Application of Failure Mode Effect Analysis (FMEA) for Efficient and Cost-Effective Manufacturing: A Case Study at Bahir Dar Textile Share Company, Ethiopia

Tsehaye Dedimas [a,*], Sisay G. Gebeyehu [a]

[a] *Faculty of Mechanical and Industrial Engineering, Bahir Dar Institute of Technology, Bahir Dar University, Bahir Dar, Ethiopia*

Abstract

The aim of this paper is to show the application of Failure Mode Effect Analysis (FMEA) for efficient and cost-effective manufacturing. Companies need better economic gains from enhanced production, but downtime affects this paradigm. Bair Dar Textile Share Company (BDTSC) is no exception. The looming section of the case company faces on average 38.69% of downtime from the total production time which highly affects its production performance, and thus profitability. The research tries to show the economic gain from the reduced high downtime in the case company by taking the advantages of Failure Mode Effect Analysis (FMEA). As a result FMEA, failure modes, cause, and their effects on the specific section of the company were identified and prioritized using their Risk Priority Numbers (RPN). By taking the FMEA on the looming process machines and focusing on the vital few 20% causes of the identified failure modes, the findings of the research show that the company can decrease the total downtime from its 178 loom machines by 299.04hrs/day. As a result, the company can save downtime that can produce 1,672.82 meters of fabric/cloth and enhance its performance by 4.18%. This downtime reduction in turn results in a daily profit of 38,220.56 ETB(Ethiopian Birr) or 11,466,168.00 ETB annually.

1. Introduction

It is long years ago that manufacturing firms were in search of a method to identify every possible failure during a process and developed FMEA (Mhetre and et.al, 2012). It is a step by step and systematic process for identifying potential failures before they occur, with the aim to eliminate or minimize the risk associated with the failures identified (Mhetre et.al, 2012, Ambekar and et.al, 2013). Carl S. Carlson (2012) also articulated an advice that FMEA should be the guide to the development of a complete set of actions that will reduce risk associated with the system, subsystem, and component or manufacturing/assembly process to an acceptable level.

As one of the core production sections of the company, the weaving section at Bahir Dar Textile Share company experiences very high downtime and this study will focus on the FMEA application in the weaving process line to identify the modes of the failures, their causes and effect and show the economic impact of reducing the high downtime through the application of robust FMEA.

2. Problem Statement

The looming section of Bahir Dar Textile Share Company with 178 loomsis expected to work for 4,272 hours a day. This time is the total sum of machine hours for the 178 loom machines. However, currently it experiences an average downtime of 1,653 hours daily, which is 38.69%

downtime, the section loses a production of 25,012.3 meters/day that can earn a profit of 571,481.03 ETB/day to the company.

3. Objective

The objective of the study is to reduce the downtime of the case company through the application of robust FMEA as a major cost effective tool and to enhance the profitability of the case company.

4. Methodology

The primary data were collected from the case company through observations including recordings, measurements and discussions with line managers and operators. To get relevant secondary data, the documentations of the company, with special focus to weaving section, were critically assessed. Finally, FMEA was applied as a problem solving tool to analyze the collected data. In addition, cause-effect diagram and Pareto analysis were among the supporting analysis methods applied in this research. After FMEA was conducted and tabulated and the failure modes were identified and prioritized, the downtime observation continued with the respective causes of the failure modes on 10 selected general purpose machines. The FMEA conducted according to the procedures depicted in the Figure 1.

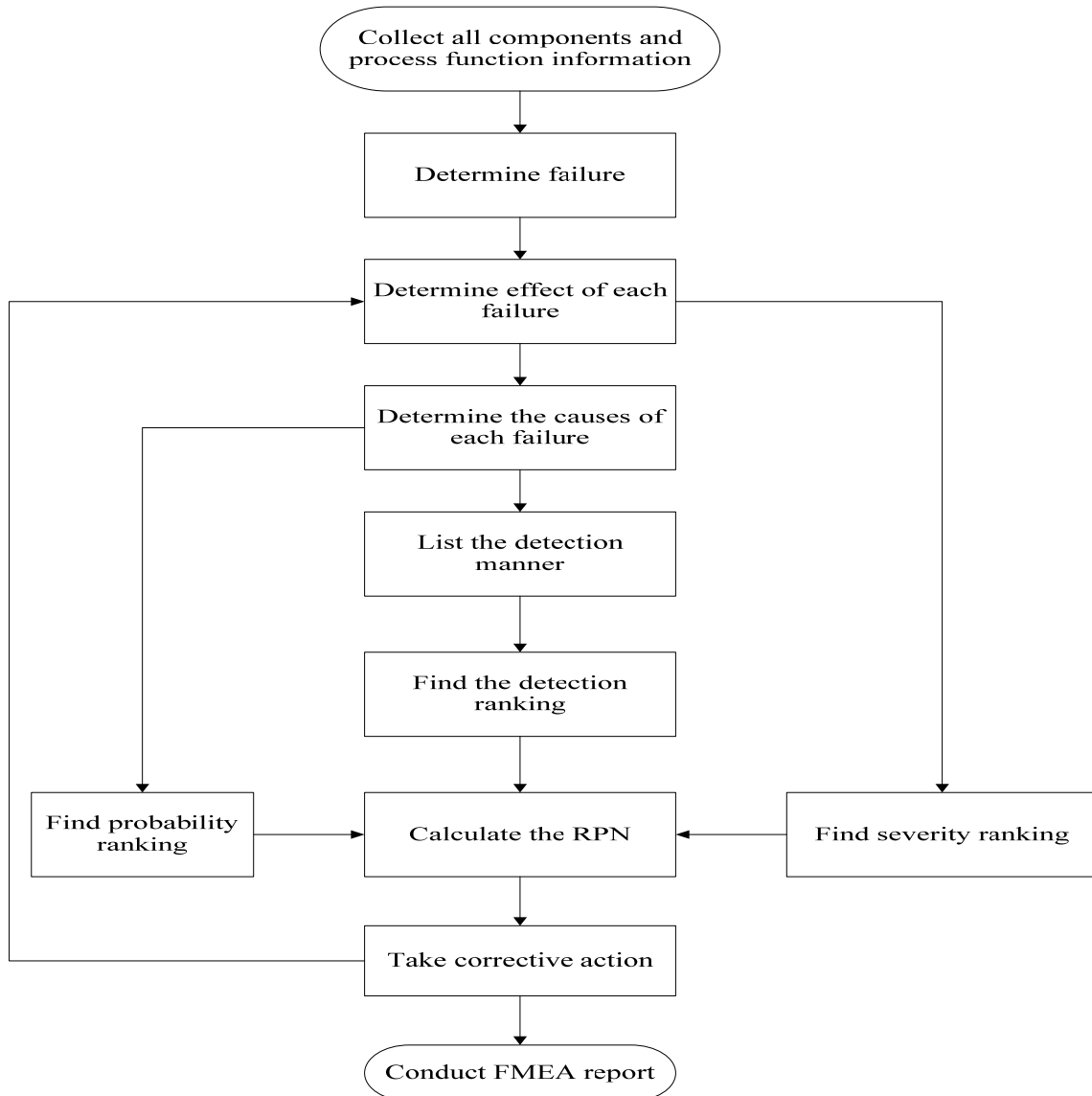*Corresponding author Email address: tsehayezechu@gmail.com

Fig. 1. FMEA procedure (Adopted from Rakesh et al., 2013)

5. Literature Review

The Textile industry is one of the earlier large-scale economic activities that led the industrialization process centuries ago in Ethiopia (FDRE MoI, 2017). Ethiopia's long history in textiles started in the year 1939 when Dire Dawa Textile Factory, the first garment factory in Ethiopia, was established (Alliance Experts, 2017). Presently, the Ethiopian textile industry is the third largest manufacturing industry, next to leather and beverage industries and the main product of the sector is 100% cotton textiles according toa report by the Ethiopian Embassy in China (2017). Based on these facts, the government of the federal democratic republic of Ethiopian has given top priority for the development of the textile sector and considers it to be a strategic sector for export expansion and rapid industrial development (FDRE MoI, 2017).

The Bahir Dar Textile Share Company, one of the oldest textile mills in Ethiopia, is founded in 1961 by the Italian government as a war compensation to Ethiopia. Currently, the company has a total capacity of producing 15 tons of spin fiber, 50,000 meters of fabric, 82,000 meter squares of finished fabric, and 10,000 pairs of garment products.

Production growth of any manufacturing company depends on the efficiency in resource (production factors such as human and capital) use and technical progress, and this efficiency in resource use is referred to as productivity (Kathuria et al., 2013). In a similar way, Chad Syverson (2011) said that productivity is an efficiency with which the input is converted into output giving. Saying this, he gives an insight that the better uses of resources play a great role in the improvement of production which in its turn increases the sales and productivity of companies.

Pekuri (2011), focusing to the reasons of production loss, tried to give an insight that the opposite of productivity can be represented by waste. Waste, of course, is the great concern of the managers for it needs, if not eliminated, to be reduced in order to improve productivity. Phusavat (2013) coined productivity improvement with the minimization of wastes and better competition, and stated that a higher productivity level implies a lower operating cost.

Downtime, one of the causes of the deadly wastes (Grebelius et al. 2011), is among the factors that retard productivity and profitability. Itcan be defined as an event that stops manufacturing processes for a significant length of time and the stop events include machine or equipment failures, raw material shortages and changeover time (Subramaniam et.al, 2009). In other words, downtime is the period which the process is off-line and not producing any products or adding value to the products. It can also be called idle time, downtime, or off line period. It is a common operations and production management key performance indicator (KPI). Production companies obviously aim to reduce the amount of downtime in a production process or at the very least should able to control it to an acceptable level and use it to the manager's advantage (Leanmanufacture.net, 2017).

Several tools can be used to address downtime problems and Failure Mode Effect Analysis (FMEA) one among them. According to Prajapati (2012) and Joshi et al. (2014), FMEA was formally introduced in the late 1940s for military usage by the US Armed Forces. Later, it was used for aerospace/rocket development to avoid errors in small sample sizes of costly rocket technology. FMEA enables the team to design those failures out of the system with the minimum of effort and resource expenditure, thereby reducing development time and costs. Prajapati (2012) widens his vision and tells that FMEA is widely used in manufacturing industries in various phases of the product life cycle and is now increasingly finding use in the service industry too.

The Resource Engineering, Inc. (2015) defined FMEA as a tool that (a) identifies the relative risks designed into a product or a process, (b) initiates an action to reduce those risks with highest potential impact, and (c) tracks the results of the action plan in terms of risk reduction. Moreover, Joshi et.al (2014) gave a detailed definition of FMEA; it is a structured approach to:

- Evaluate a process/product to identify where and how it might fail
- Estimate the risks of specific causes associated with these failures
- Assess impact of these failures
- Minimize the impact and chance of these failures by taking the appropriate actions
- Identify parts/products in systems that majorly call for a change

According to the report of IEEE (2014), minimizing the loss of production performance or performance degradation is among the many objectives of FMEA implementation. Researchers like (Kumar et.al, 2011) also have suggested its implementation as a tool to assure products quality and as a means to improve operational performance of the manufacturing process.Therefore, FMEA is very helpful in identifying and prioritizing recorded failure in relation to their causes and effects.

6. Results And Discussion

The following chart shows the relative downtime vs production loss based on data recorded for three consecutive years (2013/14 to 20115/16). As can be seen, the downtimes in hours recorded in the three years and their effect on the loss of production in meters are proportional.
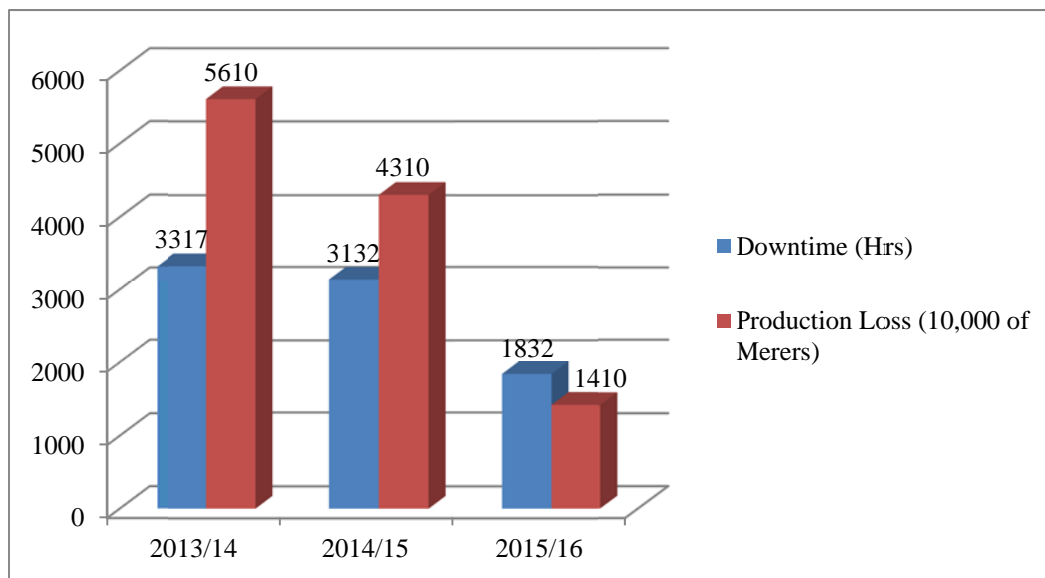

Fig. 2. Downtime vs production loss in the looming subsection

Fig. 2 indicates that with the decrease in the downtime of machiness in the section results in the overall production loss of the company. The resulting loss-curve also lies between the plan and performance curves of the Plan-Performance-Loss curve as can be seen in fig 3.

Hence, the performance of the section is suffering not only being of much lower than the plan but also less than the loss. This condition is intolerable for any production company. A performance less than a plan can be acceptable to some extent, because constraints are always there in the line of production, but a performance much less than a loss is awesome and worthy of urgent solution.
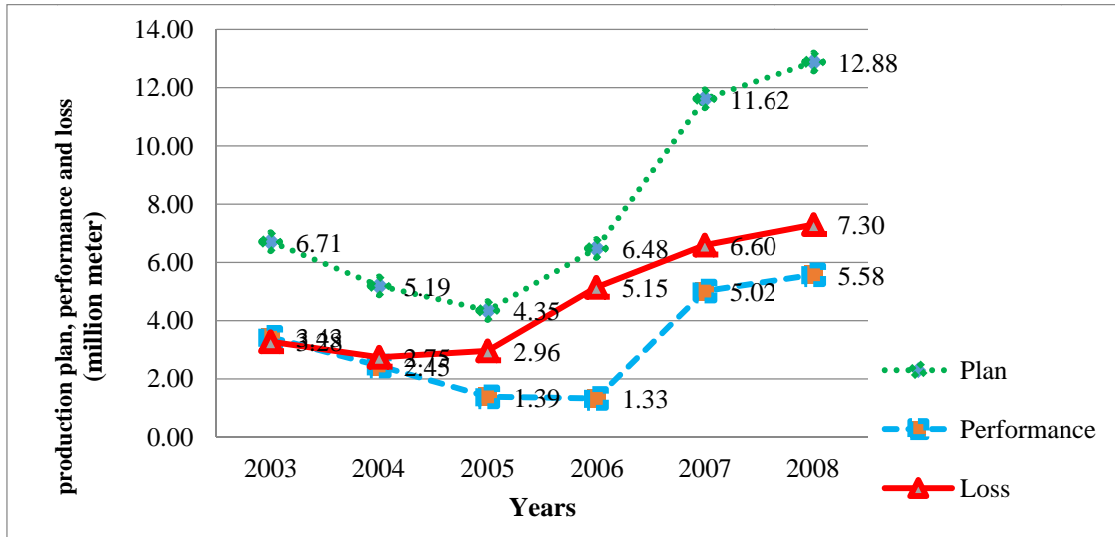

Fig. 3. Production Plan – Performance - Loss curve of the loom subsection

The above result is also validated by actual observation of the looming setion and focusedd group discussions made by the authors experts and line managers. As a result, a

step by step process revission was made before the application of the FMEA tool to reduce the downtime.
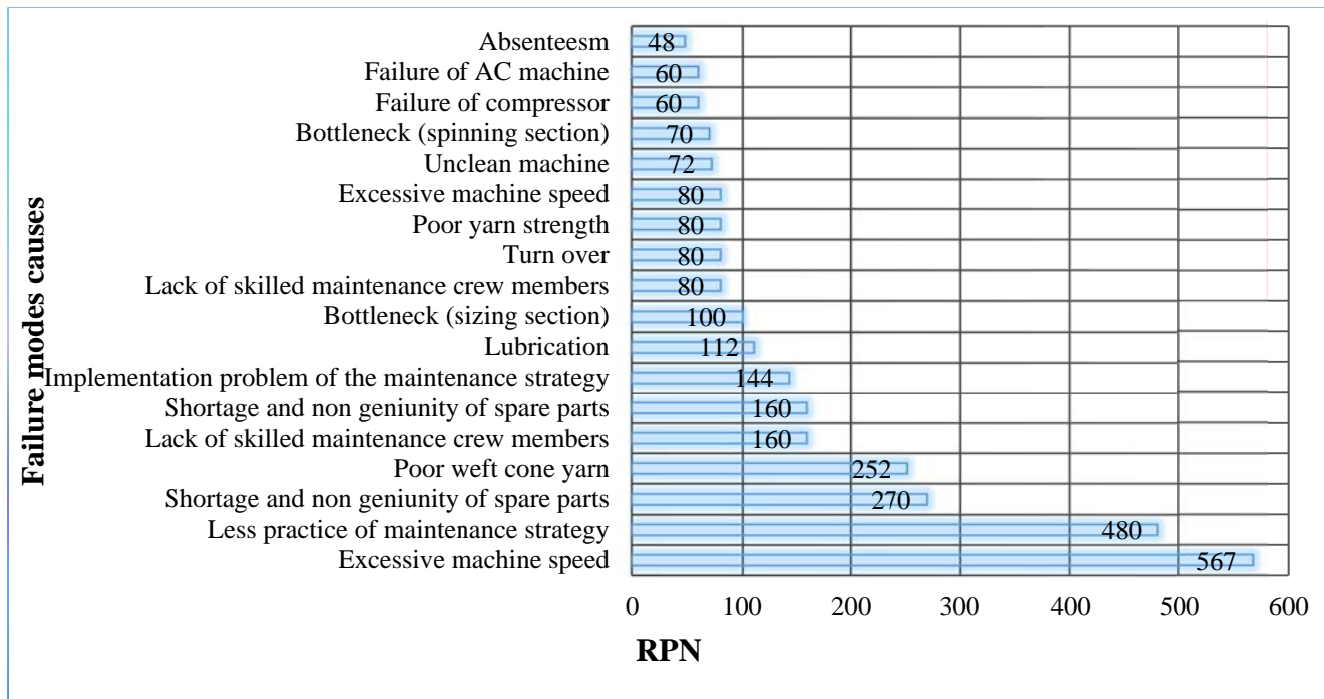

Fig. 4. Graphic Representation of the FMEA Sheet Results (Causes of the failures identified)

Application of FMEA of the Loom Section

In the application of FMEA, the potential failure modes, their respective effects, their potential causes and control mechanisms weree fed in to an FMEA sheet and the RPN is calculated. Then, the results of the FMEA sheet is translated into graphical presentation. However, this representation is only with respect to the causes of the

failure modes. While there are several several causes for a single failure mode, the subsquent alalysis were made based on the causes of the failures. The resulting FMEA templated table result shows that *eighteen potential* causes with *seven potential failure modes* and *four critical effects* were identified in the loom section (Fig. 4 and Table 1).

Table 1
Observations on the four vital causes of failure modes in a single hour

Results of the Observations (Seconds)											
Prioritized Causes	**Obs 1**	**Obs 2**	**Obs 3**	**Obs 4**	**Obs 5**	**Obs 6**	**Obs 7**	**Obs 8**	**Obs 9**	**Obs 10**	**Average DT (hrs)**
Excessive machine speed	62.0	118.0	31.0	56.0	48.0	86.0	73.0	61.0	144.0	29.0	0.02
Less practice of electrical maintenance strategy	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7	0.02
Shortage and non geniunity of electrical spare parts	48.5	48.5	48.5	48.5	48.5	48.5	48.5	48.5	48.5	48.5	0.01
Poor strength of weft cone yarn	33.0	45.0	62.0	101.0	62.0	74.0	51.0	29.0	11.0	85.0	0.02
Total											**0.07**

Source: Authors data recording

As can be seen in Fig. 5 several failure modes and their resepective effects were identified. Moreover, the various

failure modes and their respective contribution to the higher downtime of the section were identified.
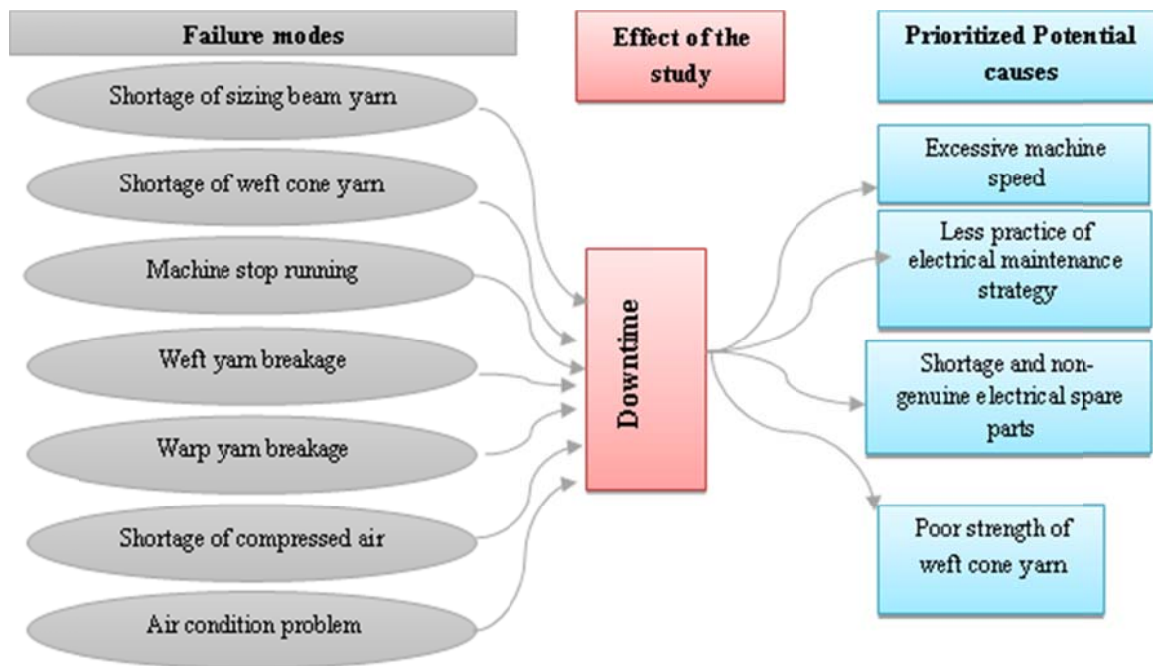

Fig. 5. Failure modes-Effect-Cause diagram for the four prioritized causes

Pareto Analysis

Pareto alalyis of the resulting causes also result in 20% of the causes of the failure modes with high RPNs that contribute more than 50% of the RPN are four, the effect being the downtime of the process.
Further observations of these vital few causes on the loom machines were also made and the results shown in

Table 1. are the downtime hours that can be reduced to the possible minimum with optimized efforts and resources.

Table 2
Production gains and profitability from the reduction of downtime through FMEA implemention

Saved production (m^2)	Unit Cost (ETB)	Total Cost (ETB)	Unit Price (ETB)	Total Sale (ETB)	Unit Profit (ETB)	Total Gross Profit (ETB)
2676.51	26.54	71,034.58	40.82	109,255.14	14.28	38,220.56

7. Production Gains And Cost Effectiveness

With a single machine experiencing 0.07hrs of reducible downtime in a single operation hour on average due to the four vital causes of the identified and prioritized failure modes, it can be translated into the 24hrs working day of the company (three shifts) and results in 1.68 hrs/day (24hrs x 0.07). Therefore, the total downtime that can be reduced from the 178 loom machines is calculated to be 299.04 hrs/day.

Hence, by saving 299.040 hrs/day downtime, the company can produce 1,672.82 meters/day of additional weaved fabric as the production rate of the section is 5.59meters/hr. The average width of the weaving section products is 160centimeter (1.6meter). This reveals that the saved production in m^2 is 1672.82m x 1.6m= 2676.51 m^2. Therefore, by taking the present average unit cost of fabric 26.54 ETB[1] per m^2 of fabric product and present average unit price of fabric 40.82ETB per m^2 of fabric product, the total gross profit can be calculated as indicated in table 2.

Therefore, from the table 2, it is clear that the case company can gain a daily earning of ETB38,220.56 by applying FMEA and taking actions on the 20% vital causes of the failure modes. The resulting annual production gain can also be calculated by simple arithmetic assuming an average production of 300 working days in a year to an 11,466,168.00 ETB.

8. Conclusion

The findings of this paper, show that as a result of the FMEA application in the weaving section of BDTSC, and by taking approparate corrective actions on the 20% of the causes of the failure modes that contribute more than 50% of the RPNs, it is found that the section can gain a gross profit of ETB11,466,168.00 annually. Therefore, the company is recommended to apply FMEA in its several section so as to reduce the high downtime in order to enhance its production performance and maximize its profit and be competitive in the market.

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[1]ETB stands for Ethiopian Birr (1 USD is equivalent to 20 ETB)

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