Original Research Article

# Lean accounting and applications in an automotive supplier industry

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***Abstract:*** Lean accounting is an approach that supports Lean Manufacturing in a financial concept. It has a different perspective than traditional costing approach and the main key point in lean manufacturing is removing or reducing the wastes in the system. In this study, the aspect of lean accounting was analyzed in a wiring harness production firm which is in an automotive supplier industry. Lean manufacturing methods were applied in the firm and line balancing applications with their results were evaluated in the study based on the lean accounting system.

***Keywords:*** Lean accounting; lean manufacturing; waste

## 1. Introduction

Lean accounting evaluates the financial performance of a firm that has lean manufacturing processes. The goal in Lean manufacturing systems is to achieve the shortest possible cycle times and to meet the demand by eliminating wastes and in this case to achieve lower costs, higher quality and shorter lead times. The wastes are transport, inventory, motion, waiting, over-processing, overproduction and defects. All these kinds of wastes are tried to be eliminated in order to add value to the products. Value is defined by the customers not by producers therefore the system and the products should be designed based on the customers' requirements in a lean manufacturing system.

Traditional financial measurements can be meaningful in the mass production system. The aim is trying to minimize the total cost per unit in this system and it is conflicted with the lean manufacturing. Financial reports are obtained by the managers in the traditional system. In lean manufacturing, everybody can work together towards continues improvement and performance. The workers can be informed briefly in a simplified way and then they can know how they can be useful to the firm's financial aims.

In this study, the aspect of lean accounting was analyzed in a wiring harness production firm which is in an automotive supplier industry. Lean manufacturing methods were started to apply in the firm and there were exist different lean manufacturing applications in the system such as 5S, SMED, VSM, Kaizen and Kanban. Upon this concept, line balancing applications with their results were evaluated in the study based on the lean accounting system.

## 2. Materials and methods

The firms have visions that show their aims in a planned duration and also they have missions that show their existence reason in a strategic management. All employees should give an effort to reach their vision by considering the aims, cultures and values of the firm. Today, there is a big competition among the firms depending on the technology. Therefore, the firms should increase their quality, decrease costs and decrease durations. These factors can be consider-


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ed together in lean manufacturing systems.

Lean manufacturing is an approach that focuses to eliminate the whole wastes and to make improvements in the system. Lean manufacturing was first improved and applied by Toyota. Seven wastes in the system are defective production, extra production, extra inventory, waiting, unnecessary work, unnecessary carrying and unnecessary action.

Principles of Lean Manufacturing can be defined as the following[1]:

1- Value: In lean, customer defines the value based on own requirements.

2- Value Flow: Each process from raw material to final production is defined to see the wastes.

3- Continuous Flow: Continuous flow is planned in desirable quality, time and at lowest cost by eliminating the wastes.

4- Pull System: Customers can reach the product or service when they want.

5- Excellence: Excellent level is tried to be reached by continuous improvement.

In lean systems, there are some applications in order to eliminate the wastes and so to reduce the costs. To see the results in financial measurements may take a while but when the lean system is ready step by step, defined valuable product or service make the system more profitable. The costs can be organized by analyzing value stream, changing inventory levels and modifying financial statements in the system. Lean accounting evaluates the financial performance of a firm that has lean manufacturing processes.

There are some applications in lean manufacturing system such as Standardization, 5S, Kaizen, Just in Time Production (JIT), Kanban, Visual Working Place, Value Stream Mapping (VSM), Single Minute Exchange of Die (SMED), JIDOKA, Poka Yoke and Lean all applications make the system more valuable and minimize the costs. One of the most important issues in lean is the full participation of the firm to adapt the system.

Lean manufacturing is fast growing process to improve the productivity of an industry. The lean manufacturing tools are not limited to industry only but are being used in many areas as hospital, education, infrastructure, repair, government, banking, service, estate and administration[2-4]. The detailed review can be found in[2].

One of the main applications in the lean system is line balancing. Boysen *et al*.[5] found that in spite of the enormous academic effort in assembly line balancing, there was remains a considerable gap between requirements of real configuration problems and the status of research. To facilitate the communication between researchers and practitioners, they have presented a classification scheme of assembly line balancing. Urban[6] in his study in 1998, presents an integer programming formulation for determining the optimal balance for the U-line line balancing problem. It is shown that this model can optimally solve larger problems than previously reported. Lapierre *et al*.[7] in their study in 2004, presents a case study where a practical balancing problem for an assembly line of appliances with two sides and two different heights is solved with an enhanced priority based heuristic. Bartholdi described the design and use of a computer program to balance two sided assembly lines in his study. The program embodies a balancing algorithm that emphasizes speed over accuracy for the interactive, rapid refinement of solutions[8]. Miralles *et al*. presented an assembly line implementation where only certain workers were capable of assembling the entire product. Their study addresses how the impact of a Universal Design philosophy applied to workplace design to provide jobs to a greater number of disabled, resulting in lower unemployment rates with relatively low investment[9]. Ramezanian and Khalesi[10] addressed the problem of integration of multi-product Supply Chain Network design and assembly line balancing in their study. They proposed a non-linear programming model. Akyol and Baykasoğlu proposed a new type of assembly line worker assignment and balancing problem which considers ergonomic risks. The problem was solved with the multiple-rule based constructive randomized search approach. Also, Occupational Repetitive Action method was used for making ergonomic risk assessment[11]. Wang *et al*.[12] established an evaluation system of partial disassembly line to balance environmental impacts and economic benefits. To obtain satisfactory disassembly schemes, a new multi objective genetic simulated annealing algorithm was proposed. A novel particle swarm optimization algorithm was proposed to solve the U-line balancing problem with stochastic task times in Aydoğan *et al*.[13]. A computational study was conducted to compare the performance of the proposed approach to the existing methods in the literature. Pearce *et* *al*.[14] presented a complex line balancing problem based on the real production environment, featuring several extensions for task-to-task relationships, station characteristics limiting assignment, and parallel worker zoning interactions. A heuristic and an integer program were proposed. Nourmohammadi *et al*.[15] studied on the assembly line balancing and supermarket location problem as two long-term interrelated decision problems considering the stochastic nature of the task times and demands. A hierarchical mathematical programming model consisting of two levels was developed in their study.

# 3. Applications in the firm

This study was applied in an automotive sector for a firm which is producing wiring harness. The lean manufacturing tools used by the firm are: 5S, kaizen, kanban, 6 sigma, line balancing *etc*.

In this study, applications of a line balancing studies were given. Line balancing is one of the most effective tools used to reduce costs and increase production efficiency in the system. There are different processes producing the same product in the shop-floor. Line1 makes overproduction and uses more labor force than it needs. Line2 works overtime due to the fact that it can't realize its aim of hourly production quantity. The target value of the production for both processes is 16 units per hour. Each employee has a minimum monthly fee of 1800 ₺ (Turkish Liras).

In the process while line balancing was being carried out, some performance measures such as loss of balance, smoothness index and line efficiency were calculated. Loss of balance (BL) is the ratio between workstation leisure time and cycle time (C). BL can be calculated as Eq.(1):

BL: Loss of balance

C: Cycle time

$C_{avg}$: Average cycle time

$$BL\ (\%) = [(C - C_{avg}) / C\ ] * 100 \qquad \text{Eq.(1)}$$

Smoothness index (SI) indicates the regularity of the processing times of the workstations in the assembly line. The low smoothness index indicates a good balance on the line. SI can be calculated as Eq.(2):

SI: Smoothness index

$C_{max}$: Maximum cycle time

$C_i$: Cycle time of workstation i

N: Total number of stations

$$SI(\%) = [(\sqrt{\sum (Cmax - Ci)^2}) / (N * C)] * 10 \qquad \text{Eq.(2)}$$

Line efficiency (LE) is the ratio of efficient time to total time and it can be calculated as Eq.(3).

LE: Line efficiency

$$LE(\%) = [\sum_{i=1}^{N} Ci\ /\ (\ N * C)] * 100 \qquad \text{Eq.(3)}$$

In line balancing process, the Longest Operation Time Method was used. This method accounts for work elements to be arranged in a descending order (with reference to the station time and work elements) to each station value which is not exceeding the allowable preceded[16]. The steps of Longest Operation Time Method are given as following[17]:

Step 1. Work components are ranked according to operations times from highest to lowest.

Step 2. Maximum process time is selected in case of the work components have more than one.

Step 3. Assignment is done based on the priority rules and cycle time.

The result of the line balancing problem is given according in Appendix 1. Line1 produces 18.9 units per hour with 9 employees and 3.17 cycle times. In the process, the total standard time was 27.78 minutes and it was seen that hourly 16 units could be produced with 8 employees. It can be seen that both labor costs were reduced and overproduction was eliminated by line balancing approach. **Table 1** and **Table 2** show the situations before and after line balancing of Line1.

| | |
|---|---|
| **Number of stations** | 9 |
| **C(Cycle time)(min)** | 3.17 |
| **Cavg (Average cycle time) (min)** | 3.09 |
| **Loss of balance** | 2.6% |
| **Smoothness index** | 1.1% |
| **Line efficiency** | 97.4% |
| **Hourly production (units)** | 18.9 |

**Table 1**. Line1 before Line Balancing

| | |
|---|---|
| **Number of stations** | 8 |
| **C(Cycle)(min)** | 3.56 |
| **Cavg (Average cycle time) (min)** | 3.47 |
| **Loss of balance** | 2.4% |
| **Smoothness index** | 1.0% |
| **Line efficiency** | 97.6% |
| **Hourly production (units)** | 16.9 |

**Table 2**. Line1 after Line Balancing

After balancing, 0.2% improvement in balance loss, 0.1% improvement in smoothness index and 0.2% improvement in line efficiency were observed. The pre-balancing and post-balancing yamazumi diagrams of Line1 are given in **Figure 1** and **Figure 2.**

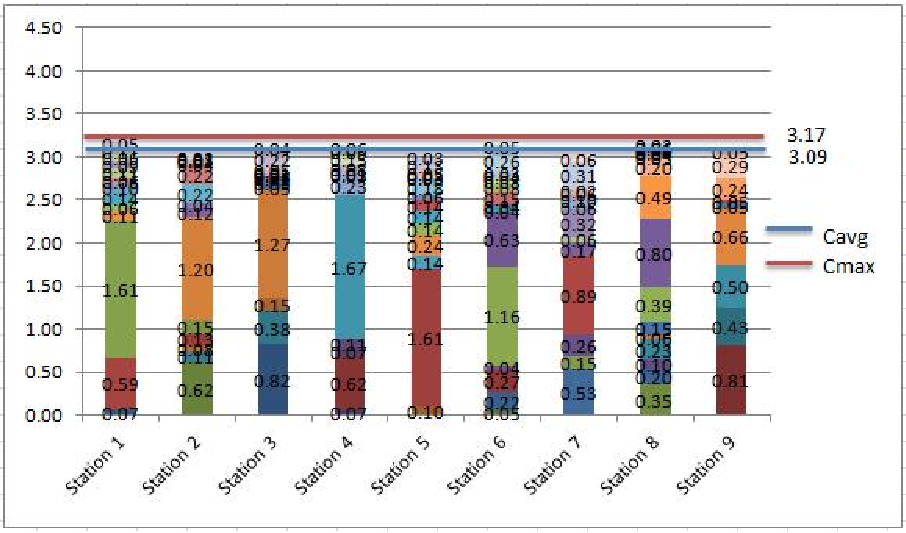


**Figure 1.** Line1 before Line Balancing

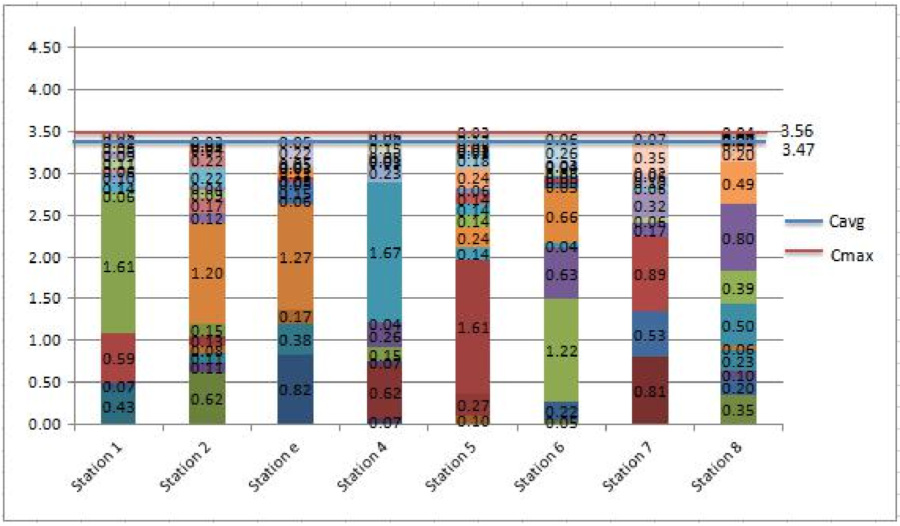


**Figure 2.** Line1 after Line Balancing

**Table 3** shows the annual earning after line balancing.

| | |
|---|---|
| **The minimum monthly fee of an employee (₺-Turkish Liras)** | 1800.0 |
| **The earning from annual employee cost (₺)** | 21600.0 |

**Table 3**. The earning from annual employee cost (₺)

The purpose of work for Line2 is to realize the target number of production unit per hour. There are 23 employees in the process, where the total standard time is 86.03 minutes. Before the balancing process, the cycle time is 4.42 minutes and 13.6 units of wiring harness can be produced per hour. The required unit of production has been reached with the line balancing of Line2, which has 16 units of hourly production target. **Table 4** and **Table 5** show the situations before and after line balancing of Line2.

| | |
|---|---|
| **Number of stations** | 23 |
| **C(Cycle time)(min)** | 4.42 |
| **Cavg (Average cycle time) (min)** | 3.74 |
| **Loss of balance** | 13.2% |
| **Smoothness index** | 3.6% |
| **Line efficiency** | 86.8% |
| **Hourly production (units)** | 13.6 |

**Table 4**. Line2 data before Line Balancing

| | |
|---|---|
| **Number of stations** | 23 |
| **C(Cycle time)(min)** | 3.75 |
| **Cavg (Average cycle time) (min)** | 3.74 |
| **Loss of balance** | 0.4% |
| **Smoothness index** | 0.1% |
| **Line efficiency** | 99.6% |
| **Hourly production (units)** | 16.0 |

**Table 5**. Line2 data after Line Balancing

Hourly production quantity was realized by line balancing. After balancing, 12.8% improvement in balance loss, 3.5% improvement in smoothness index and 12.8% improvement in line efficiency were observed. The pre-balancing and post-balancing yamazumi diagrams of Line2 are given in **Figure 3** and **Figure 4.**

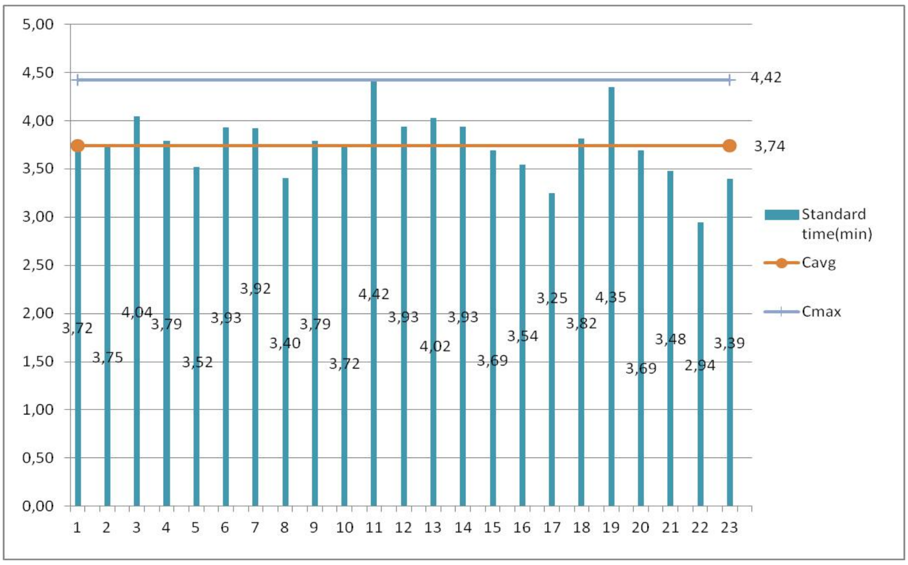


**Figure 3.** Line2 before Line Balancing

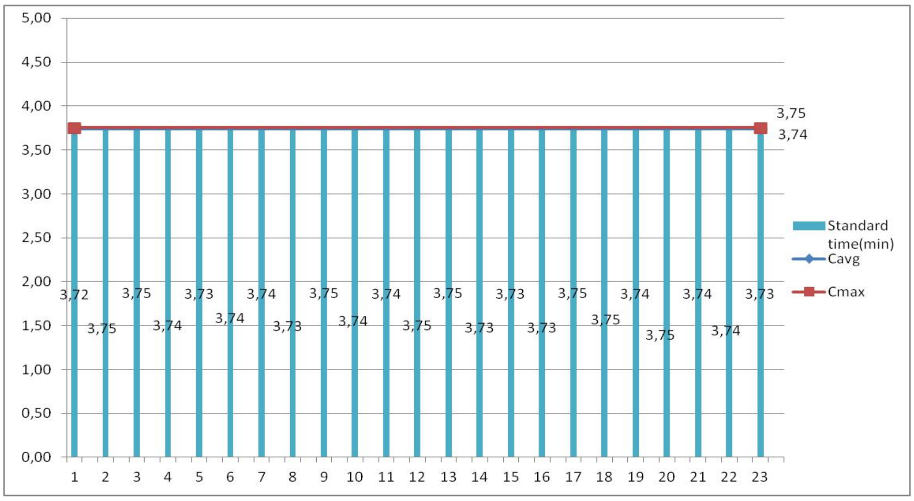


**Figure 4.** Line2 after Line Balancing

The annual earning of the Line2 based on line balancing is given in **Table 6**.

| | |
|---|---|
| **Hourly production increase (units)** | 2.4 |
| **Daily production increase (units)** | 19.2 |
| **Annual production increase (units)** | 5529.6 |
| **Standard time (min)** | 86.03 |
| **Time required for annual production (min)** | 475711.5 |
| **Annual duration of an operator (min)** | 21120 |
| **Number of employees earned per year (units)** | 22.5 |
| **The minimum monthly fee of an employee (₺)** | 1800.0 |
| **The earning from annual employee cost (₺)** | 40543.6 |

**Table 6**. The annual earning of Line 2 (₺)

As a result of the study, it can be seen that the use of labor becomes more efficient by line balancing and the other kaizen applications. The holding costs were decreased by eliminating the unnecessary production and rework durations.

Employees can work in equal conditions and this makes them feel in confidence and calm in their firm. On the other hand, the overtime productions were also decreased and consequently costs were decreased.

All these applications are the start points of the lean manufacturing adaptation process in the firm. The whole system should be adapted to the lean manufacturing system with all employees and then the lean accounting become actually lean.

# 4. Conclusions and suggestions

Lean manufacturing guru Taiichi Ohno thought that costs do not exist to be calculated, costs exist to be reduced. Calculations should be made but the results are also required to achieve the goal. Then effective approaches can be used in the system to analyze, evaluate and solve the problems. Lean manufacturing system tries to eliminate wastes and causes reduction in the costs of the products and services. Also, lean accounting can be thought as lean and it can be result as profit. In addition, it can be said that lean manufacturing systems can achieve lower costs, higher quality and shorter lead times.

In this study, a line balancing approach was analyzed and its contributions were described as a part of lean manufacturing and lean accounting system. The other lean manufacturing applications can be analyzed in the future studies. The firm has been in an adaptation process of lean manufacturing system and the improvements of the studies can be also achieved in the future. The customers only want to take and pay the value that they define, so the systems should be lean in the competitive environment.

# Acknowledgments

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# Appendix

| Stations | Assigned Work Components | Operation Times (min.) | Task Precedence Relations | Total Work Time in Stations (min) | Stations | Assigned Work Components | Operation Times (min.) | Task Precedence Relations | Total Work Time in Stations (min) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0,06 | - | 3,49 | 5 | 36 | 0,14 | - | 3,50 |
| | 2 | 0,06 | - | | | 37 | 0,14 | - | |
| | 3 | 0,11 | - | | | 39 | 0,14 | - | |
| | 4 | 0,07 | - | | | 40 | 0,10 | - | |
| | 6 | 0,14 | - | | | 41 | 0,18 | - | |
| | 7 | 0,10 | - | | | 38 | 1,61 | 36,37,39,40,41 | |
| | 8 | 0,09 | - | | | 42 | 0,06 | - | |
| | 9 | 1,61 | 1,2,3,4,6,7,8 | | | 43 | 0,14 | - | |
| | 10 | 0,59 | - | | | 44 | 0,24 | 43 | |
| | 78 | 0,43 | - | | | 75 | 0,24 | - | |
| | 82 | 0,05 | - | | | 49 | 0,27 | - | |
| | 83 | 0,11 | - | | | 98 | 0,03 | - | |
| | 84 | 0,06 | - | | | 99 | 0,13 | - | |
| 2 | 11 | 1,20 | - | 3,39 | | 100 | 0,03 | - | |
| | 12 | 0,22 | - | | | 101 | 0,03 | - | |
| | 13 | 0,62 | - | | | 102 | 0,05 | - | |
| | 14 | 0,22 | - | | 6 | 45 | 0,05 | - | 3,44 |

| | | | | |
|---|---|---|---|---|
| | 15 | 0,15 | - | |
| | 16 | 0,13 | 15 | |
| | 19 | 0,04 | - | |
| | 20 | 0,04 | - | |
| | 21 | 0,12 | - | |
| | 35 | 0,11 | - | |
| | 17 | 0,11 | - | |
| | 18 | 0,08 | - | |
| | 52 | 0,17 | - | |
| | 53 | 0,09 | - | |
| | 85 | 0,03 | - | |
| | 86 | 0,01 | - | |
| | 87 | 0,03 | - | |
| 3 | 22 | 0,38 | - | 3,41 |
| | 23 | 0,17 | - | |
| | 24 | 0,05 | - | |
| | 72 | 0,15 | - | |
| | 26 | 0,06 | - | |
| | 27 | 0,05 | - | |
| | 25 | 1,27 | 23,24,72,26,27 | |
| | 5 | 0,11 | - | |
| | 28 | 0,82 | 15,16 | |
| | 88 | 0,05 | - | |
| | 89 | 0,22 | - | |
| | 90 | 0,01 | - | |
| | 91 | 0,03 | - | |
| | 92 | 0,05 | - | |
| 4 | 29 | 1,67 | 11,12,21,35,17,18,52,30 | 3,48 |
| | 30 | 0,07 | - | |
| | 32 | 0,07 | - | |
| | 31 | 0,62 | 32 | |
| | 33 | 0,23 | - | |
| | 34 | 0,06 | - | |
| | 63 | 0,26 | - | |
| | 64 | 0,15 | 63 | |
| | 54 | 0,04 | - | |
| | 93 | 0,04 | - | |
| | 94 | 0,15 | - | |
| | 95 | 0,01 | - | |
| | 96 | 0,03 | - | |
| | 97 | 0,08 | - | |

| | | | | |
|---|---|---|---|---|
| | 46 | 0,05 | - | |
| | 48 | 0,04 | - | |
| | 47 | 1,22 | 45,46,48 | |
| | 50 | 0,22 | - | |
| | 51 | 0,63 | - | |
| | 79 | 0,05 | - | |
| | 80 | 0,05 | - | |
| | 81 | 0,66 | 79,80 | |
| | 103 | 0,06 | - | |
| | 104 | 0,26 | - | |
| | 105 | 0,04 | - | |
| | 106 | 0,08 | - | |
| | 107 | 0,03 | - | |
| 7 | 57 | 0,53 | - | 3,45 |
| | 59 | 0,17 | - | |
| | 58 | 0,89 | 59 | |
| | 60 | 0,06 | - | |
| | 61 | 0,06 | - | |
| | 62 | 0,32 | 60,61 | |
| | 76 | 0,81 | - | |
| | 108 | 0,07 | - | |
| | 109 | 0,35 | - | |
| | 110 | 0,06 | - | |
| | 111 | 0,10 | - | |
| | 112 | 0,02 | - | |
| 8 | 65 | 0,10 | - | 3,56 |
| | 67 | 0,06 | - | |
| | 66 | 0,23 | 65,67 | |
| | 68 | 0,39 | - | |
| | 69 | 0,80 | - | |
| | 70 | 0,35 | - | |
| | 71 | 0,54 | - | |
| | 73 | 0,20 | - | |
| | 77 | 0,50 | - | |
| | 74 | 0,20 | - | |
| | 113 | 0,04 | - | |
| | 114 | 0,06 | - | |
| | 115 | 0,04 | - | |
| | 116 | 0,05 | - | |
| | 117 | 0,00 | - | |

**Appendix 1.** Result of line balancing process

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