Combining simple motion measurement, lean analysis technique and historical data review for countering negative labor cost variance: A case study

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Abstract
Negative labor cost variance (NLCV) is an important problem in many manufacturing companies today. NLCV refers to the situation that expected or standard costs are less than actual labor costs in production. Management of NLCV, including the identification of causes for NLCV and the elimination or significant reduction of NLCV, is the topic discussed in this paper. The question studied in this paper is thus: what is an effective methodology in the environment of strong privacy protection to identify causes for NLCV and to significantly reduce it? The study presented in this paper proposed a methodology by combining a simple motion measurement (stopwatch), lean analysis techniques, and historical data review to study the NLCV problem. A case study was taken on a particular company called ABC to test the effectiveness of this methodology. Specifically, the result of the study revealed that (1) the employees in ABC waited for one reason or the other for almost 5 h (idle time) in a 16-h daily operation period (2 shifts running at 8 h each), which accounts for 32% of the total productive time, and (2) the elimination of the waiting time or idle time over the years concerned could account for 83% of all identified wastes in ABC. Through this case study, the effectiveness of the proposed methodology was demonstrated and the applicability of the proposed methodology was also implied.

Keywords
Production planning and control, production cost, lean manufacturing, labor cost variance, value stream mapping, non-value-added activity (NVA)

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Introduction
The importance of production cost (PC) and labor cost (LC) in pharmaceutical industries cannot be overemphasized. This holds true in other manufacturing industries as well. Generally, in production planning and control (PPC), the cost of production is the cost required during the inception of an investment to carry out the production process. In manufacturing, PC includes all possible cost incurred in making products. However, there are constraints that should be exploited effectively to significantly increase the performance of production while minimizing the cost. According to Chamber et al., PPC involves integrating different activities of labor, production capacity and other resources such as raw materials with their respective costs in order to implement production plans.

An important factor to consider to optimize the cost of production is the LC in manufacturing, which is a significant part of the entire PC. Indeed, the cost of bringing skilled labors to the pharmaceutical industry is significantly
increasing recently. Also, there is an increase in non-value-added activities (NVA) associated with workers in manufacturing. According to Womack and Jones, NVA is defined as “an activity which absorbs resources but creates no value”. Among NVA, idle time is the time an employee stays idle or engages in activities that are out of the scope of manufacturing, and it needs to be reduced if not completely eliminated.

This paper presents an approach to identifying NVA with a focus on idle time and aims to investigate why there is an increase in negative labor cost variances (NLCV), so as to understand the impact of NVA on NLCV. To achieve this aim, a time and motion study is conducted by the direct observation of employees using the stop-watch.

The rest of this paper is organized as follows. Second section gives some background knowledge as well as the literature. In third section, a case study is presented to explain the problem description. Fourth section represents the methodology used in the study. Fifth section presents the results and discussion. Sixth section presents the conclusion and suggestions for future research.

Background and literature review

Activities in manufacturing are classified into value-added and non-value-added kinds. Operation Management (OM) aims to transform NVA activities to valued products and services or to reduce these activities over the entire set of activities. It involves production planning and scheduling, production control, operation management with consideration of human factor, supply chain and inventory management. Additionally, concepts such as robustness and resilience are also important to operation management.

To better understand OM, the cost of production (CoP) has become an escalating problem in manufacturing. According to Shih and Liu, CoP includes manufacturing labor costs, overhead costs and material costs that are needed for production. CoP increases when the total quantity of production increases. Meanwhile, the major concern in PPC is to consistently find a method to reduce the total CoP overtime. However, most manufacturers consider CoP only in the planning phase, while ignoring other costs than production cost, especially ignoring the idle labor cost in production.

For instance, Cheraghalikhani et al. considered that the cost relating to regular and overtime working hours as well as cost of backorders in inventory are merely considered as a sort of disturbances to the total CoP models.

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As shown in Figure 1, ABC packaging process involves sorting, loading, filling, transferring, capping and depositing capped bottles in a tote after bottles have been sealed. Afterwards, the bottles are wiped to ensure dryness and properly labeled. In Process 1 (i.e., sorting), the raw materials (bottles, oil, and packing materials) need to be sorted. This activity is completed by three employees at an average throughput rate of 1275 units per hour. Process 2 (i.e., loading) involves loading the sorted bottles out of Process 1 to the dispensing machine with the aid of a conveying system. In Process 3 (i.e., filling), the bottles are set for the dispensing machine. The multi-headed packaging machine is configured such that each of the lanes contains a dedicated load cell. The process begins by filling the center of the overhead scale with the bulk product. Then, the bulk product will be spread from the center of the scale cone to each of the vibratory feeder pans. The feeder pans will transfer products to buckets, where the weights of the products are determined. Upon this, a suitable bucket on the dispensing machine is selected to contain products, and the machine then dispenses the product in the bucket to bottles on the conveyor at the same time. In Process 4 (i.e., transfer), Process 5 (i.e., capping) and Process 6 (i.e., wiping), all bottles are transferred through the conveyor belt to the table in order to cap and deposit into the tote (i.e. material...
to keep packaged products away from dust) and the filled bottles are further cleaned for good appearance. In Process 7 (i.e., loading II) and Process 8 (i.e., sealing), all packaged bottles are sealed and transferred to the conveyor for induction sealing and finally, in Process 9 (i.e., loading III), the bottles are loaded on the labeling conveyor. The labeling machine then labels the bottles in Process 10 (i.e., labeling) and Process 11 (i.e., toting) before palletizing the finished product for shipment.

The general objective of the manufacturing process, such as “Packaging Process” in the context of this paper, is to package specific finished goods on time at an optimized cost. The production process adopted for the packaging operation is batch production process. This production process comprises skilled and semi-skilled workers who are packaging products in high volumes from an initial stage (i.e. Process 1) to the final stage (i.e. Process 11). For the most traditional batch production process, “products” or “goods” are processed as one entity. This means, each process stage must be completed before another process stage is carried out.

Problem description

In the manufacturing world, the labor variance is the difference of the expected or budgeted direct employees’ hours minus the actual direct employees’ hours. The labor variance trend in ABC in the past 4 years has been increasing on the negative side. That is, the expected CoP is less than the actual CoP. The leadership of ABC did not place as much emphasis on labor cost as much as on ensuring good quality of products. At the current phase of ABC’s growth and financial reality, quality product and speed to market are not optional but mandatory for ABC’s business survival and profitability. However, there is an inherent opportunity to improve the performance of the packaging operations, as this production process accounts for more than 60% of the entire workforce. Also, Table 1 shows the annual total NLCV from year 2016 to 2019. From Table 1 it can be seen that in 2016, the total NLCV was approximately 500,000 dollars. The NLCV was further dropped to 2 million dollars in 2017 and plummeted further in 2018 to 9 million dollars. The information in Table 1 is reproduced in Figure 2 for clarity. By the end of the reporting year 2019, a huge sum of 14 million dollars has been lost to NLCV. Given this trend, it is fair to assume that, if nothing is done to curb the increase in NLCV, subsequent years might record the same, if not worse, labor efficiency results. Therefore, the quickest and easiest way out of this operational quagmire would be to adjust standard unit cost of production to reflect operational reality; thus attaining sustainability, resilience, and efficiency of production.

Methodology

The main purpose of this section is to explain the techniques adopted to understand the current state manufacturing

Table 1. Labor performance for the packaging department for four consecutive years.

| Year | Total negative labor cost variance |
|------|-----------------------------------|
| 2016 | $500,000                          |
| 2017 | $2,000,000                        |
| 2018 | $9,000,000                        |
| 2019 | $14,000,000                       |

Figure 1. High level packaging process.
process. Also, we will identify key areas of waste across the process and develop a future state version of the process to reduce the waste if any is found. There are several manufacturing processes in the case company (ABC). However, only a part of the manufacturing process, known as the “Packaging Process”, was considered due to its labor intensiveness and high repetitive tasks among workers. To have a clearer understanding of ABC manufacturing system, this paper will present a lean systematic approach.

Research design
In this study, the research design was expected to enable the researcher to systematically show the relationship between NVA and ABC’s increasing trend of NLCV. The data utilized in the study are from the direct observation of the process using stopwatches to record real-time activities due to restriction of using real-time cameras for the privacy protection reason. Furthermore, historical data such as labor cost per shift, overtime cost per shift, employee hourly rate, customer demand per shift, number of employees in packaging unit, and so on were collected over a span of 4 years, as shown in Figure 2, further establishing real-time facts concerning labor variances from the production planning team on labor variance reports. Also, productivity reports from packaging operations and quality outage reports from the quality assurance (QA) are applied. These data were input in the current state value stream map [VSM (a detailed introduction of this will be given later in this paper)] of the packaging process, along with lead-time (LT) and cycle time (CT), and all were based on the current state baselines.

Methods of data collection
According to Flanagan et al., there are a number of methods available for data collection involving humans. However, further research show that three major work-measurement techniques may be adopted for such studies. These are: estimation (using available historical data), direct observation (time study and work sampling), and predetermined motion time systems to calculate standardized work, Takt time, lead-time and CT. The method of data collection used in this paper involves observing the production and packaging line workers using the Time and Motion Study through direct observation of employees utilizing stop watches. This helped to analyze the operational task by measuring activities that are value-adding to the process. In a similar vein, it also identifies activities that do not add value to the process being observed. In addition, to collect and process the standard time for ABC packaging process, the rating of normal elapsed times, the allowance factor of each identified work element that allows for personal fatigue and delay, and break times, were determined through the Westinghouse approach, as shown in Tables 2 and 3, respectively. In Table 2, the Westinghouse system of rating considered four factors (i.e., Skill, Effort, Condition, and Consistency) to measure the workers’ performance. The first column under each factor shows the value representing the performance rating. For example, the rating factor of excellent skill (B1) is 0.11, under good condition (C) is rated as 0.08, while good effort (C2) is rated as 0.08 and a fair consistency (E) is rated as —0.02, therefore, the algebraic sum of the factor ratings will determine if a worker is above or below average performance. In Table 3, the effort and environmental conditions are the two major factors considered to calculate the allowance factors of worker’s activities.

Lean systematic approach
This section explores the theoretical foundation for the case study to identify wastes that could make ABC company run
at a higher cost of production than anticipated as a result of the increasing trend of the NLCV. According to Womack et al., lean manufacturing is a systematic approach to identify and eliminate wastes (non-value-added activities) through different continuous improvement processes developed at the various stages in the packaging section. Werkema stated that lean manufacturing seeks to get rid of wastes from the process. Lean manufacturing is also about efficient product (or service) flows, eliminating NVA, shortening overall lead-time and continuous improvement. There are seven wastes associated with manufacturing processes as identified by Toyota, according to Mayer et al.,

| Waste        | Description                                                                 |
|--------------|------------------------------------------------------------------------------|
| First        | Related to transportation; which is the transfer of work in process (WIP) from one place to another. |
| Second       | Related to inventory; which shows the excessive raw materials, WIP resulting in prolonged lead-time, storage, damaged goods and obsolescence. |
| Third        | Related to motion; which can be described as every movement employees have to make in searching, grabbing, and disposing of things. |
| Fourth       | Related to waiting. This shows how employees often stand by and watch because there is no work to do, whether due to machine failure, process bottlenecks or other delays. |
| Fifth        | Related to over-processing. This is when employees invest productive hours performing unnecessary activities or tasks. |
| Sixth        | Related to overproduction. This involves producing items in larger quantities or sooner than required. |

The final waste is related to defects, which accounts for wastes due to production or correction of defective parts.

**Value stream map (VSM)**

Value stream is one of the major activities toward effective lean management. It encompasses the flow of products and services through various activities in bid to providing value to the customer. According to Rother and Shook, a supporting and implementation tool of lean philosophy is VSM. It is defined as all the steps required from the beginning to the end of the process taking cognizance of the information and material flow. This also involves capturing time periods required for various activities in the entire stream. Such activities could either be activities that is value-added (VA) or activities that do not add value. The purpose for the use of VSM is to zoom in on inherent opportunities in the process and identify areas where improvements can be made to enhance better productivity and efficiency. According to Rother and Shook, the goal of VSM is to identify all wastes in the value stream and take decisive steps to eliminate or minimize those wastes. The VSM process encompasses various steps as shown in Figure 3. In addition, product family and process categorization are important to understand the process flows for all the product categories for the purpose of the VSM. Process steps 1, 2, 3 and 4 shown in Figure 3 will be captured as part of this study while the implementation of proposed changes in Step 5 is not considered.

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Table 3. Westinghouse allowance factor system.

| Physical effort | Mental effort | % Recovered time | Recovery Factor B | Cycle duration (min) | Monotony |
|-----------------|---------------|------------------|-------------------|----------------------|----------|
| Effort          | %            | %                | 0–5               | 1                    | 0.05     | 7.9 |
| Very light      | 1.8          | 0                | 6–10              | 0.9                  | 0.06–0.25 | 5.4 |
| Light           | 3.6          | 0.6              | 16–20             | 0.71                 | 0.26–0.50 | 3.6 |
| Average         | 5.4          | 1.8              | 21–25             | 0.62                 | 0.51–1.00 | 2.1 |
| Heavy           | 7.2          | 3                | 26–30             | 0.54                 | 1.01–2.00 | 1   |
| Very Heavy      | 9            | 0                | 31–35             | 0.46                 | 0.51       | 0.5 |
|                 |              |                  | 36–40             | 0.39                 | 2.1        | 0.2 |
|                 |              |                  | 41–45             | 0.32                 | 0.51       | 1   |
|                 |              |                  | 46–50             | 0.26                 | 0.25       | 0.2 |

| Environmental conditions | Temperature | Thermal % | Local | Atmospheric % | Other |
|--------------------------|-------------|-----------|------|---------------|-------|
|                          | 0–7°C       | 3.6       | Well-ventilated | 0  | Noise | Low level | 0  |
|                          | 8–15°C      | 1.8       | Poorly-ventilated or light smoke | 2.4 | Humidity | Dry and pleasant environment | 0 |
|                          | 16–25°C     | 0         | Heavy smoke or dust | 5.6 |     |                | 1.8 |
|                          | 26–34°C     | 1.8       | Heavy smoke or dust | 5.6 |     |                | 1.8 |
|                          | 35–40°C     | 3.6       | Vibration | Ground or machine |      |                | 1.8 |

Source: Adapted from Contador.
Also, a systematic approach will be used to illustrate further improvement and progress in order to make future decision on the cost of labor, and assist in visualizing and eliminating all forms of waste. The critical steps needed to develop the VSM current state of ABC is illustrated in Figure 4. As shown in Figure 4, the knowledge of customers’ annual demand is critical to determining the capacity available (and required) to support demand. Hence, gaining this insight and determining the available production time will be the building blocks for working the takt time and mapping the process flows.

**Pareto analysis**

According to Taman and Tanya, Pareto analysis is based on the observation that operational results and wealth are not evenly distributed and that some inputs contribute more than others. This is referred to as the “80/20 rule”, a name that has popularized a complicated economic concept introduced by Vilfredo Pareto—a renowned 19th century Italian economist. Pareto noticed a pattern of “predictable imbalance” where 80% of Italy’s wealth was held by 20% of the country’s population. An application of this instance is that in a pharmaceutical industry, the quality control team might find the majority of defects come from a small set of issues. One good example is having one raw material out of many. The Pareto analysis is used majorly in this paper to evaluate all the identified types of wastes and narrow down on where to focus improvement activities to derive the most benefit.

**Results and discussions**

The results obtained in this paper using the Pareto analysis describe the observed average daily wastes in the packaging process. After considering the process activities (VA) and (NVA) captured over a period, we found that employees are waiting for one reason or the other for almost 5 h, as shown in Figure 5, in a 16-daily operation hours (2 shifts running at 8 h each). That cumulates to 32% of the total productive time. Also, the research findings show that the major identified waste types as discussed in the previous section are waiting, defects and transportation. Therefore, by eliminating or reducing waiting as a type of waste, 83% of the identified wastes would have been tackled.
Furthermore, the data shows a significantly high waiting time in the process. Therefore, further work was done to investigate the composition of NVA activities responsible for high waiting time. As shown in Figure 5, 4.93 h are the average total elapsed time observed for waiting daily. Also, 0.5 h and 0.08 h are the average elapsed time for defects and transportation respectively per day. Additionally, line clearance, change over, set up, re-calibration and transportation are the causes of NVA, as shown in Figure 6.

Similarly, the observed average daily wastes identified above were allotted costs by simply considering the elapsed time for the causes of wastes, and the numbers of employees working on the process and the average hourly employee rate, as shown in Figure 7. Figure 7 shows the corresponding cost of each of the identified wastes. Consequently, it is found that available to promise (ATP) is not met, hence the need to run overtime to fulfill customer orders. This often results in more costs than expected, leading to a further increase in NLCV.
In addition, Figure 8 shows a direct correlation between NVA and labor costs. As the elapsed time for NVA increases, the labor cost also increases. This relationship indicates that a unit reduction in the NVA of the process would result in a unit decrease in the labor cost variance. Regarding the financial impact of NVA, 16 people were assigned to work on each packaging line per shift. This means that if we assume an approximate hourly rate of $30 per labor, there will be $1,800 pay with no equivalent productivity to match. Labor variance is driven principally...
by the gap in the planned labor hours and equivalent productivity. In other words, around $9,000 would be lost for the average productivity lost hours of about 5 h per day for a single line. Conservatively, if the 5 h waiting time due to no faults of the frontline employees are to be monetized without considering overtime days and overtime premiums.

To further analyze VSM and its dynamic behavior, there is need to identify the product and process family. ABC runs six major SKUs that will be referred to as product families. A, B, C, D, E and F flows through the major process steps 1, 2, 3, 4, 5, 6 and 7, respectively.

As shown in Table 4, product families A, B, E and F are considered for the purpose of the VSM. Product families C and D are not considered because of the low overall combined annual volume of 20,800 units versus 780,000 units of annual volume of the rest of the product families. As shown in Table 4, the weekly average volume of each product family was calculated to understand the impact of each product family in the VSM analysis.

Therefore, after the successful selection of the product family and associated volumes, the next step is to develop a current state value stream map as company ABC currently operates its bottling process. The current state map is completed with the basic lean six sigma principles for easy representation of the existing flow of materials and information using the lucid chart. The critical steps followed in mapping out the current state VSM of the ABC bottling process and the data for current state VSM were obtained according to the approach as stated in the methodology. The data boxes for each process step captures the LT, CT, inventory and percentage estimate of defect rates as observed.

Figure 9 shows the current state VSM of the packaging process of ABC. The process begins with the customer requirements in the form of orders. The PPC team uses the order information to raise purchase orders for raw and packaging materials from different suppliers required as input for the packaging process. The production management schedule manufacturing activities based on the availability of manpower, machine packaging materials and so on. The process steps, LT and CT for each step are captured in the time ladder in the VSM.

A comparison of the CT for the various steps required in the bottling process against the Takt time as shown in Figure 10 indicates that there are gaps between each of the steps versus the Takt time. The effect of this is that customers’ orders will not be fulfilled within the available time. Therefore, the only possibility to hit ATP target in ABC given this Takt time is the need to run overtimes (OT) to fulfill customer orders which has a significant impact on cost and hence, profitability. Figure 10 shows Step 1 as the process constraints at 28 s. Regardless of the shorter CT for other process steps, the manufacturing line will be bottlenecked by the step with the highest CT.

In addition, Figure 11 shows the flow of material from the warehouse to the production line through process steps 1 to 8 with their respective LT and CT. Information flow is also shown from the production planning team, with key information on customer requirement through the production manager to the frontline team. CT and LT are plotted in the time ladder below the map. The key identifies potential opportunity areas in red balloons in the map.

The opportunities identified in ABC from the above current state VSM as shown in Figure 11 are analyzed further. During communication analysis, it is found that after weekly and subsequent daily demands are communicated to the Team Leads via the Production Manager, the daily targets are not properly communicated with metrics that are measurable at the end of every hour. Team effort needs to align with production demands and in order to achieve this, and there is need to increase the frequency of status reporting. The current state practice is that production daily results are only communicated after each day’s shift when it is too late to influence productivity. The opportunity here is to help front line workers to clearly define hourly targets that can be reported to share status of production against targets. This would alert the production manager (a two-way communication) to intensify efforts to support functional groups (Production Planning, Maintenance, QA departments and so on) as needed to affect actions that can positively improve productivity. As part of this, visual boards or displays may be used to communicate productivity in a timely fashion to help improve communication.

### Table 4. Product family analysis.

| Process Steps | Step 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9 | Step 10 | Average weekly volume |
|---------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-----------------------|
| Product A     | X      | X      | X      | X      | X      | X      | X      | X      | X      | X      | 2,500                 |
| Product B     | X      | X      | X      | X      | X      | X      | X      | X      | X      | X      | 3,500                 |
| Product C     | X      | X      | X      | X      | X      | X      | X      | X      | X      | X      | 3,000                 |
| Product D     | X      | X      | X      | X      | X      | X      | X      | X      | X      | X      | 3,000                 |
| Product E     | X      | X      | X      | X      | X      | X      | X      | X      | X      | X      | 6,000                 |
| Product F     | X      | X      | X      | X      | X      | X      | X      | X      | X      | X      | 15,400                |
In addition, data of quality-related issues for the bottling process as shown in Figure 10 suggests that, the process steps 3 and 5 have 30.8% each of identified quality issues while the process step 1 has 19% of the quality issues. The process steps 4, 6 and 8 have 6.4% defect rate, respectively, and there are no observed quality issues emanating from other process steps. Usually, the current state practice is that defective products would be captured at the end of the process and brought back to be reprocessed. This ends up taking half an hour to reprocess defective products in a day. The time required to reprocess these defective products could have been utilized for other value-add activities. In order to quantify the monetary impact of this, at an assumed rate of $30 per
hour per employee, assuming 16 employees are on a bottling line, and half an hour lost to reworks. Then, the annual loss will result to $62,400. Figure 12 shows the captured quality defects requiring reworks attributed to each of the process steps in the value stream.

The process steps 3 and 5 have the lion share of quality defects, followed by the process step 1. By focusing efforts to fix issues from these three processes, about 81% of the total quality defects will be resolved.

The area with potentials for the biggest impact is cutting down on “waiting associated mostly with changeover, line clearance, and set-ups” assuming these cannot be eliminated. For example, scheduling can be improved to reduce a need for frequent die changeovers. Set up and line clearance can also be drastically reduced as actual observed numbers are higher than standard times. As discussed, the throughput rate of the system is largely dependent on the throughput rate of the bottleneck step of the entire process.
Hence, based on the current state bottle-neck CT, 15 shifts are theoretically required to meet the customer demand of 15,000 units of product per packaging line, as shown in Table 5. However, the identified wastes of 300 min (5 h) per shift makes this unattainable, thus, the choice of overtime to fulfill ATP.

To further analyze the future state, the current state VSM helped reveal opportunities for improvement. So, based on the identified gaps, some changes are proposed to help streamline the future state map as outlined in the opportunities in the current state session.

Figure 13 shows the flow of material from the warehouse through the process steps 1 to 8 with their respective LT and CT. Information flow is also shown from the production planning team with key information on customer requirement through the production manager to the frontline team. CT and LT are plotted in the time ladder below the map. In a bid to ensure CT is less than or the same as the Takt time, Single Minute of Exchange of Dies (SMED), is proposed to reduce die changeover time from 2 h per day to 20 min. Across the process steps, predictive breakdown maintenance is proposed to cut down breakdowns and machine failures to the barest minimum.

Based on the proposed future state as shown in Figure 14, CT for the process step 1, the bottlenecked process step in the current state would be reduced from 28 s to 9 s, leaving all process steps balanced and below the required Takt time. This will help meet ATP targets and eliminate overtime.

Based on the data collected in ABC, the opportunities identified are summarized in Table 5. The reported NLCV for 2019 is $14 M which is 71% less than the identified opportunity of $48M. In practice, this means that if overtime is reduced by 40%, it will neutralize the $14 M negative variance reported in 2019.

In conclusion, it is found that NVA in a process is correlated with the labor cost. An increased NVA in the process will result in an increased NLCV. But the VSM shows opportunities to reduce the CT of the bottlenecked process

| Table 5. Summary of monetized opportunity. |
|------------------------------------------|
| Cost of identified NVA $624,000.00 |
| Cost of quality defects $62,400.00 |
| Overtime cost $48,000,000.00 |
| Total opportunity $48,686,400.00 |

Figure 13. The future State VSM of ABC packaging process.
by 68% (from 28 s to 9 s), thereby mitigating the need to run overtime shifts. The future state process shows a more efficient process with the reduced CT, quality defect and low inventory.

**Conclusion and future work**

The findings of this study indicates there are several factors causing an increase in the cost of negative labor cost variance over a period. Furthermore, this study reveals that there is a correlation between NVA and increased NLCV. In other words, this study has been able to establish that the high manufacturing cost (including NLCV) can likely be linked to high NVA activities, which is certainly the case of ABC packaging department. The time and motion study help establish the baseline for improvement within an organization, a technique that emanates alongside the lean manufacturing methodology in the Toyota Production System. The technique guarantees the optimization of production processes, flexibility, and faster delivery of product to customers at a reduced cost. The application of the time and motion study proved effective to identifying activities considered as “wastes”.

Also, the VSM technique helped identify more opportunities in the value stream. The current and future state maps were prepared and analyzed to outline the benefits of the lean system in the packaging operation of ABC. The result of this study has demonstrated the accomplishment of the specific research objectives, proving that the increase in the NLCV overtime in ABC is impacted by the NVA that is not being monitored in the packaging process. The immediate benefit of cost savings to offset NLCV is only a fraction of the identified opportunities. However, long-term benefits of improvement such as increased revenue due to a predictable increase in sales or brand name value, remain unquantified.

The main contribution of this study is in the area of analysis, using lean manufacturing tools to explore opportunities inherent in the manufacturing process. In the existing literatures, there is a gap not captured in NVA, where cost is allotted to each component. Although, previous work done by Abdillah et al.,34 and Singh and Singh,35 and many others, have applied lean principles to identify NVA, none of these works linked NVA to labor cost variance or quantified the cost of losses due to NVA. This paper provides the methodology to allot costs to NVA, and the methodology of using time study and motion to capture NVA in the manufacturing domain.

In a similar vein, this paper has provided a well proven argument for looking beyond changing the standard costing model by the finance department in order to write-off NLCV. Manufacturing organizations with similar challenges as ABC can now investigate business processes to identify opportunities in the form of NVA that can be improved to neutralize NLCV and better position the business for profitability.

Several future studies are suggested upon the study presented in this paper. First, one limitation in this case study was that there is no answer to the question of why the NLCV increases over the 4 years in that pattern, as shown in Figure 1 or Table 1. This warrants a further analysis. Second, more research could be carried out on other manufacturing processes, e.g. service systems,36 to consolidate the effectiveness of the proposed methodology. Third, customers and businesses are becoming aware of the efficiencies that 3D printing is making possible. Often, this fuels customer excitement regarding customized products, e.g. in apparel industry,37,38 resulting in potential cost savings for both the manufacturer and the customer. Hence, future works exploring the compatibility and quantifying the benefits of 3-D printing and lean manufacturing will be beneficial. The lean principles have the potential to play a key role in a variety of industries beyond manufacturing and traditional service industries. Fourth, as companies transition from the industrial economy to a digital one, future studies should also focus on how lean philosophies can be...
applied to influence Internet of Things (IoT). Additionally, the results and recommendations in this paper can be validated using empirical data as another prospect for further future works. Last, another future work is to take a context that information is imprecise, and apply a group decision-making technique combining both objective and subjective optimization techniques to develop lean and resilient production systems.

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