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# Value Stream Performance Measurement in Lean Manufacturing Business

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## Abstract

Lean manufacturing and other processes need quite different performance measurements. When old measurements are mixed with lean operations the lean changes fail to achieve their objectives. The performance measurements must be directly related to company's business strategy. Therefore in this study, theoretical information is given on befitting performance measurements for companies that use lean production system and the box score that enables monitoring of these measurements is discussed.

**Key words:** Lean production; Value stream measurement; Lean performance measurement

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## INTRODUCTION

The number of enterprises manufacturing with lean production techniques has been increasing every day. Successful lean production practices result in several operational and financial improvements. One way for companies to be more successful in global markets is to focus on performance and quality. The companies that gravitate towards improving quality and performance achieve better results with less cost, and more customer satisfaction.

It would be much convenient for enterprises manufacturing with lean production techniques and implementing value stream costing to use befitting performance measurement compared to traditional performance measurement. Therefore in this study, the box score that enables monitoring of these measurements is discussed by giving theoretical information on befitting performance measurements for companies that use lean production system.

## 1. VALUE STREAM PERFORMANCE MEASUREMENT

Lean thinking is a set of methods that eliminate operations that do not create added value, and waste, a process improvement approach, and a management philosophy. Lean production emerging from the lean thinking system in enterprises; is a production system that most flexibly manufactures the cheapest and impeccable production in the shortest time by less waste (or without any) and using all production factors in a way that can directly respond to customer demand (Okur, 2005).

Lean thinking allows identifying value, ranking actions that create value in such a way that will give the best result, and doing these activities continuously and most effectively (Womack & Jones, 2003). The identification of value stream is the second step of lean thinking. Value stream comprises all the phases of the transformation process of raw material to end product between the manufacturer and the consumer (Rother & Shook, 1999; Fullerton, Kennedy, & Widener, 2013).

Performance measurement is a process that is carried out to measure efficiency and sufficiency, and improvement of quality. Both continuous improvement and excellence follow-up have vital importance in lean thinking. All the lean enterprises implement methods that motivate continuous improvement. One of these methods

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is value stream performance measurement (Davies & Greenough, 2015).

The aim of value stream performance measurement is to ensure continuous improvement in value stream. When choosing performance measurement for a value stream, one should focus on improvement. These measurements demonstrate the ability of value stream in efficient value production for customers. The measurements lead the value stream team in improving the whole value stream performance. What is needed for value stream performance measurement is value stream team and manager's focusing their attention on improvement (Baggaley & Maskell, 2003).

Continuous improvement teams are assigned in lean value streams. Continuous improvement team for value stream can be one or more. These teams are formed in order to measure performance for value stream and improve it. Continuous improvement teams carry out performance measurement every week and develop new projects to perform proper performance measurement (Carroll, 2007).

Although it is common that specialists outside the enterprise are part of the team, most people in continuous improvement teams work in value stream. In some cases, manufacturers and even customers can be represented within the team. The personnel employed in accounting and financing is part of the continuous improvement team (Carroll, 2007).

The continuous improvement team meets weekly to review the latest performance measurements, update the team members in the improvement project, and start new improvement projects. All the projects are designed in order to improve value stream performance measurements. These projects are for a short term (less than two or three months). The projects comprise specific issues within value stream. Some only contains improvement goals, whereas some others substantially provide continuous improvements to value stream (Carroll, 2007).

Value stream manager and value stream team are responsible for improving value stream performance. The wastes in value stream process are clearly indicated in value stream maps. Value stream team must increase value for customers, eliminate waste within value stream flow, and boost value stream profit.

Although value stream performance measurements do not have to be a detailed explanation of value stream, these measurements allow value stream team to make changes in value stream by reflecting key indicators of lean impacts related to expectations. These changes should be directed towards increasing value, decreasing waste, improving stream, and high profitability. Value stream performance measurements are selected to put proper changes and improvements in motion (Fullerton, Kennedy & Widener, 2014).

Value stream performance measurement primarily used to ensure continuous improvement. The official process used for continuous improvement must be implemented for achieving this. The factors to take into consideration for successful lean enterprise while carrying out value stream measurements are listed below (Maskell & Baggaley, 2003):

a) Measurements are not used to decide whether value stream is good or bad, but to start continuous improvement projects that are designed to prompt value stream performance measurements going in correct direction every week. These measurements are manually prepared by value stream teams, are used by value stream team and the team is responsible for the measurements' results. In accordance with lean thinking's principle of acquiring excellence, value stream team is assigned in systematic and continuous process improvement. Weekly value stream income table and target costing along with performance measurements guide the value stream team in acquiring excellence.
b) There is no use in comparing one value stream with another. The measurements used for two or more value stream can be the same. Yet it is detrimental to make uncalled-for comparisons between them.
c) Continuous improvement teams must use a standard and formal improvement method. There are various good methods for this. At the starting point of most processes, one must specify the problems that need to be solved or opportunities that need to be developed. This can be performed by value stream performance measurements, target costing, and value stream income table.
d) Performance measurement must be directly related to the enterprise strategy of that particular enterprise. Measurements must completely support the enterprise strategy. It is not obligatory to use the same performance measurement for the whole value stream. There are generally differences in measurements used in various value streams of a particular enterprise. However, the measurement must be consistent.

## 2. TRADITIONAL MEASUREMENTS AND THE DIFFERENCE OF VALUE STREAM MEASUREMENTS

Some of the measurements used in lean value stream are similar to the ones used in traditional production organizations. The difference is how they are used so. Most traditional manufacturers measure the whole production factory and generally report results monthly. Most traditional manufacturers use the measurements for assessing the competence and abilities of the factory management. Same measurements are also used to

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compare all factories and thus factory manager might boost competition between them (Stenzel, 2007).

Lean value stream performance measurements are not designed for assessing the managers' activities, but to start continuous improvement. Measurements are generally reported on a weekly basis, as this frequency is befitting to the value stream continuous improvement team's schedule. Weekly reporting is significant for process control as well. Monthly reporting is a long time for solving problems and controlling the process.

Measurements are definitely not used for unwanted competition between value streams. It is important to collaborate for value stream managers and their teams. There will be success unless value stream managers are compared and assessed (Maskell & Baggaley, 2003).

Lean value stream measurements are also used as a control mechanism of the primary enterprise as well as creating continuous improvement. These measurements not only report results, but also conduct changes. True numbers reported for each measurements have less significance compared to change instructions, and rates. Continuous improvement team is responsible for all the value stream measurement's speed and their continuous improvement. True results vary between value streams. The results of all value stream measurements, however, must demonstrate improvement and order step-by-step.

## 3. VALUE STREAM PERFORMANCE MEASUREMENTS AND PROCESS CONTROL

Value stream performance measurement is a primary control mechanism within the enterprise. Not only does it enable continuous improvement, but also generates solutions outside the enterprise' control (Tupa, 2014). If important problems beyond the authority and competence of the continuous improvement team, one must consult to top managers for these problems. The enterprise' employees in accounting and financing are assigned to the control level within enterprise process (Maskell & Baggaley, 2003).

Table 1 shows what value stream performance measurements and what they measure.

**Table 1**
**Value Stream Performance Measurements**

| Value stream performance measurement | What does it measure? | Lean principle |
|---|---|---|
| Sales per person | The efficiency of value stream expressed in terms of sales amount performed by employees.<br>Sales amount is divided to the number of persons in value stream. | Increase value created by the same or less resources. |
| On time delivery | The sufficiency of value stream in delivering the product to the customer on the desired day or time.<br>The sales by percentages delivered on the correct time. | Control the whole process within value stream. |
| Dock to dock day | The amount of stocks throughout value stream expressed in terms of required day or time.<br>Total amount of stock within value stream is divided into delivery rates of products. | Increase material flow rate throughout value stream. |
| First time through | The sufficiency of value stream for always-perfectproduction and service.<br>First time through products are calculated in every step of value stream process. | Always do standardized enterprise throughout flow stream process. |
| **Average cost per unit** | Total cost of value stream is divided into the number of manufactures delivered to the customer. | Always decrease resource amount necessary for producing and selling products. |

*Note.* Adapted from *Practical Lean Accounting: A Proven System for Measuring and Managing the Lean Enterprise*, by B. H. Maskell and B. Baggaley, 2003, p.131. Copyright 2003 by Productivity Press, New York.

### 3.1 Sales per Person

Sales per person measures the value created by value stream, and the efficiency of value stream. It is important that the value stream efficiency regularly increases in time. When it does increase, value stream can manufacture and sell more products through the same resources (Maskell & Baggaley, 2003).

In order to calculate sales per person, one must divide sales into required number of persons. Sales are the sales value of products manufactured in value stream. Thus it is necessary to sales orders or products combined with value stream. This procedure usually requires placing a flag or a field mark into the sales system and coding sales orders in order to determine which value stream belongs to which order line. This way coded sales are later reported with value stream. The number of persons working in value stream involves all the personnel. If part-time or temporary employees are assigned in the value stream, these are regarded as equal as full-time employees in the value stream. In the case of one person being in more than one value streams during the first phases of value stream management, it might require them to be used as equivalent number of persons. This should be performed only for a short term, as the results

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of these implementations performed this way might be easily warped. Cross training must be used to rule out the personnel working in more than one value streams, as quickly as possible.

One must pay attention to change rates in all lean performance measurements, rather than actual results. The goal of lean organizations is an annual improvement by 20% or %25. This is equal to an annual improvement by 1.5% or 2%. The enterprises that do not use lean production can less determine the success level they desire (Huntzinger, 2007).

The rate of units per person for some enterprises is a better measurement compared to sales per person, as it is easy to comprehend. The products should be quite similar for units per person being used. If value stream has a completely homogenous product family, the unit per person measurement is more befitting. On the contrary, if value stream manufactures a wide spectrum of products consisting of different price, process, and materials, sales per person is a better measure (Maskell & Baggaley, 2003).

When many machines are used in operations, it might be beneficial to use sales per machine-hour. Machine-hours can be either valid total of machine hours or normal working hours of the enterprise. Using the working hours of the machine can twist the results. It requires monitoring the machine-hours, which is a waste. Machine-hours might demonstrate an improvement even when the production time decreases and sales drop.

It might be a little difficult for enterprises that perform seasonal business to calculate sales per person, as these enterprises can save temporary seasonal stocks. In this case, great rise and falls are observed in sales per person by season. These enterprises usually use units by manufacture per person. This measurement should be carefully used as there is efficiency in its sales not in its manufacturing. It might be necessary to save stocks for a particular period of a year in a seasonal environment and sell the completed products during high season. Some enterprises prefer measuring income per person, rather that sales, thus focusing on the profitability of value stream.

### 3.2 On Time Delivery

On time delivery measures control level within value stream and is a percentage measurement of orders delivered to the customers on time (Searcy, 2009). If value stream is under control, on time delivery is high. Low on time delivery rate means that value stream is unsuccessful and the process in not under control.

Measuring control level is quite important for finance personnel in a lean organization. Since lean accounting is implemented, work that is traditional and based on control system is removed for the benefit of lean operation control. Finance personnel use performance measurement to make sure the process in under control. On time delivery is a fine general measurement for determining control level within process.

On time delivery shows measurement of customer orders loaded on the correct loading date, by percentages. There are several methods to calculate this. Some units follow loaded unit number compared to required unit number. Other follow loaded order line, whereas some follows the number of all orders loaded on time. Some enterprises track loading date of the product towards product date committed to the customer, while others use the loading date requested by the customer. In most cases, an order loaded long before the loading date will not be accepted to be delivered on time (Maskell & Baggaley, 2003).

The strictest measurement is all the orders loaded towards the date the customer wants. Desired and smallest measurement is the number of units loaded on time compared to the promised date. Which measurement unit is used is not important as long as it is convenient for customers and products, provided that value stream team focuses on improving the results of their work. When a less requested measurement is used and the result reaches to around 90%, a more strict method can be practiced. Therefore improvement and excellent process will continue (Maskell & Baggaley, 2003).

If the number of customers that report on time deliveries is a lot, it takes a lot more precision to use the same measurement method in customer reports.

The measurement of on time delivery generally demands required time and a computer system to track loading time. Most lean organizations prefer using manually made visual methods in performance measurement. A fine manual measurement calculate the number of orders that must be delivered every day, yet not delivered. This method is used for only performed duties that could be reported visually on a performance measurement table. Sometimes delivered orders are separated into sections such as “a day late”, “two days late”, etc. This measurement is shown with other results table measurements or alternatively, in a visual table used for planning customer orders. Thus delivered orders can easily be viewed and there would be no additional reporting.

If data can be acquired, it might be better to measure on time distribution, rather than on time loading measurement. Enterprises that have methods of reporting the actual time of purchases from their customers can use this type of reporting. Measuring on time delivery is better than measuring on time loading. Taking only the product is a factor that adds value for the customer; yet loading the product is not one (Maskell & Baggaley, 2003).

### 3.3 Dock to Dock Day

Dock to Dock Day is a measurement of time passed throughout taking the delivery of an item or a raw material, its production, and its delivery to the customer. This time demonstrates the speed of the raw material’s transformation into the product completed in value stream. Dock to Dock Day measures the material’s stream throughout value stream (Searcy, 2009)

Lean production, at that rate, is related to the

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material's stream. The third principle of lean thinking is to focus on the stream. There are three types of stream: material, information, and cash flow. Lean organizations value increasing stream speed. Dock to Dock Day is a measurement used to motivate improving material flow. If Dock to Dock Day's dates or hours drop, material flow rate increases and stock levels in value stream decrease (Maskell & Baggaley, 2003).

Calculating total stocks in value stream and dividing it into average rate of delivered products is equal to Dock to Dock Day. Stocks include raw material, work in process, and completed products. Delivery rate is the average number of last units delivered per hour. The results is the stock in value stream expressing hours or days.

$$\text{Dock to Dock Hours} = \frac{(\text{Raw material} + \text{Work in process} + \text{Completed Product Stock})}{(\text{Products Delivered This Week} / \text{Hours in a Week})} \quad (1)$$

An example for Dock to Dock Day in a value stream is shown in Table 2 (Maskell & Baggaley, 2003).

**Table 2**
**Dock to Dock Day**

| Stock | Deliveries | Dock to dock day |
|---|---|---|
| Raw material: 50 Units | Units delivered this week: 1200 | |
| Work in process: 70Units | Hours in this week: 50 | 130units / 24hours Delivery per hour= 5.41 |
| Completed products: 10 units | Delivery per hour:24 | |

Enterprises doing business with a simple product and very few items can easily calculate the number of items in stock. Units loaded per week can be figured out easily from loading and sales information. Thus Dock to Dock Day is manually calculated.

Although they have more complex product structure, enterprises that have a fine *kanban* (pulling) system throughout value stream can calculate kanban for primary product stream and multiply by kanban quality in order to get total stock quality.

Most organizations feel the need to use sample items. It is a problem that most production processes have hundreds of items, raw materials, components, integration of work in process, and completed products. To calculate them manually is both exhausting and wasteful. One must calculate sample items in order to solve this problem.

Sample items are items that used and completed in each phase of production. Sample item must be a key item of the product, as it represents the whole material flow of the product. A typical sample item in a machine store is the inventory purchased. Inventory is bought from the supplier and the definite quantity of the item stock is sent to the nearest cell or storehouse. Inventory is manufactured during production process and assembled into the completed product. Work in process including inventory can easily be determined. Completed products include inventory; to come up with the number of inventory, the number of completed products is calculated. A personnel or another value stream team member, who procure products once a week, calculates the number of sample items in value stream. This number is used to calculate Dock to Dock Hours.

If it is impossible to determine sample item, one might need to use stock numbers obtained from the continuous inventory system of the enterprise. It is an undesired one, as it is not convenient for manual visual measurement lean implementations. What's more the goal of system is to rule out the use of continuous inventory system in time (Maskell & Baggaley, 2003).

Dock to Dock Day is reported weekly along with other value stream performance measurements. The results can be demonstrated through run charts, block charts, and graphics as well as other visual methods. Alternatively, Dock to Dock Day can be shown as primary value stream measurement in a box score (Searcy, 2009).

Some lean enterprises follow total stock items, weight, and price in value stream. Others use classic stock turnover. Some prefer all the stock, whereas some prefer focusing on key materials. If total stocks are preferred, it might not be understood due to changes in stream, over-stock accumulation, and obsolescence. The goal of this measurement is not to measure all the stock at that particular moment, but to focus on the material's stream. Stocks are shown in the balance sheets or performance measurement on factory level.

Other lean organizations do not only focus on material flow. These organizations create a combined measurement that includes order process' stream and cash flow along with material flow. The purpose of this kind of measurements is to point out the fact that information and cash flows have the same importance as material flow.

### 3.4 First Time Through-FTT

First time through measures the percentage of products manufactured in value stream regardless of reprocessing, fixing, retesting, resetting or rejection. This is considered the measurement of production quality and is a fine one as a measurement of process sufficiency. The process in the value stream must be expressed well and variables in the process must be eliminated in order to increase First Time Through measurement of the value stream. First Time Through can be regarded as a measurement of standardization level within the business methods of the enterprise.

First Time Through for cells is calculated via formula (2) below. First Time Through for value stream is calculated by multiplying all First Time Through rates in cells (Maskell & Baggaley, 2003).

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$$\text{First Time Through (FTT)} = \frac{\text{Units Whose Total Process Completed} - \text{Reprocessed Units}}{\text{Units Whose Total Process Completed}} \quad (2)$$

$$FTT = FTT1 * FTT2 * FTT3 * \ldots\ldots\ldots FTTn \quad (3)$$

These cells maybe cells of manufacturing as well as non-manufacturing such as order entry, invoicing and production setting. There may be a margin of error in performing each process. First Time Through helps eliminate mistakes systemically by assisting continuous improvement with determining the main reason and creating a solution by identifying mistakes.

In the example shown in Table 3, value stream contains three steps. Each step represents a cell level measurement of first time through manufacturing. Value stream of first time through is calculated by multiplying six cell levels of First Time Through (Maskell & Baggaley, 2003).

**Table 3**
**Value Stream First Time Through**

| Order entry | Fabrication | Ready to assemble | Final assembly | Loading | Invoicing | Total value stream |
|---|---|---|---|---|---|---|
| 93% | 90% | 92% | 100% | 94% | 88% | 63.69% |

First time through on the value stream level might be disheartening. If there are several steps in the value stream and first time through is registered for each step, First Time Through may look quite fine. For example, it could be 90% for each step. However, if first time through rates for each step are multiplied by each other, this rate surprisingly turns out to be low. It is not uncommon that first time through measurement for value stream could be 20% or less. When first time through is null for several weeks, it means there is a serious quality or process problem within a cell (Baggaley, 2003).

The objective of measuring value stream First Time Through is to reflect control level within process, to the continuous improvement team and value stream manager.

Some enterprises use PPM in measuring the quality of processes. These enterprises can measure internal Parts per Million. This includes faulty items of the production process or it measures faulty items rejected by customers. Some enterprises use rejection rate or production return measurement (Maskell & Baggaley, 2003).

These measurements are successful in most organizations and can be easily comprehended by anyone. Yet, these are not as comprehensive as first time through. First time through tracks production as well as rejected, discarded, and reprocessed items. First time through follows detailed reprocessing that helps improve standardization.

### 3.5 Average Cost per Unit

Some value stream managers and their teams think that there is no need for reporting product cost, where most value stream managers calculate average cost per item, as it is an important indicator of all the exercises of value stream process.

Average unit cost is calculated by adding all the costs of weekly value stream and dividing it into the amount of units, weekly delivered to the customer. Some value streams use total average value stream cost that also includes material costs. Some use average conversion cost per unit. Conversion cost is calculated by subtracting material costs from the total value stream costs. If products are alike and have similar material costs, then using average total cost is convenient. However, if products have different material costs and their production processes are similar, using average conversion cost is more proper. For example a value stream that manufactures similar products from both aluminum and titanium have different material costs but the same conversion process. In this case, average conversion cost can be a fine value stream measurement (Baggaley, 2003).

Total value stream cost is calculated by using value stream costing system. It covers all value stream costs that comprises of material costs, machine costs, labor costs including production specialists and all the personnel supporting operations, opportunity costs, equipment as well as other costs. If the enterprise is managed through value stream, it is easy to calculate costs for value stream directly as a cost. There is no difference between production and labor costs, as well as other support costs (Maskell & Baggaley, 2003).

Average cost is calculated from current and weekly total value stream cost. Average cost is calculated by dividing the number of products delivered to the customer into total cost. The number of products delivered can be easily determined from sales and invoicing system. There is an example regarding the calculation of average cost for value stream in Table 4.

**Table 4**
**Average Cost per Unit ($)**

| | |
|---|---|
| Labor cost | 35.120 |
| Machine cost | 4.200 |
| External processing | 3.400 |
| Other costs | 7.500 |
| Material costs | 70.000 |
| Value stream cost | 120.220 |
| Conversion cost | 48.000 |
| Loaded unit | 2.000 |
| Average product cost | 60.11 |
| Average conversion cost | 24.00 |

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If all the products within the value stream is alike, it is significant and helpful to use average production cost. Even if the products within the value stream are not alike, average cost is significant if the combination of weekly production is consistent (Maskell & Baggaley, 2003).

Most lean enterprises use level planning techniques to organize production flow through value stream. Consistent production combination strengthens value stream and average product cost is more reasonable, when these techniques are applied.

Average cost per unit sheds light to all the aspects of value stream. If production in value stream is more than the sales, average cost will increase. If there are more sales than products manufactured in value stream, the average cost will decrease. Average cost will decrease when enterprise volume goes up and average cost will increase when there is a bottleneck in on time delivery. Average cost will go down in cases where there are lean productions and cost reductions.

Most lean production enterprises do not experience financial impacts when they start lean production. These improvements will manifest themselves in time in average cost of the product. For example, it is not possible to financially improve visual management techniques, 5S and pulling system in a short time. Yet personnel, employed in the value stream, work more effectively, as the information is easy to understand. Another example is enterprises that redesign products to decrease raw material, items and assembly cost, while the range of products with a completed production increase. At this point, a substantial and long-term impact is in effect. That said, these changes reflect gradual and stable reduction of average cost.

Average cost as a summarized measurement impels value stream to research major reasons and develop different range of products in order to reduce costs. According to lean method, the best way to decrease costs is to increase sales without ramping up resources.

Average cost can be used for stock assessment. However, the true usage of average cost is to call value stream team's attention towards continuous improvements. Some value streams use average total costs, while some use conversion cost (Maskell & Baggaley, 2003).

## 4. BOX SCORE

Box score is a spreadsheet used by the personnel in the value stream team to measure value stream performance (Ramanan, 2002). The table contains weekly up-to-date operational and financial information.

Performance measurements and value stream profitability in the table are updated every week. Value stream capacity is updated only if there are major changes in the value stream, the new value stream is mapped, and cost analyses are completed.

There are several usages of box score. Here, the value stream manager and his/her team use it to reflect activities and present weekly performance information used for ensuring improvement. Table 5 is a box score example that includes current situation, targeted improvement, and the actual change that demonstrates the true difference between them.

**Table 5**
**Box Score**

| | Base value | Future value | Targeted improvement | Current results | Actual change |
|---|---|---|---|---|---|
| Sales per person | 25,000$ | 26,500$ | 1,500$ | 25,500$ | 500$ |
| On time delivery | 99% | 100% | 1% | 100% | 1% |
| First time through | 48% | 96% | 48% | 50% | 2% |
| Dock to dock day | 20 | 4 | (16) | 19 | (1) |
| Average Cost per Unit | 32.50$ | 30$ | (2.50)$ | 31$ | (1.50)$ |

***Note.*** Adapted from "Developing a Lean Performance Score," by D. L. Searcy, September 2009, *Strategic Finance*, p. 38.

Apart from this table, a box score that contains weekly columns to monitor improvements can be created.

## CONCLUSION

Performance measurement is a necessary process for measuring efficiency and sufficiency of enterprise operations. To carry out correct and successful performance measurement, standards suited for the enterprise's structure must be used.

Lean production enterprises use lean production methods apart from traditional production methods. Lean enterprises that use lean production methods instead of traditional ones must use befitting performance measurements. The enterprises that practice the concept and principles of lean production must develop performance measurements suited for lean productions in order to achieve continuous improvement and make strategic decisions.

Value stream is a set of operations in lean production enterprises that start from the order to its production and delivery to the customer. The ideal performance measurement to ensure continuous improvement and excellence in all lean enterprises' value stream is value

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stream performance measurement.

The value stream team performs value stream measurement. Value stream team weekly calculates performances and performance indicators are put on a board so that all the team members could see. The objective here is not to make comparisons between other value streams and team members but deliver continuous improvement.

Box score is a substantial table that shapes value stream team's weekly assessments and decisions they will make for continuous improvement. Table can be changed every week or reorganized to observe changes in all weeks better.

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