019 | 1.161 | 4000 | 3 | 12000 | 25.8 | 1548 |
| | | LH | | | | | | | | | |
| NON-CYCLIC ELEMENTS | | | | | | | | | | | |
| 1 | Hold the water pool | RH | M5G1 | 6 | 0.013 | 0.774 | 1 | 1 | 6 | 0.013 | 0.774 |
| | | LH | | | | | | | | | |
| 2 | Open the water pool | RH | M7P0 | 7 | 0.015 | 0.903 | 1 | 1 | 7 | 0.015 | 0.903 |
| | | LH | | | | | | | | | |
| 3 | Get the gloves | RH | W2.36M7G 1 | 10.36 | 0.022 | 1.336 | 1 | 1 | 10.36 | 0.022 | 1.336 |
| | | LH | W2.36M7G 1 | 10.36 | 0.022 | 1.336 | 1 | 1 | 10.36 | 0.022 | 1.336 |
| 4 | Wear the gloves | RH | M2P5 | 7 | 0.015 | 0.903 | 1 | 1 | 7 | 0.015 | 0.903 |
| | | LH | M2P5 | 7 | 0.015 | 0.903 | 1 | 1 | 7 | 0.015 | 0.903 |
| 5 | Go to the gas springs | RH | W2.36 | 2.36 | 0.005 | 0.304 | 1 | 1 | 2.36 | 0.005 | 0.304 |
| | | LH | | | | | | | | | |
| 6 | Get the air gun | RH | M4G3 | 7 | 0.015 | 0.903 | 1 | 1 | 7 | 0.015 | 0.903 |
| | | LH | M4G0X4 | 8 | 0.017 | 1.032 | 1 | 1 | 8 | 0.017 | 1.032 |
| 7 | Drying time | RH | | | 10 | 600 | 1 | 1 | | 10 | 600 |
| | | LH | | | | | | | | | |
| 8 | | RH | W38.75 | 38.75 | 0.083 | 4.999 | 1 | 1 | 38.75 | 0.083 | 4.999 |

| | | | | | | | | | | |
|---|-------------------------------|----|--|-------|--------|---------|----------|------------|---------------|---------------|
| | Transfer to the painting room | LH | | | | | | | | |
| 9 | Painting time | RH | | 120 | 7200 | 1 | 1 | | 120 | 7200 |
| | | LH | | | | | | | | |
| | | | | TOTAL | MODS | MINUTES | SECONDS | Total MODS | Total MINUTES | Total SECONDS |
| | | | | | 276.63 | 130.928 | 7855.686 | 180924.857 | 785.66 | 47139.627 |

Table 3.23 shows the Re-MODAPTS table that analyses the motions of the operators after combining stations 12 and 13 in one final station.

Table 3.23. Re-MODAPTS table for station 12&13

| STATION NAME | | | STATION NUMBER | | | | | | | | |
|------------------------------------|--|------|----------------|------|---------|---------|-------|------|------------|---------------|---------------|
| END FITTING ASSEMBLING & PACKAGING | | | 12&13 | | | | | | | | |
| Ele. No. | DESC. | Hand | MODAPTS CODES | MODS | MINUTES | SECONDS | FREQ. | PER. | Total MODS | Total MINUTES | Total SECONDS |
| 1 | Get the gas springs from the trolley | RH | M7G1 | 8 | 0.017 | 1.032 | 800 | 3 | 2133.33 | 4.587 | 275.2 |
| | | LH | | | | | | | | | |
| 2 | Put the gas spring on the table | RH | M7P2 | 9 | 0.019 | 1.161 | 800 | 3 | 2400 | 5.16 | 309.6 |
| | | LH | | | | | | | | | |
| 3 | Get the gas spring Get the fork | RH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 3 | 6666.67 | 14.333 | 860 |
| | | LH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 |
| 4 | Assemble the fork | RH | M4P2C4 | 10 | 0.022 | 1.29 | 4000 | 3 | 13333.3 | 28.667 | 1720 |
| | | LH | | | | | | | | | |
| 5 | Switch the gas spring Get the joint | RH | M2 | 2 | 0.004 | 0.258 | 4000 | 3 | 2666.67 | 5.733 | 344 |
| | | LH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 |
| 6 | Assemble the joint | RH | M4P2C4 | 10 | 0.022 | 1.29 | 4000 | 3 | 13333.3 | 28.667 | 1720 |
| | | LH | | | | | | | | | |
| 7 | Put the gas spring back | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 |
| | | LH | | | | | | | | | |
| 8 | Get the gas spring again | RH | | 5 | 0.011 | 0.645 | 4000 | 2 | 10000 | 21.5 | 1290 |
| | | LH | M4G1 | | | | | | | | |
| 9 | Put the fork in the director tool | RH | | 9 | 0.019 | 1.161 | 4000 | 2 | 18000 | 38.7 | 2322 |
| | | LH | M4P5 | | | | | | | | |

| | | | | | | | | | | | | |
|---------------------|---------------------------------|----|-----------------|-------|-------|---------|---------|---|---------|------------|---------------|---------------|
| 10 | Get a holder | RH | M4G1 | 5 | 0.011 | 0.645 | 1 | 1 | 5 | 0.011 | 0.645 | |
| | | LH | | | | | | | | | | |
| 11 | Put the holder on the joint | RH | M7P2J2C4 | 15 | 0.032 | 1.935 | 4000 | 2 | 30000 | 64.5 | 3870 | |
| | | LH | | | | | | | | | | |
| 12 | Get the gas spring | RH | | | | | | | | | | |
| | | LH | M1G0 | 1 | 0.002 | 0.129 | 4000 | 2 | 2000 | 4.3 | 258 | |
| 13 | Put on the table | RH | | | | | | | | | | |
| | | LH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 2 | 12000 | 25.8 | 1548 | |
| 14 | Get the gas spring | RH | M4G1 | 5 | 0.011 | 0.645 | 4000 | 3 | 6666.67 | 14.333 | 860 | |
| | | LH | M4G3 | 7 | 0.015 | 0.903 | 4000 | 3 | 9333.33 | 20.067 | 1204 | |
| 15 | Put the gas spring in the bag | RH | M4P5J2 | 11 | 0.024 | 1.419 | 4000 | 3 | 14666.7 | 31.533 | 1892 | |
| | | LH | | | | | | | | | | |
| 16 | Put the gas spring on the table | RH | M4P2 | 6 | 0.013 | 0.774 | 4000 | 3 | 8000 | 17.2 | 1032 | |
| | | LH | | | | | | | | | | |
| 17 | Open a box | RH | | | 0.3 | 18 | 160 | 2 | | 24 | 1440 | |
| | | LH | | | | | | | | | | |
| 18 | Get the gas springs (5 pcs) | RH | M4G3 | 7 | 0.015 | 0.903 | 800 | 2 | 2800 | 6.02 | 361.2 | |
| | | LH | | | | | | | | | | |
| 19 | Put in the box | RH | M7P5 | 12 | 0.026 | 1.548 | 800 | 2 | 4800 | 10.32 | 619.2 | |
| | | LH | | | | | | | | | | |
| 20 | Close the box | RH | | | 0.183 | 11 | 160 | 2 | | 14.666 | 880 | |
| | | LH | | | | | | | | | | |
| 21 | Get the box | RH | M4G3L3 | 10 | 0.022 | 1.29 | 160 | 2 | 800 | 1.72 | 103.2 | |
| | | LH | | | | | | | | | | |
| 22 | Put in the parcel | RH | W15.5M7P5 L3 | 30.5 | 0.066 | 3.935 | 160 | 2 | 2440 | 5.246 | 314.76 | |
| | | LH | | | | | | | | | | |
| 23 | Close the parcel | RH | | | 2.5 | 150 | 2 | 1 | | 2.5 | 150 | |
| | | LH | | | | | | | | | | |
| NON-CYCLIC ELEMENTS | | | | | | | | | | | | |
| | | | | TOTAL | MODS | MINUTES | SECONDS | | | Total MODS | Total MINUTES | Total SECONDS |
| | | | | | 193.5 | 3.399 | 203.962 | | | 188711.667 | 446.897 | 26813.805 |

These MODAPTS tables provide the data of the standardize time of each station and process after using VSM tools to improve the production area and build a new and better status. The new data was used in the future status of VSM to complete it.

3.4.3. The Final Status

This study used some VSM techniques combined with MODAPTS methodology in order to improve a production line, as shown in Figure 3.5 which displays the future status of the value stream mapping. A new real-life example to prove the adding value of Lean Manufacturing tools and their great impact on production facilities. The next section will discuss the results and the limitations of the study proving its success and prefacing new studies to build on this case.



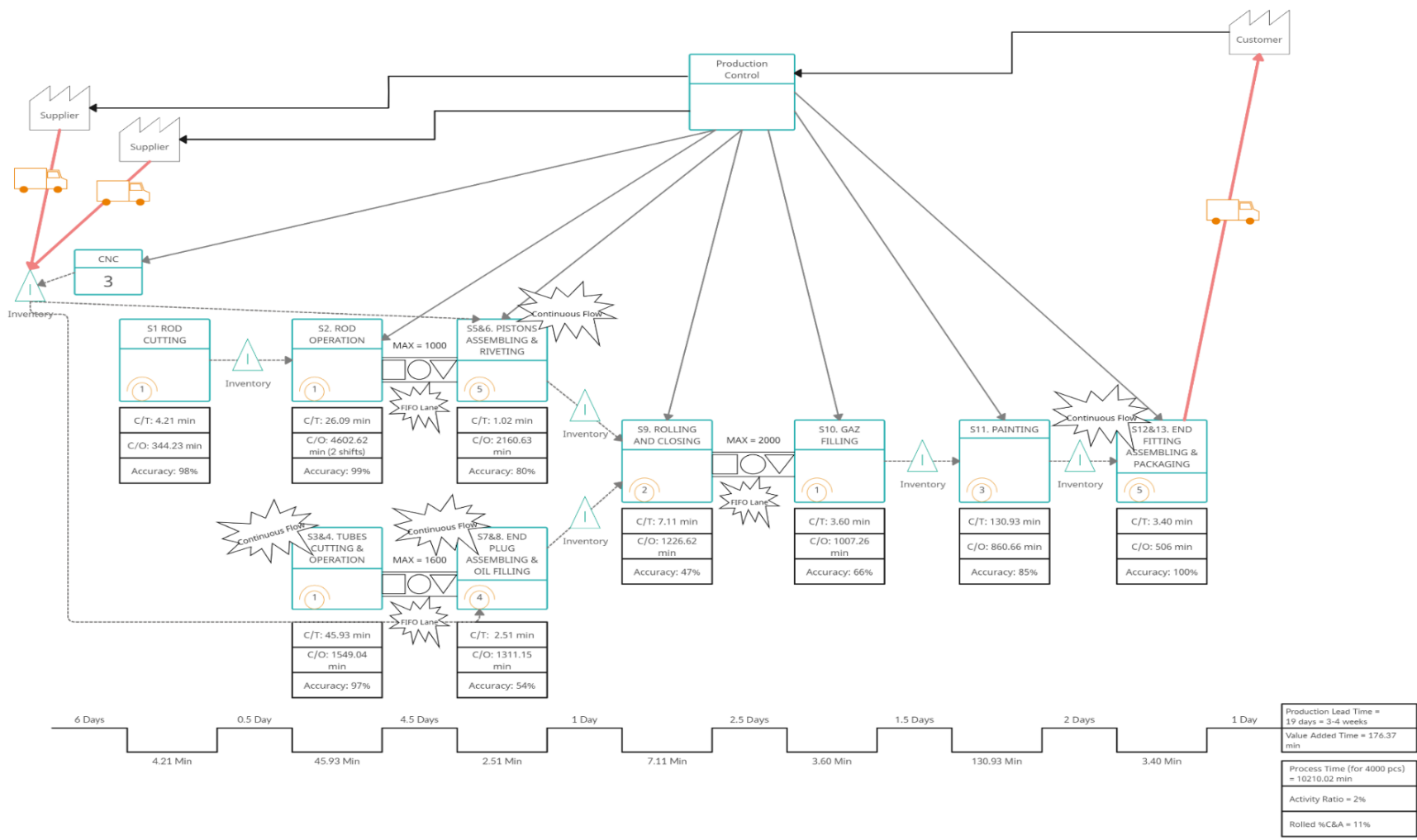


Figure 3.5. The future state of VSM

CHAPTER 4

DISCUSSION AND CONCLUSION

The application outputs in this study display the efficiency of the VSM and MODAPTS combined model. By analysing the output data, the model's capability will be proved to apply, and the obstacles will be observed to improve.

4.1. DISCUSSION

The figures of the current state and future state display an improvement that happened from the application. To be able to evaluate the results objectively, Time & Quality Value Stream Performance Metrics provide a numerical comparison between the current state and the future state of VSM. The matrix of this case study is going to be as Table 4.1 shows.

Table 4.1. Time & quality value stream performance metric

| Metric | Current | Future | Improvement |
|----------------------------------|----------------|---------------|--------------------|
| Production Lead Time | 36 days | 19 days | 47% |
| Value Added Time | 193.82 min | 176.37 min | 9% |
| Process Time for 4000 pcs | 11185.79 min | 10210.02 min | 9% |
| Activity Ration | 1% | 2% | 100% |
| Rolled %C&A | 5% | 11% | 120% |

The improvement percentages evidence touchable progress in different ranges. Improving the lead time by 47% increases the satisfaction level of the customer due to the fact that the delivery time became shorter by more than two weeks. Also, saving two weeks in the gas spring industry is an advantage that puts the factory at competitive level with the competitors in the market. The development in activity ratio and rolled percent complete and accurate (%C&A) prove the success of the study as well, especially the percentage of rolled %C&A, which is 11%, and this percentage is close to the general target of VSM, which should be around 15%. These results illustrate and summarize the study and exhibit its success and efficiency. To observe the results in more detail Table 4.2 shows the cycle time and change over time as MODAPTS calculated them for each station.

Table 4.2. MODAPTS output summary

| Current | | | Future | | |
|---------|---------|----------|---------|---------------|-----------------|
| Station | C/T | C/O | Station | C/T | C/O |
| 1 | 4.207 | 374.712 | 1 | 4.207 | 299.23 |
| 2 | 26.092 | 4182.62 | 2 | 26.092 | 4096.642 |
| 3 | 15.772 | 655.908 | 3&4 | 45.931 | 1384.045 |
| 4 | 30.288 | 778.883 | | | |
| 5 | 0.588 | 812 | 5&6 | 1.025 | 1935.627 |
| 6 | 0.448 | 1159.455 | | | |
| 7 | 2.268 | 881.359 | 7&8 | 2.512 | 1191.146 |
| 8 | 0.244 | 309.787 | | | |
| 9 | 7.114 | 1106.623 | 9 | 7.114 | 1106.623 |
| 10 | 3.604 | 902.26 | 10 | 3.604 | 902.26 |
| 11 | 130.928 | 785.66 | 11 | 130.928 | 785.66 |
| 12 | 0.226 | 299.291 | 12&13 | 3.399 | 446.896 |
| 13 | 3.174 | 147.606 | | | |

The table compares the consumed time for each station, and it is obvious that most of the development happened in the first six stations whether for the C/T or the C/O. This output shows the influence of MODAPTS on VSM and its effectiveness. In summary, the model's competence that combines VSM and MODAPTS has been proved with numbers in a real-life experience.

Nevertheless, there were some limitations too. The obstacle confronting the study is the wasted time adjusting the machines. The workers spend too much time adjusting the machines because the adjustment is set manually, and they set the machine calibration, try, check, reset, try, check...etc. These useless repeated activities should be reduced as much as possible, but this model couldn't interfere with solving this issue because it needs machinery modification. After the machinery modification or even with it, using SMED as a lean manufacturing tool would also be very effective. The development in this area would directly affect all the parameters in the value stream metric. It is believed that value-added time would be influenced and get better by solving this issue. This was the dilemma recognized while conducting this study. Mainly, there are four processes that urgently need to be interfered mechanically to eliminate the adjusting time of the machines. These operations are riveting, end plug assembling, rolling & closing, and gas filling. In this section, approximate data will be provided assuming that all these machines were adjusted and ready to be used directly to eliminate the adjusting time and get a theoretical overview about the change that could happen by developing the time of adjustment. For riveting, checking the length of the rod and adjusting it with the mold of the machine is taking too much time and the workers are checking it at least 3 times. With improving the adjusting time, the cycle time would be improved by 11.54% and increasing the accuracy of the process to 89%. Assembling the end plug and rolling & closing processes are very similar. They both go through machines that they dig lines in particular places on the tubes of the gas springs. In this process, there are 2 challenges which are determining the distance between the line and the beginning of the tube and the depth of the line. The complexity of assembling the end plug is less than the rolling & closing process due to the fact that the assembling needs only digging one line, but it needs 2 for rolling & closing so it makes the determination of distance and depth much harder. This does not negate the increase in efficiency that would happen after eliminating the adjusting time for assembling the end plug. The cycle time would decrease by 56.39% and the accuracy might increase from 54% to 84%. Similarly, the accuracy of the rolling & closing process might increase from 47% to 90% while the cycle time could reach an enormous improvement with 91.84%. The situation is the same in the operation of gas filling. There is a big mold that needs both physical power and flexibility to be assembled and adjusted. Also, after adjusting, it needs to be tested by charging the first

gas spring smoothly and carefully and then checking the gas because any mistake in this process may lead the gas spring to explode causing a real disaster in the workplace. This checking process is a must because the adjustment is done manually but if there is an automated adjusted machine to be ready directly to be fed, the cycle time would have increased by 87.86% and the accuracy could be almost 100%. Using this data in the performance metric will change the rolled %C&A of the future status to 50% showing a 1000% development rate. Of course, these numbers and output are purely theoretical and not practical at all, but they give the motivation to apply a new real-life case study to develop this one and come up with real and practical data. Additionally, the time spent on the rod operation and painting is too much, but this study couldn't detect the possible reasons and suggested solutions, it shows that there are potential hidden obstacles in these working stations, so it might be needed to change the mechanism of the whole operation so studying these processes could be also a future project.

All in all, the study showed enormous progress in the production line and achieved the target of the application. There was a limitation to which could make bigger improvement. It is healthy for any study to recognize these obstacles in order to solve them and this study highlighted them with some details and suggested future projects that can be done to solve these problems and develop this study more and more. That's the core of lean manufacturing technique in general and VSM particularly, it is an ongoing process that needs to be conducted and developed day by day. Lastly, it is possible to claim that by using MODAPTS to support VSM, most of the production problems and wastes, especially the hidden ones, can be found and solved from a Lean Manufacturing perspective.

4.2. CONCLUSION

In conclusion, this thesis worked on an interesting model that could be helpful and useful for factory supervisors. VSM alone is a perfect method to use to be able to identify the troubles in the workplace. With the support of a PMTS methodology that takes the ergonomic aspects into consideration, the influence of VSM aggrandizes. Most of the problems executives seek to solve are classical and obvious disorders.

However, this model would enhance their way of seeing to start recognizing the hidden deficiencies in all processes. Applying this model is just like using a microscope to see the unseen. The main purpose of these improvements is to decrease the delivery time of the orders. This study could reduce the delivery time from 36 days to 19 days which means two weeks earlier and almost doubling the production capacity. VSM provides different tools to be used in order to eliminate non-value-added activities, such as merging stations and FIFO, which were used to improve the production line in this case study. An advancement could happen simply by reordering the assembling tables in the workstations. This is the advantage of Lean Manufacturing tools, reaching developments doesn't need complicated or costly solutions always, sometimes these issues can be solved with a very simple move like these kinds of studies focus on. Although VSM was the main methodology and MODAPTS was a supporter method, MODAPTS added great value to the study, which makes it no less important than VSM. MODAPTS was conducted on 13 stations in the current state and nine stations in the future state of the VSM, providing very accurate standardization for the spent time in each workstation. On the other hand, there was a limitation too: the machines' adjustment time. That was a non-value-added activity that the application couldn't eliminate. Nonetheless, the study showed very valuable results. Therefore, I suggest building on this study by finding solutions for the wasted time in adjusting and preparing machines for work such as direct mechanical interference or with a lean manufacturing tool like SMED. Also, it is recommended to convert this model to an automatic program or application that can be used on computers or similar devices to make this model easier and more effective. Finally, this study displayed the harmony between VSM and MODAPTS in an active combination. It confirmed the prosperity that this model can achieve and expanded the horizon for more studies in the future.

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RESUME

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