Performance of Warehouse Operations

Science4You Case Study

André Filipe Silva Pinto

Department of Engineering and Management, Instituto Superior Técnico

Abstract

Science4You is a young Portuguese company that manufactures toys and experiences. As a result of the accentuated growth that the company faces, the need arose to analyze the efficiency of each operation, as well as to improve and requalify the performance indicators present in its warehouse and factory. This need led to the development of this master's thesis.

The company, its factory, warehouse and respective processes, as well as the various performance indicators that are already implemented will be presented in this work. Flowcharts that represent the warehouse and factory processes as well as the location of the performance indicators will be developed. A review of the existing scientific literature will also be developed, using concepts related to warehouses and performance measures.

In order to solve the presented problem and based on the literature review, a methodology will be proposed consisting of interviews with the person in charge of the warehouse and factory department (Fab4You) as well as the responsible for each area of this department, an analysis of the indicators already implemented in this department and a proposal for potential new indicators. Finally, with the application of this methodology, 5 new indicators (Final Production Line Operating Time, Overall Equipment Effectiveness, Inventory Turnover, Processing Time of Returned Units and Dispatch Units per Worker per Hour) were suggested and the results obtained were analyzed.

Keywords: Kitting, Key Performance Indicators, Warehouse Management, Warehouse Operations

1. Introduction

Science4You is a young Portuguese company which core business is to develop, produce and sell scientific toys. Their current moment is characterized by a huge growth that leads to an overutilization of their warehouse. For this reason, it was necessary to analyze and evaluate their current processes and efficiency. This analysis must respect the company's values, that are the excellence, effort, and efficiency. Inside of this process of evaluation, there is a point where it is necessary to act, that it is the performance measurement system

The main objective of this work is to propose a performance measurement system that helps to measure the performance of the company's operations and warehouse. With this, it will be structured and propose a methodology supported by the literature review. This literature review will allow identifying the set of key performance indicators to measure the performance of the actual operation, production, and warehouse of Science4You,

To solve the main objective of this work, some intermediary goals must be accomplished:

- Contextualize and analyze the current moment and the indicators already implemented in the company's warehouse and factory;
- Structure a methodology based on a literature review which allows identifying new indicators;

- Collect and treat the data necessary to the application of the methodology;
- Implement the methodology;
- Analyze and discuss the results.

This paper will be structured as follows:

- Section 2: Case Study
- Section 3: Literature Review
- Section 4: Methodology
- Section 5: Interviews
- Section 6: Critical Analysis of Current Key Performance Indicators
- Section 7: Proposal of New Key Performance Indicators
- Section 8: Conclusions

2. Case Study

Science4You is a Portuguese company that develops, produces and commercializes scientific toys and experiences. This company was founded in January 2008 and their sales began in October 2008. Currently, they are selling in 35 countries, spread across 5 continents.

At the present time, Science4You is located in MARL (*Mercado Abastecedor Região de Lisboa*) where they have their warehouse and factory. The company is divided into 4 main departments that are responsible for each part of their business: Lab4You, Fab4You, Sales4You, and Support4You. This paper will be only focused in Fab4You, the department responsible for the warehouse and factory. Fab4You is responsible for the production of the products and for each operation related to warehousing since raw materials enter the warehouse until the final products are dispatched. This department is divided into 8 areas, each responsible for different aspects of the warehouse and factory:

- Planning – responsible for planning the company's production;
- Logistics – responsible for order processing and also notifying Planning about the demand that must be produced;
- Reverse Logistics – responsible for raw materials' arrival and returns;
- Intermediate Production – responsible for dealing with raw materials and put them in small bags or boxes and tagging all the bags and boxes;
- Final Production – responsible for the assembly of the intermediate products with the manual and packaging;
- Expedition – responsible for checking the order, picking all the final products and storing them in a pallet before shipping the orders to their clients;
- Hospital – responsible for requalifying and fixing the returns;
- Facilities – responsible for security, environment, and cleaning of the warehouse. This area is also responsible for the warehousing of the products.

In order to analyze the performance of the processes that occur inside the warehouse, Science4You implemented 14 Key Performance Indicators that are distributed into 4 groups: Intermediate Production, Final Production, Warehouse and Expedition. However, because of their growth and youth, there is a need to reevaluate these Indicators and propose new ones, in order to improve the current indicators and measure the performance of processes that are not yet been evaluated. This reevaluation and the proposal of new indicators will be analyzed in Section 6 and 7, where all indicators that Science4You already installed will be presented and the new Key Performance Indicators that emerged from the reevaluation will be proposed, respectively.

3. Literature Review

According to Christopher (2016), logistics is the planning of the flow of products between entities and information, while supply chain is a structure that wants to achieve the connection and coordination between entities. Nowadays, logistics is complex and it is used to distinguish between competitors. Krittanathip et al. (2013) refer some factors and costs that affect logistics, like transportation, inventory, warehousing and administrative costs. Also for Krittanathip et al. (2013), the main costs between those that were referred, are the inventory and warehousing.

Currently, there is a necessity to use warehouses, even if that represents a high cost (Bartholdi III and Hackman, 2011). For these authors, a warehouse allows to consolidate the product (reducing transportation costs, schedule the flow of products and to improve the customer service through the access of inventory), take advantage of economies of scale, provide value creation (allows postponement) and reduce the response time to fulfill the demand of clients, improving the production flexibility. According to Tompkins (1998), there are 3 types of warehouses, the Raw Materials warehouse, the Work-in-Progress warehouse and the Final Products warehouse. The difference between those warehouses is related with the type of operations that are practiced, being that in Raw Materials and Work-in-Progress warehouses, the type of operation used is Kitting, while in Final Products warehouse is Picking. This paper will only focus on kitting operation and not picking operation.

For Bozer and McGinnis (1992), Brynzér and Johansson (1995) and Christmansson et al. (2002), kitting is the assembly process of components or kits that are previously prepared. For Bozer and McGinnis (1992), there are some advantages that kitting provides, like reduction of space and work-in-progress, flexibility related to possible changes in products, higher control and flexibility during the handling and transportation of these kits, higher facility in robotic handling in the assembly line and higher potential of product's quality and higher productivity in the assembly line, related to the availability and positioning of the kits. Also, there are some limitations, like the time that is needed to prepare the kits, the fact that the handling does not bring value-added to the product, more space to inventory, requires an additional planning to attribute the components to the kits and missing parts can lead to a reduction of global efficiency of operation.

There are some concepts that can be an alternative to kitting like stocking line and supermarket. For Hua and Johnson (2010) and Hanson and Brolin (2013), stocking line is a continuous supply, where the components are stored near to assembly stations, where they will be assembly. The main idea of these authors is to reduce the time of preparation, like in kitting, and to reduce the handling of the components. Furthermore, there is no time wasted to look for the right component. Another fundamental idea in stocking line and in kitting, is explained by Limère et al. (2012) and is related to supply of the operation. In a stocking line the supply is fulfilled in a homogeneous way (*"supply components to the assembly line in individual component containers"*), while in kitting it is done in a heterogeneous way (*"kitting systems group together various components into one package according to a future assembly schedule and supply these kits to the line"*). For Emde and Boysen (2012) and Battini et al. (2013), supermarket consists of decentralized logistics areas near to the assembly lines that stores components and supplies these lines. Those logistics areas are supplied with a "train" that follows the assembly lines and receives the components by a central receiving store that is supplied by the company's suppliers. According to Battini et al. (2013), supermarket allows the improvement of flexibility in a possible adjustment of the assembly lines or components and the reduction of the workers' strength and handling time by giving an efficient and ergonomic access to the workers.

In order to manage all the operations in an efficient way, it is necessary to measure the performance achieved in those operations. Weber and Thomas (2005) pronounces that measures of performance are one of the fundamental principles of management because it identifies and registers the difference between the actual performance and the target performance. According to Neely et. al (1997) to develop an indicator, there are some details that must be defined. Those details are: the name (use a name that avoid ambiguity), the objective (the relationship between the metric and the organizational objectives must be clear), scope (which area or part of organization must be included), value-target, the equation, units of the indicator, the frequency of registers, the data source, the property (the responsible for collect the data), the drivers and possible commentaries (factors that influences the performance). Peterson (2004) says that the idea of KPI is to obtain data, evaluate and compare the performance of each process and to presented in a common language.

Hudson, Smart and Bourne (2001) and Staudt et al. (2015) define some operational dimensions that must be measured, e.g. quality, time, productivity, flexibility, finance, customer's satisfaction and human resources.

4. Methodology

To solve the problem described in Section 2, a methodology will be developed based on the knowledge gathered in Section 3. This methodology consists of three steps. The first step consists of interviews to the responsible of Fab4You and the responsible for each area of this department. The second step is a critical analysis of each key performance indicator that already exists. Finally, the third step is to propose new key performance indicators.

Semi structure interviews (Hague, 2006) will be used in the first step This type of interviews uses closed and open questions which will allow to discuss in detail each topic that is relevant to this problem (Section 5).

The key performance indicators already used by the Fab4You department will be analyzed according to some characteristics: name, scope and owner; objective, formula, units and data source; values; frequency (Section 6).

To conclude this methodology, some new key performance indicators will be proposed. This proposal will follow a defined structure: Name; Objective; Scope; Values; Formula; Units and Frequency (Section 7).

5. Interviews

The interviews will be made to the responsible of Fab4You and the responsible for each area of this department. According to those responsible, the expectation is a system of key performance indicators that focus on results and efficiency. Also, this system should allow an easy and quick access to these indicators in a way to identify the performance of operations. Furthermore, in these interviews, some requirements and suggestions for the new indicators were given. According to the Reverse Logistics' responsible and Expedition's responsible, it is necessary to analyze the productivity of each worker. For this reason, the time and units processed in reverse logistics and the orders expedited per hour and a worker will be analyzed. The stopping time and the Overall Equipment Effectiveness of the final production line will be analyzed given the suggestions provided by the Final production's responsible. Finally, the warehouse must be analyzed, through inventory turnover. Each new indicator must be analyzed on a monthly basis and they must be coupled to the software that the company uses.

6. Critical Analysis of Current Key Performance Indicators

Currently, Fab4You has 14 key performance indicators that are divided into 4 groups: Intermediate Production (Intermediate Production Amount and Breaks); Final Production (Final Production Amount, Final Production Amount per Minute and Plastic Waste); Warehouse (Absenteeism Rate, Warehouse Occupation and Cost per Billing); and Expedition (Service Level, Shipment Efficiency, Quantity Efficiency, Expedition Time, Expedition Total Cost and Fill Rate).

From these 14 key performance indicators, there is no data collection regarding 2 (Breaks and Plastic Waste) and 2 others do not respect the concept of indicator (Expedition Time and Expedition Total Cost). For these reasons, the 10 indicators consider useful for the company are:

- Intermediate Production Amount

This indicator represents the daily intermediate production. According to the responsible for the Intermediate Production area, the relation between Final and Intermediate Production is 15 final production units to 100 intermediate production units. The average Intermediate Production Amount registered in 2016 was 76 836 units, an amount lower than the target value of 80 000 (large boxes) to 113 333 units (small boxes). This indicator is register and consulted daily.

- Final Production Amount

This indicator represents the daily final production. In 2016, the average Final Production Amount was 11 525 units, an amount lower than the target value of 12 000 units (large boxes) and 17 000 units (small boxes). The results of this indicator are register and consulted daily.

- Final Production Amount per Minute

This indicator represents the instant final production and is measured through a sensor at the end of the final production conveyor belt. With final production working at 100% capacity, the value of this indicator varies between 25 and 35 boxes per minute (target values), depending on the dimension of the boxes. In 2016, the average Final Production Amount per Minute was 24 boxes. This indicator is not registered and in order to obtain its average value it is necessary to divide the Final Production Amount by 480 minutes (factory operates eight hours a day).

- Absenteeism Rate

Absenteeism Rate allows to monitor the absences given by the workers, including the unexcused and justified absences (vacations). This indicator is used by all areas and it is registered daily by the responsible of each area, according to the location of each worker. In the first semester of 2016, the average Absenteeism Rate was 19.44%.

- Warehouse Occupation

Warehouse Occupation is responsible for registering the occupation of the racks by raw materials, work-in-progress and final products. The average Warehouse Occupation in March 2017 was 85.13%. This value is far from the target value that is 80%. It was only possible to withdraw data for the month of March 2017 because this indicator requires continuous inventory monitoring and a Warehouse Management System has only been fully implemented since the beginning of 2017. This indicator is register daily and consulted monthly.

- Cost per Billing

The Cost per Billing indicator is one of the most important indicators in Science4You as it reflects the financial health of the company. This indicator is calculated using the cost to bill ratio. The costs associated with this indicator are salaries, raw materials, new machinery, and software. The average Cost per Billing in 2016 was 16% (every 100 euros of billing had a cost of 16 euros), a percentage higher than the target value of 11%. The results of this indicator are registered daily and consulted monthly.

- Service Level

This indicator represents the percentage of orders delivered in the correct time. In 2016, Service Level registered an average of 88.03%. The target value of this indicator is 95%. So, the actual average value is beneath the expectations. The results of this indicator are register daily and consulted monthly or even quarterly.

- Shipment Efficiency

Shipment Efficiency represents the percentage of orders fulfilled. This indicator has a target value of 98%. The average value recorded in the first 6 months of 2016 was 97.76%, being close to the target value. Like the Service Level indicator, the Shipment Efficiency indicator is recorded daily (through every order that leaves the system) but is consulted on a monthly or quarterly basis, depending on the needs of the company. However, this indicator is less complete when compared to the Service Level because it considers only the number of orders satisfied, while the Service Level considers the number of orders satisfied in the correct time.

- Quantity Efficiency

This indicator represents the percentage of quantity ordered by the customers that is fulfilled. In the first semester of 2016, the average value recorded was 71.09% of quantity fulfilled. This value is far from the target value of 75%. Like the previous two, this indicator is also recorded daily and consulted on a monthly or quarterly basis. A potential indicator could result from the aggregation of the Service Level, Shipment Efficiency and Quantity Efficiency indicators, which would evaluate the orders that were shipped on time and in correct quantities.

- Fill Rate

Fill Rate is an indicator that reflects the number of orders met through the available inventory, being registered daily and consulted bi-annually or annually. While the Quantity Efficiency indicator only considers differences between quantities ordered and shipped, this indicator considers the orders that are not fulfilled because customers ask for discontinued products or because there is a lack of materials to manufacture the products. The average Fill Rate recorded in the first semester of 2016 was 76.84%, a percentage far below the target value of 90%.

7. Proposal of New Key Performance Indicators

After the interviews and the analysis of the 10 key performance indicators that are useful for the company and should be maintained, the proposal of new key performance indicators will be developed in this section. The new indicators' development was prepared to take into account the most relevant concerns of Science4You already explained in Section 5.

7.1. Processes in Analysis

A proposal was made for 5 new indicators, after analyzing the areas and defining the company's needs, that will complement the set of 10 indicators already implemented by Science4You and that should be maintained. These new indicators will focus on the Final Production area, the Warehouse, the Reverse Logistics area and the Expedition area, and have the following reasoning:

- Final Production – two new indicators (Final Production Line Operating Time and Overall Equipment Effectiveness) will focus on this area due to anomalies related to line stops and the inefficiency they bring;
- Warehouse – a new indicator (Inventory Turnover) related to warehouse operations is necessary due to the need to know how much time all raw materials, intermediate and final products spent in stock;
- Reverse Logistics – a new indicator (Processing Time of Returned Units) in this area is justified by the fact that almost 10% of what is dispatch is returned later and there is lack of information about time and units of these returns;
- Expedition – a new indicator (Dispatch Units per Worker per Hour) in this area is justified because, although not so critical, there is a care to be taken in relation to the processes and the number of orders to be dispatched, given the average quantity they carry. This indicator will assist in the planning of the area in question.

After analyzing the areas, it is possible to formulate the proposal for new indicators.

7.2. New Indicators

The 5 new indicators are analyzed in more detail in this subsection.

- Final Production Line Operating Time

This new indicator allows the company to understand the percentage of time that its final production line is operational compared to the planned operating time (8 hours daily). Sometimes the final production line is stationary due to inefficiencies which limit the production capacity of Science4You. The calculation of the Final Production Line Operating Time indicator is given by the expression:

$$\text{Final Production Line Operating Time (\%)} = \left(1 - \frac{Total\ Stops\ (minutes)}{Total\ Planned\ Time\ (minutes)}\right) \times 100\%$$

In order to support the proposal of this indicator, data from 2 days (May 15 and 18, 2017) was collected including the scheduled (related to changes in the toy being produced) and unscheduled (e.g. problems with the film that the plasticizer uses or adjustments related to the size of the boxes to be plasticized) stops, the total planned operating time and the actual total operating time of the final production line. These data are presented in Table 1.

Table 1 – Final Production Line Operating Time

	15 may	18 may	Total
Scheduled Stops (hours)	00:51:00	00:42:00	01:33:00
Unscheduled Stops (hours)	00:37:45	01:08:35	01:46:20
Total Stops (hours)	01:28:45	01:50:35	03:19:20
Total Planned Time (hours)	08:00:00	08:00:00	16:00:00
Total Operating Time (hours)	06:31:15	06:09:25	12:40:40

In the 2 days that the data were collected, the final production line operated for 12 hours, 24 minutes and 40 seconds from the 16 hours planned meaning it was stationary for 3 hours, 19 minutes and 20 seconds. Applying the expression to the data in Table 1, it is possible to conclude that the value of the Final Production Line Operating Time during the two days of the sample (May 15 and 18, 2017) was 79% of the total planned operating time. Since the percentage of scheduled stops is equal to 10% of the total planned operating time, the target value for this indicator should be 90%, which will be achieved by eliminating unscheduled stops equal to 11% of the total planned operating time.

- Overall Equipment Effectiveness

According to Singh et al. (2013), the Overall Equipment Effectiveness (OEE) will allow the company to evaluate the efficiency that the final production line faces. This indicator consists of three variables (Availability, Quality and Performance) and its calculation is given by the expression:

$$OEE\ (\%) = Availability\ (\%) \times Quality\ (\%) \times Performance\ (\%)$$

The first term, Availability, is calculated by dividing the total run time (operating time) by the total planned run time of the final production line as in the following expression:

$$Availability\ (\%) = \frac{Run\ Time\ (hours)}{Total\ Planned\ Time\ (hours)} \times 100\%$$

Given this expression, Final Production Line Operating Time corresponds to Availability so the value of this variable in 2016 was 79% (assuming this value is representative). Table 2 presents the run time and total planned time of the final production line(s) in 2016. The run time values in Table 2 are calculated by applying 79% to the total planned time of 176 hours per month (8 hours per day on 22 days per month) in the first 8 months of the year and 352 hours per month (176 × 2) in the last 4 months of the year when there are 2 final production lines running.

Table 2 - Values of Availability in 2016

	Jan – Aug	Sep – Dec
Run Time (hours)	139	278
Total Planned Time (hours)	176	352
Availability	79%	79%

The second term, Quality, measures the quality of production and is calculated through the expression:

$$Quality\ (\%) = \frac{Good\ Count\ (\#)}{Total\ Count\ (\#)} \times 100\%$$

The good count value corresponds to the total number of toys that were produced without problems and the total count value corresponds to the total number of toys produced. Both counts are performed at the end of the final production line. The values reached in 2016 were obtained in a conversation with the responsible for the Final Production area and are presented in Table 3.

Table 3 - Values of Quality in 2016

	Good Count (#)	Total Count (#)
January	97 621	99 613
February	168 517	171 956
March	285 657	291 487
April	208 597	212 854
May	189 023	192 881
June	95 036	9 976
July	76 460	78 020
August	158 319	161 550
September	279 998	285 712
October	416 855	425 362
November	575 412	587 155
December	491 224	501 249

The average value of Quality achieved in 2016 was 98%. The remaining 2% refers to the percentage of units produced with some problem due to production errors or problems with poor plasticization.

The calculation of the last term, Performance, involves the ideal cycle of production (ideal cycle time), the total running time of the line (run time) and the number of units produced without defects (good count), and is given by the expression:

$$Performance\ (\%) = \frac{Ideal\ Cycle\ Time\ \left(\frac{hours}{\#}\right) x\ Good\ Count\ (\#)}{Run\ Time\ (hours)} \times 100\%$$

The ideal cycle time in 2016 was 35 units per minute (2100 units per hour, that is, 0.00048 hours per unit). For each month, the run time is present in Table 2 and the good count in Table 3.

So, the values of Performance and OEE for each month in 2016 are present in Table 4:

Table 4 - Values of Performance and OEE in 2016

Months	Performance	OEE
January	33%	26%
February	59%	46%
March	100%	77%
April	73%	56%
May	66%	51%
June	33%	26%
July	27%	21%
August	55%	43%
September	49%	38%
October	73%	56%
November	100%	78%
December	86%	66%
Average	63%	49%

The average value of Performance and OEE in 2016 was 63% and 49%, respectively. This last value is far from the target value of 60% obtained through the average plus the standard deviation (18.5%) of OEE.

In order to improve the OEE, it is necessary to analyze the 3 terms. If Quality improves from 98% to 100%, the OEE will only improve 0.04% which does not represent a significant improvement. So, it is necessary to evaluate the other two terms, both of which use in their calculation the value of the total operating time (run time) of the final production line. As mentioned before, the target value of the Final Production Line Operating Time indicator and, consequently, the Availability variable is 90%, allowing only scheduled stops. Maintaining the 176 hours per month of total planned operating time in the first 8 months of the year and 352 hours per month in the last 4 months of the year, the new run time values assuming 90% Availability will be 158 and 317 hours per month, respectively. These new data are shown in Table 5.

Table 5 - Values of Availability with a reduction of 11% of stops

	Jan – Aug	Sep – Dec
Run Time (hours)	158	317
Total Planned Time (hours)	176	352

This decrease of total stops will lead to an increase of the units produced since the line will be operational longer. Table 6 shows the good count data for the year 2016 (21% of the total planned operating time corresponds to stops) and the new good count (only 10% of the total planned operating time corresponds to stops).

Table 6 - Values of Quality with a reduction of 11% of stops

	Good Count (#)	New Good Count (#)
January	97 621	111 214
February	168 517	191 981
March	285 657	325 432
April	208 597	237 642
May	189 023	215 343
June	95 036	108 269
July	76 460	87 106
August	158 319	180 364
September	279 998	318 985
October	416 855	474 898
November	575 412	655 533
December	491 224	559 623

Given the new run time and good count values, the new Performance and OEE values are presented in Table 7.

Table 7 - Values of Performance and OEE with a reduction of 11% of stops

Months	Performance	OEE
January	32%	28%
February	57%	50%
March	96%	85%
April	70%	62%
May	63%	56%
June	32%	28%
July	26%	23%
August	53%	47%
September	47%	41%
October	70%	62%
November	97%	85%
December	82%	73%
Average	60%	53%

The reduction of 11% of unscheduled stops allows an increase of OEE from 49% to 53%.

- Inventory Turnover

This indicator reflects the inventory rotation and will allow the company to analyze the frequency with which it renews its inventory. Inventory Turnover is calculated through the expression:

$$Inventory\ Turnover = \frac{Sales\ (€)}{Average\ Inventory\ (€)}$$

The value of sales and inventory in 2014, 2015 and 2016 are display in Table 8.

Table 8 - Values of Inventory Turnover

	Economic Value (€)	Inventory Turnover
Sales 2014	6.500.000 €	2,88
Inventory 2014	2.254.000 €	
Sales 2015	11.300.000 €	2,98
Inventory 2015	3.789.000 €	
Sales 2016	18.226.000 €	2,83
Inventory 2016	6.440.000 €	

The average value of Inventory Turnover is 2,90. This means that the inventory rotates almost 3 times per year or every 4 months. This indicator is close to the target value of 3.

- Processing Time of Returned Units

Processing Time of Returned Units is an indicator that reflects a quantity of units returns and the time needed to process these units. The expression used to calculate this indicator is:

$$Processing\ Time\ of\ Returned\ Units\left(\frac{\#}{minutes}\right) = \frac{Units\ Returned\ (\#)}{Processing\ Time(minutes)}$$

The values collected for 14 days between April and May are present in Table 9.

Table 9 - Values of Processing Time of Returned Units

Days	Units Returned (#)	Processing Time (minutes)
1	441	230
2	1 510	675
3	2 471	635
4	709	365
5	615	300
6	1 910	240
7	2 006	655
8	1 420	1 260
9	88	140
10	1 123	445
11	8 666	1 010
12	2 631	810
13	180	120
14	1 343	580

In this 14 days, the average Processing Time of Returned Units was 3.07 units per minute, a value still far from the target value of 5.42 units per minute.

- Dispatch Units per Worker per Hour

Finally, the objective of this indicator is to analyze the hourly productivity of a worker operating in the Expedition area and it is calculated through the expression:

$$Dispatch\ Units\ per\ Worker\ per\ Hour = \frac{Units\ Dispatched\ (\#)}{Time\ (hour) * Workers\ (\#)}$$

The values concerning the first semester of 2016 are displayed in Table 10.

Table 10 - Values of Dispatch Units per Worker per Hour

	Time	Units Dispatched	Workers	Dispatch units per Worker per Hour
January	723:41:10	97 621	6	22.48
February	1192:25:04	168 517	6	23.55
March	3146:13:41	285 657	6	15.13
April	1522:36:42	208 597	6	22.83
May	1778:49:28	189 023	6	17.71
June	875:42:40	95 036	6	18.09

The average value of this indicator in the first semester of 2016 was 19.97 units per worker per hour. This allows the Expedition area to calculate the number of workers needed to dispatch the units in 1 hour.

8. Conclusions

In this section, the main conclusions, limitations and suggestions for future work will be presented.

- Main Conclusions

Science4You is a young company that produces toys and experiences. In the 8 years of activity, a huge growth was registered. This growth results in a necessity to study and measure the efficiency of operations and the space of their warehouse. To do this, a description of the department (Fab4You) responsible for the warehouse, factory and respective operations, as well as an analysis of the key performance indicators already implemented in this department was necessary.

A literature review was developed, focusing on logistics, warehouse, warehouse's operations, kitting, stocking line, supermarket and key performance indicators. Nowadays is recognized the great importance of logistics as a starting point to competitive advantage. So, the scientific community has been studying elements of logistics, namely warehouse's operations. The operation of kitting is a specific operation in some warehouses and was studied in more detail because it is a core operation in Science4You's warehouse. Kitting is present in the great sectors of activity, like in aeronautic and car industry. This concept is considered to add value to each product and it is a way to standardize, reduce the time and space used. However, no indicators that help to evaluate the performance of this type of operation was found. The concept of key performance indicators was an approach to analyze the performance of a warehouse.

Based on the literature review, a methodology was developed in order to solve the problem. This methodology consisted of interviews to the responsible of Fab4You and the responsible of each area of this department, followed by a critical analysis of the indicators already implemented and a proposal of new indicators.

The interviews revealed that the company's expectation is a system of key performance indicators that focus on results and efficiency. Also, this system should allow an easy and quick access to these indicators in a way to identify the performance of operations. Furthermore, in these interviews, some requirements and suggestions for the new indicators were given. The critical analysis of the indicators already implemented showed that Fab4You has 14 key performance indicators divided into 4 groups: Intermediate Production (Intermediate Production Amount and Breaks); Final Production (Final Production Amount, Final Production Amount per Minute and Plastic Waste); Warehouse (Absenteeism Rate, Warehouse Occupation and Cost per Billing); and Expedition (Service Level, Shipment Efficiency, Quantity Efficiency, Expedition Time, Expedition Total Cost and Fill Rate). From these, only 10 indicators should be kept because there is no data collection regarding 2 (Breaks and Plastic Waste) and 2 others do not respect the concept of indicator (Expedition Time and Expedition Total Cost). After this analysis, 5 new indicators were proposed. These new indicators will focus on the Final Production area (Final Production Line Operating Time and Overall Equipment Effectiveness), the Warehouse (Inventory Turnover), the Reverse Logistics area (Processing Time of Returned Units) and the Expedition area (Dispatch Units per Worker per Hour).

- Limitations

During this work, Science4You was always available to respond to any solicitation of data. However, some problems arose in the data collection because, in the end of 2016, Science4You decided to rotate the teams and areas' responsible which meant that there was no update or data processing in some periods. This also affected the first months of 2017. For example, in Expedition, they only had data related to the January and March 2017, which did not bring coherence to the data. Another aspect related to data collection is the fact that exists some problems with some software used by Science4You. For example, the hour registered in xLog is different every day and hinders the data collection.

- Future Work

Finally, some ideas for future work are suggested. Having in account the growth that Science4You faces, it makes sense to analyze all processes, in particular, those that are not analyzed in this work. The software used should be reevaluated in order to improve the limitations of the data collection. Also, they should review their areas' connections and communications to increase the efficiency of operations and processes and to eliminate errors. Another idea for future work is to propose a methodology of evaluation to their partners (transportation or raw materials), in order to standardize all process. At last, it would be interesting to develop a tool for global performance measurement, that helps to report each key performance indicator. This will only be possible when Science4You consolidates the data.

9. References

Bartholdi III, J. J., & Hackman, S. T. (2011). Warehouse & distribution science: release 0.92. *Atlanta, GA, The Supply Chain and Logistics Institute, School of Industrial and Systems Engineering, Georgia Institute of Technology*.

Battini, D., Boysen, N., & Emde, S. (2013). Just-in-Time supermarkets for part supply in the automobile industry. *Journal of Management Control*, *24*(2), 209–217. http://doi.org/10.1007/s00187-012-0154-y

Bozer, Y. A., & McGinnis, L. F. (1992). Kitting versus line stocking: A conceptual framework and a descriptive model. *International Journal of Production Economics*, *28*(1), 1–19. http://doi.org/10.1016/0925-5273(92)90109-K

Brynzér, H., & Johansson, M. I. (1995). Design and performance of kitting and order picking systems. *International Journal of Production Economics*, *41*(1–3), 115–125. http://doi.org/10.1016/0925-5273(95)00083-6

Christmansson, M., Medbo, L., Hansson, G. Å., Ohlsson, K., Unge Byström, J., Möller, T., & Forsman, M. (2002). A case study of a principally new way of materials kitting - An evaluation of time consumption and physical workload. *International Journal of Industrial Ergonomics*, *30*(1), 49–65. http://doi.org/10.1016/S0169-8141(02)00077-X

Christopher, M. (2016). *Logistics and Supply Chain Management* (5th ed.). New York: Education, Pearson.

Emde, S., & Boysen, N. (2012). Optimally locating in-house logistics areas to facilitate JIT-supply of mixed-model assembly lines. *International Journal of Production Economics*, *135*(1), 393–402. http://doi.org/10.1016/j.ijpe.2011.07.022

Hague, P. (2006). An Introduction to Questionnaire Design. *A Practical Guide to Market Research*, 129–149. Retrieved from https://www.b2binternational.com/files/08-market-research-ch8.pdf

Hanson, R., & Brolin, A. (2013). A comparison of kitting and continuous supply in in-plant materials supply. *International Journal of Production Research*, *51*(4), 979–992. http://doi.org/10.1080/00207543.2012.657806

Hua, S. Y., & Johnson, D. J. (2010). Research issues on factors influencing the choice of kitting versus line stocking. *International Journal of Production ResearchOnline) Journal International Journal of Production Research International Journal of Production Research*, *483*(3), 20–7543. http://doi.org/10.1080/00207540802456802

Hudson, M., Smart, A., & Bourne, M. (2001). Theory and practice in SME performance measurement systems. *IJOPM International Journal of Operations & Production Management*, *21*(8), 1096–1115. http://doi.org/10.1108/EUM0000000005587

James A. Tompkins, J. D. S. (1998). *Warehouse Management - Handbook* (2nd ed.). Raleigh: Tompkins Press.

Krittanathip, V., Cha-um, S., Suwandee, S., Rakkarn, S., & Ratanamaneichat, C. (2013). The Reduction of Inventory and Warehouse Costs for Thai Traditional Wholesale Businesses of Consumer Products. *Procedia - Social and Behavioral Sciences*, *88*, 142–148. http://doi.org/http://dx.doi.org/10.1016/j.sbspro.2013.08.489

Limère, V., Taylor, P., Landeghem, H. Van, Goetschalckx, M., & Mcginnis, L. F. (2012). Optimising part feeding in the automotive assembly industry : deciding between kitting and line stocking, 37–41. http://doi.org/10.1080/00207543.2011.588625

Singh, R., Shah, D. B., Gohil, A. M., & Shah, M. H. (2013). Overall equipment effectiveness (OEE) calculation - Automation through hardware & software development. *Procedia Engineering*, *51*, 579–584. http://doi.org/10.1016/j.proeng.2013.01.082

Staudt, F. H., Alpan, G., Mascolo, M. Di, & Carlos, M. (2015). Warehouse performance measurement : a literature review. *International Journal of Production Research*, *7543*(November 2016), 1–21. http://doi.org/10.1080/00207543.2015.1030466

Weber, A., & Thomas, R. (2005). Key Performance Indicators - Measuring and Managing the Maintenance. *IAVARA Work Smart*, (November), 1–16.