# Warehouse Performance Measurement Using Edward H. Frazelle's Warehouse Key Performance Indicator

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## ABSTRACT

This research aims to break down the Method of Edward H. Frazelle's (2002) Warehouse Key Performance Indicators (WKPI). This work will explain how quantitative and qualitative data are collected, organized, and analyzed to perform this WKPI with a real-life example.

The case study introduces a quantitative measuring tool used to analyze the efficiency and effectiveness of the warehouse by comparing past and current performance.

Analytic Hierarchy Process AHP (Saaty (1993)) is introduced for the weightage of all activities to assign their different importance and is used to normalize the collected data. This model can specify the problem area of the warehouse.

## Introduction

Due to the increased globalization in recent years, there has been increased pressure on the logistics sectors. The warehouse is the sector that is most affected by this scenario as it majorly contributes to the performance of the supply chain. A well-performed warehouse has been proven to contribute to better performance (in the supply chain), such as on-time delivery, improved customer satisfaction, cost reduction, etc. (Marco & Mangano, 2011). Therefore, the warehouse's performance and measurement have become crucial factors. There is a constant need to evaluate and improve its performance (Wu & Dong, 2007).

There are different types of warehouse performance measurements model based on the one's requirements. It could be lead time, financial contribution, performance accuracy, overall productivity, etc. (Staudt et al., 2015). Even though warehouse performance evaluation is critical, there is little to no article or research elaboration on warehouse measurement metrics (Axelsson & Frankel, 2014). Therefore, managers must identify and understand the study's key objective and performance and select a model based on that (Kusrini et al., 2018).

One such model is Edward Frazelle's Warehouse Key Performance Indicator, which divides warehouse activities into five categories; Receiving, Put-away, Storage, Order picking, and Shipping. This paper breaks down step-by-step how to collect the data and evaluate and compare the results. For this, three local warehouses have been taken into consideration. It combines private and communal warehouses with 1546 $m^2$ (average), with employees ranging from 10-16. This study area will be the perfect fit since these warehouses do not involve complex activities, and their general activities start from receiving up until shipping.

## Literature Review

A warehouse performance evaluation is a way of assessing the performance of a warehouse, such as the performance of the activity, services, programs, etc. (Kusrini et al., 2018). Performance measurement relates to how work is done; it may also be described as a statistic used to assess an operation's efficiency and effectiveness. Due to the critical role

the warehouse plays in the supply chain, a warehouse measurement is essential as it provides vital information for any decision-making or impact of any decision already made (Ghaouta et al., 2018). These measurement tools help the company to evaluate the current outcomes compared to the present goals and help them form decisions to achieve the intended goal (Berrah et al., 2000). A performance measurement metric system is essential for employees to have complete control over the warehouse and immediately detect and solve problems (Ghaouta et al., 2018).

Edward Frazelle's warehouse KPI divides all the warehouse's everyday activities into more general categories, making it one of the most flexible performance indicators. This KPI gives an overall idea of how each activity affects the warehouse's overall performance and, in some cases, even pinpoints the apparent issues (area). This type of metric system is great for general performance measurement and great for beginners.

## Frazelle's Warehouse Key Performance Indicator

Frazelle (2002) introduced a simple KPI system for the warehouse. He explains how the warehouse is accountable for the same business measurement indicators. Especially for the 3PL companies, the warehouse competes with other 3PL companies. This method also measures the warehouse into essential criteria such as financial, productivity, quality, and cycle time (p.52). Figure 1 represents Frazelle's (2002) WKPI, and it shows how each process in the warehouse can be measured based on five criteria: financial, productivity, utilization (resources), quality, and cycle time. With this measurement, one can analyze the current performance compared to the expected performance.

Warehouse Key Performance Indicators (WKPIs)

| | Financial | Productivity | Utilization | Quality | Cycle Time |
|---|---|---|---|---|---|
| Receiving | Receiving cost per receiving line | Receipts per man-hour | %Dock door utilization | % Receipts processed accurately | Receipts processing time per receipt |
| Put-Away | Put-away cost per put-away line | Put-away per man-hour | %Utilization of putaway labor and equipment | %Perfect putaways | Putaway cycle time |
| Storage | Storage space cost per line | Inventory per square meter | %Location and cube occupied | %Location without inventory discrepancies | Inventory day on hand |
| Order Picking | Picking cost per order line | Order lines picked per man-hour | %Utilization of picking labor and equipment | %Perfect picking lines | Order picking cycle time |
| Shipping | Shipping cost per customer order | Orders prepared for shipment per man-hour | %Utilization of shipping docks | %Perfect shipments | Warehouse order cycle time |

**Figure 1.** Warehouse key performance indicator (Frazelle, 2002)

Figure 1 demonstrates how the activities of the warehouse are generalized and divided into common activities. In addition, each is divided into different categories/criteria, which evaluate the costs, productivity and utilization of resources, the accuracy of the activity and the lead time. These divisions and sub-divisions help the observers/managers get specific insights into how well the warehouse performs in each activity. This will help them pinpoint the problem area and develop relevant solutions.

## Method

This research will require some essential steps, which are as follows;

a) Identifying the necessary values based on Frazelle's WKPI model; b) distributing weightage to each criterion with the help of AHP; c) Normalizing the data with the allotted weight; d) Measuring the values based on appropriate measuring scales and graphically presented.

Although Frazelle has not put forth any specific equations, various other sources have presented their versions of a WKPI. The proposed equations are a combination of both own equations and sourced from other authors (referenced below); they are:

Warehouse Key Performance Indicators (WKPIs)

| | Finance | Productivity | Utilization | Quality | Cycle Time |
|---|---|---|---|---|---|
| Receiving | (Cost of Receiving/No. of line items) | (Volume received/No. of man hrs.) | (Dock utilized for receiving/Total no. of docks)*100 | (Orders received/Orders expected)*100 | Receiving time per pallet |
| Put-Away | (Cost of put-away/No. of line items) | (Volume per put-away/No. of man hrs.) | (Equipment/No. of labors used for put-away)*100 | (Pallets put-away correctly/Total put-away)*100 | Put-way time per pallet |
| Storage | (Cost of storage/No. of line items) | Inventory per $m^2$ | (Pallet locations occupied/Total no. of pallet location)*100 | (Location recorded correctly/Occupied locations)*100 | Average days inventory stored |
| Order Picking | (Cost of order picking/No. of line items) | (Volume picked/No.of man hrs.) | (Equipment/No. of labors used for picking)*100 | (Orders picked accurately/Total orders)*100 | Picking time per pallet |
| Shipping | (Cost of loading/No.of line items) | (Volume loaded/No. of man hrs.) | (Dock utilized for loading/Total no. of docks)*100 | (Orders shipped/ Orders requested)*100 | Shipping time per pallet |

**Figure 2.** Frazelle's 2002 WKPI equations

The results of these equations may vary based on various factors. However, the values should be collected regularly for a set period of days. Then the average values can be taken to gain a fixed value for each criterion. The value of this research is as follows;

**Table 1.** WKPI values

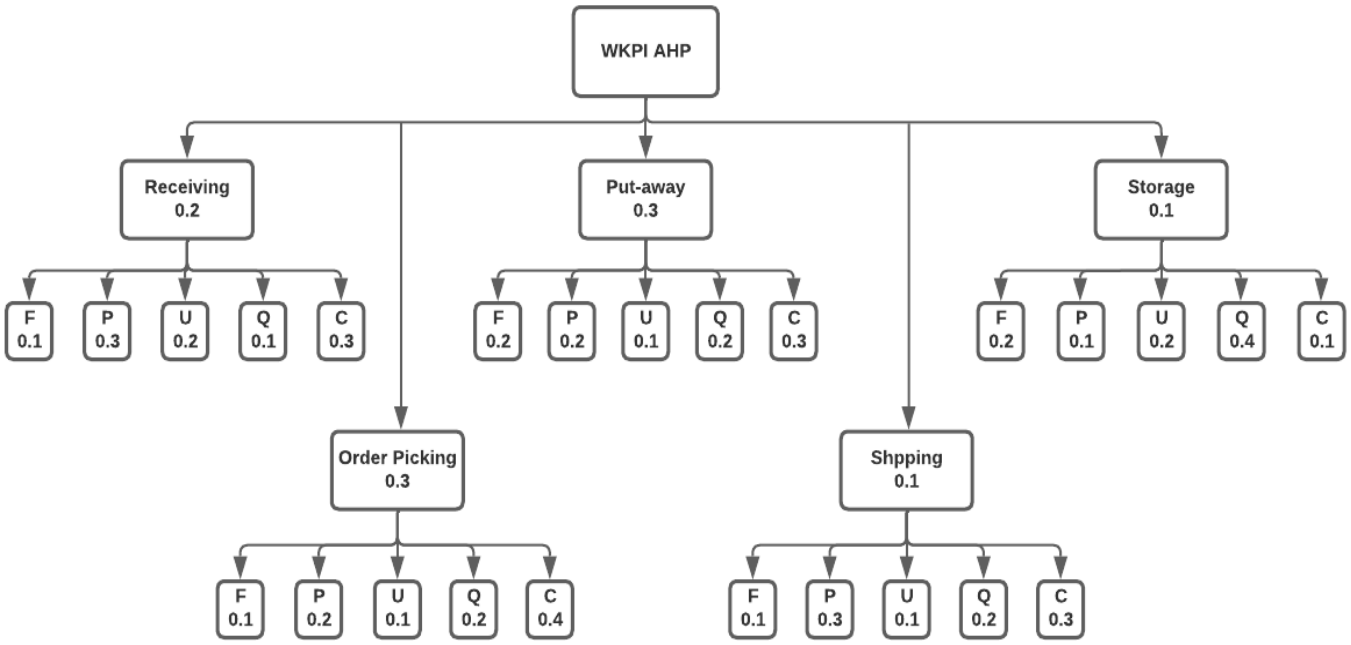
| Process | WH 1 Performance | WH 2 Performance | WH 3 Performance |
|---|---|---|---|
| 1. Receiving | | | |
| - Finance | 21.23 | 5.26 | 30.14 |
| - Productivity | 82.26 | 56.4 | 46.1 |
| - Utilization (%) | 82.61 | 20.46 | 56.85 |
| - Quality (%) | 98.1 | 74.2 | 78.5 |
| - Cycle Time (hrs.) | 0.021 | 0.034 | 0.046 |
| 2. Put-Away | | | |
| - Finance | 16.44 | 6.52 | 36.45 |
| - Productivity | 88.45 | 34.86 | 69.61 |
| - Utilization (%) | 86.44 | 72.12 | 68.23 |
| - Quality (%) | 96.32 | 92.26 | 86.22 |
| - Cycle Time (hrs.) | 0.035 | 0.048 | 0.056 |
| 3. Storage | | | |
| - Productivity ($m^3$) | 82.53 | 62.4 | 96.1 |
| - Finance | 16.28 | 15.29 | 37.74 |
| - Utilization (%) | 96.48 | 63 | 96.89 |
| - Quality (%) | 64.15 | 82 | 93.45 |
| - Cycle Time (hrs.) | 30 | 15 | 20 |
| 4. Order Picking | | | |
| - Finance | 19.48 | 25.1 | 24.65 |
| - Productivity | 66.32 | 57.43 | 61.23 |
| - Utilization (%) | 87.78 | 15.85 | 45.26 |
| - Quality (%) | 98 | 56.15 | 89.23 |
| - Cycle Time (hrs.) | 0.026 | 0.046 | 0.22 |
| 5. Shipping | | | |
| - Finance | 45.32 | 12.1 | 26.1 |
| - Productivity | 82.46 | 35.48 | 96.45 |
| - Utilization (%) | 98 | 55.2 | 42.49 |
| - Quality (%) | 100 | 100 | 100 |
| - Cycle Time (hrs.) | 0.04 | 0.04 | 0.06 |

Analytical Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a method of comparing one element over another to decide which one is more important. This is based on various criteria or properties that may differ based on situations (Saaty, 2008). It is often a graphical representation to help understand and prioritize the elements. The weightage can be acquired via personal observation or interviewing/questionnaire to relevant parties. In this case, relevant parties were asked to rate each criterion based on the level of effect each has on the overall performance of the warehouse. The weightage is divided into two levels, level 1 weightage of warehouse activities and level 2 of the criteria; they are as follows;

**Figure 3.** AHP weightage

This measurement is allotted for all three warehouses. Since the data vary from one another due to different criteria, they can be multiplied by the weightage. This will give the data in percentage, which will then be more accessible to represent as one unit. This unit will help compare each warehouse to one another. Table 2 represent how to normalize the data by multiplying the data via level 2 weightage.



| Process | Weightage | WH1 Performance * Weight | WH2 Performance * Weight | WH3 Performance * Weight |
|---|---|---|---|---|
| 1. Receiving | | | | |
| - Finance | 0.1 | 2.123 | 0.526 | 3.014 |
| - Productivity | 0.3 | 24.68 | 16.92 | 13.83 |
| - Utilization (%) | 0.2 | 16.522 | 4.09 | 11.37 |
| - Quality (%) | 0.1 | 9.81 | 7.42 | 7.85 |
| - Cycle Time (hrs.) | 0.3 | 0.0063 | 0.01 | 0.0138 |
| Total | | 53.14 | 28.97 | 36.08 |
| 2. Put-Away | | | | |
| - Finance | 0.2 | 3.288 | 1.304 | 7.29 |
| - Productivity | 0.2 | 17.69 | 6.97 | 13.92 |
| - Utilization (%) | 0.1 | 8.644 | 7.212 | 6.823 |
| - Quality (%) | 0.2 | 19.26 | 18.45 | 17.24 |
| - Cycle Time (hrs.) | 0.3 | 0.0105 | 0.0144 | 0.0168 |
| Total | | 48.90 | 33.95 | 45.30 |
| 3. Storage | | | | |
| - Finance | 0.2 | 3.256 | 3.058 | 7.548 |
| - Productivity ($m^3$) | 0.1 | 8.25 | 6.24 | 9.61 |
| - Utilization (%) | 0.2 | 19.30 | 12.6 | 19.378 |
| - Quality (%) | 0.4 | 25.66 | 32.8 | 37.38 |
| - Cycle Time (hrs.) | 0.1 | 3 | 1.5 | 2 |
| Total | | 59.465 | 56.20 | 75.916 |
| 4. Order Picking | | | | |
| - Finance | 0.1 | 1.948 | 2.51 | 2.465 |
| - Productivity | 0.2 | 13.26 | 11.49 | 12.25 |
| - Utilization (%) | 0.1 | 8.778 | 1.585 | 4.526 |
| - Quality (%) | 0.2 | 19.60 | 11.23 | 17.85 |
| - Cycle Time (hrs.) | 0.4 | 0.0104 | 0.0184 | 0.088 |
| Total | | 43.6004 | 26.8294 | 37.171 |
| 5. Shipping | | | | |
| - Finance | 0.1 | 4.532 | 1.21 | 2.61 |
| - Productivity | 0.3 | 24.74 | 10.64 | 28.94 |
| - Utilization (%) | 0.1 | 9.8 | 5.52 | 4.249 |
| - Quality (%) | 0.2 | 20.00 | 20.00 | 20.00 |
| - Cycle Time (hrs.) | 0.3 | 0.012 | 0.012 | 0.018 |
| Total | | 59.08 | 37.39 | 55.81 |

**Table 2.** AHP normalization

The normalized values are added and narrowed down by multiplying via level 1 weightage. This process will significantly narrow down the data that can be easily compared. Table 3 presents how the data are narrowed down. Table 3 also represents the performance difference in each warehouse based on the activities. This will be helpful if one is looking to compare warehouses based on specific activities.

| Process | Weight | WH1 Weight* Normalized | WH2 Weight* Normalized | WH3 Weight* Normalized |
|---|---|---|---|---|
| Receiving | 0.2 | 10.63 | 5.79 | 7.22 |
| Put-away | 0.3 | 14.67 | 10.19 | 13.59 |
| Storage | 0.1 | 5.95 | 5.62 | 7.59 |
| Order picking | 0.3 | 13.08 | 8.05 | 11.15 |
| Shipping | 0.1 | 5.91 | 3.74 | 5.58 |
| **Total** | | **50.23** | **33.39** | **45.13** |

**Table 3.** Level 1 weightage

## Results

Table 3 presents the performance of all three warehouses in general. It can be observed that WH1 comparatively has shown the best performance with a total of 50.23. At the same time, it has been observed that WH2 has performed the lowest. This result is excellent for observers who want to compare the general performance of the warehouse/s. However, for one to study and differentiate based on specific activities/ areas, Figure 4 can be a good example.


**Figure 4.** WKPI spider diagram

Figure 4 fittingly represents the performance of each warehouse based on the warehouse activities. Similar to our previous conclusion from Table 3, WH1 has the best performance, whereas WH2 has the least. WH1 performed best in receiving, put-away, order picking and shipping. This is because WH1 has been proven to utilize its available resources to the maximum, thus leading to employee productivity. This combined leads to a reduction in cost, leading to increased revenue. On the contrary, WH3 had the highest performance regarding storage. This is because their utilization of resources for storage is very efficient. The goods are immediately transferred from the dock to the assigned shelf location. In addition, the locations are carefully noted, which helps with correct order picking. These results accurately point out the pros and cons of each warehouse over the other. This will help the observers study and understand where the problem lies and how to improve them. This can also help customers pick between warehouses based on their ability in each activity.

Overall, it can be concluded that WH1 had the best performance by excelling in most categories. However, warehouse managers can take these data, compare them with WH3 and improve the storage sector. Similarly, WH2 and WH3 can take work on improving their other sectors. In addition, customers may select WH3 as their best option if they prioritize storage activities.

In general, WH1 has shown the best performance, especially in order picking activity. This can be considered a significant achievement since some authors believe that over 50% of the total cost in the warehouse is from order picking. Any error in this process can significantly increase the cost (Vries et al., 2015).

## Conclusion

This research paper aims to elaborate more on Frazelle's warehouse KPI with real-life examples. This paper explains this WKPI and how the data is collected and evaluated. Rather than measuring specific performance or areas, this KPI takes the warehouse as a whole, making it relatively easy to evaluate and compare performances. The activities are divided into receiving, put-away, storage, order picking, and shipping. In addition, each activity is measured based on the costs, productivity and utilization of resources, performance accuracy and lead time.

This data is collected throughout a relevant period; the average was taken (since data may vary each time). AHP was used to allot weightage (based on interviews), which was also used to normalize the data. This gave an overall performance of the warehouses. Although WH1 had the best performance, all three warehouses can learn and improve the lacking areas.

## Limitation

Although the model is fantastic, it does have some restrictions. Although adaptable and can identify a problem area, it cannot describe it. Thus it is also incapable of providing appropriate solutions.

Even though this report was significantly easy, there were data collection issues. Since it was local, it was not easy to open their minds to such studies. In addition, one of the warehouses refused to have their names public; all the other warehouses had to be made anonymous. The data were pretty inconsistent. Therefore, the study period had to be extended. However, it was a fascinating study overall.

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