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An Application of Failure Mode and Effect Analysis on Improving Occupational Health and Safety Process of Marble Factories

Case Study

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Abstract

Marble excavation and processing are the most risky endeavors of the mining industry. Many precautions are taken to determine or prevent occupational accidents. Failure Mode and Effect Analysis (FMEA) is a risk assessment tool that can be easily applied to an occupational health and safety (OHS)-based improvement process. In this paper, marble processing techniques and failure mode effect analysis method were summarized, and a case study was performed in the marble processing plants of Afyonkarahisar, Turkey. The study tried to eliminate or improve primary risks by preparing an improvement program. The theoretical improvement was realized as 50.08% for the first period.

Keywords: Occupational Health and Safety (OHS); Failure Mode and Effect Analysis (FMEA); Risks Analyzes; Process Improvement; Marble Factory.

Introduction

Marble and natural stone companies can be classified into two main groups: quarrying and processing. Quarrying produces marble as blocks by applying many methods. In processing, removed blocks from bedrock are first cut as slabs or strips then sized as tile, countertop, according to customer requirements [1, 2].

Occupational health and safety (OHS) is one of the most important issues throughout the world. Occupational accidents are inevitable due to the economic and social problems in work life, illiteracy, inexperience of workers and irresponsible employers [3]. Furthermore dealing with many uncontrollable parameters until handling natural materials makes mining one of the most hazardous parts of the industry [4]. Serious accidents occur during removing (cutting) the blocks from bedrock, and transporting and installing them. This is caused by the high tonnage due to the density of marbles or natural stones, and the requirement to produce them in blocks [5]. Recurring accidents include falling, crashing, trapping and losing a part of body or life [6-8]. Preventing occupational accidents is an important task of human resource management. Multifactorial interventions can be effective in decreasing occupational accidents [9]. Process analysis and improvement methods can be easily implemented for OHS-based improvement attempts. One of the methods, Failure mode and effect analysis (FMEA) is preferred due to its easiness of practical application and applicability to qualitative assessment [10].

When reviewing existing literature on the topic, there are many studies about FMEA, most of which are focused in product and process improvement. Some of the studies releated to FMEA are listed below;

- Legg, 1978, aimed to apply FMEA method to engineers [11].
- Kara et al., 1992, determined the risk importance [12].
- Gilchrist, 1993, aimed to evaluate the risks as they increase costs and cost analysis methods [13].
- Price, 1996, evaluated the risk generated in thermal systems [14].
- Vandenbrande, 1998, determined and evaluated the

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environmental risks of FMEA [15].

- Yılmaz, 2000, examined the use of FMEA in quality development problems [16].
- Houten& Kımura, 2000, used FMEA in developing imaginary products design and visual inspection system [17].
- Cristiano et al., 2000, studied the quality development model in product management [18].
- Sankar & Prabhu, 2001, ranked the risks according to importance level [19].
- Price & Taylor, 2002, showed how approximate failure rates for components can be used to select the most likely combinations of failures for automated investigation using simulation [20].
- Scipioni et al., 2002, implemented FMEA on increasing operational performance with HACCP in production cycle and integrated an Italian food company [21].
- Baykasoğlu et al., 2003, described a FMEA application which was performed in a mid-sized enterprize in Gaziantep and specified the practical difficulties [22].
- Seung & Kosuke, 2003, studied the application FMEA to cost based production process [23].
- Eryürek & Tanyaş, 2003, have ranked how risks increase the costs with ELECTRE and attempted to reduce them using FMEA [24].
- Erginel, 2004, studied an evaluation of consumer expectations by AHP method and then integrated FMEA [25].
- Teoh & Case, 2004, used FMEA while analyzing knowledge based models and made a software design [26].
- Atmaca & Keskin 2005, searched FMEA applicability with statistical studies to develop quality management systems in the automotive sector [27].
- Kılıç, 2005, examined FMEA as a method for occupational health and safety management systems [28].
- Zapanta et al., 2005, detailed the feasible methods of technology education to develop an ideal and successful process and identified one of them as FMEA [29].
- Casanelli et al., 2006, applied ordinary FMEA during the design phase of an electric motor control system for vehicle HVAC (Heating/Ventilation/Air Conditioning) [30].
- Chin et al., 2009, proposed a FMEA which uses data envelopment analysis (DEA) and measures the maximum and minimum risks of each failure mode [31].
- Chiozza & Ponzetti, 2009, described the main steps of the FMEA process and reviewed data available on the application of this technique to laboratory medicine [32].
- Ersoy, Eleren & Şimşek, 2009, applied FMEA to improve work safety based process in marble quarries of Iscehisar, Turkey [2].
- Eleren & Ersoy, 2011, compared the diamond wire and chain saw machines in marble quarries by using FMEA [33].
- Liu et al., 2012, proposed a fuzzy FMEA based on fuzzy set theory and VIKOR method for prioritization of failure modes, specifically intended to address some limitations of the traditional FMEA [34].
- Sellappan & Palanikumar, 2013, attempted to develop a new RPN prioritization method and evaluated by case studies and statistical analysis techniques [35].
- Çiçek & Çelik, 2013, studied the advantages of the failure modes and effects analysis (FMEA) to adapt innovative marine technologies integrated with the operational aspects in order to prevent crankcase explosion failure on board ships [36].
- Kurt & Özilgen, 2013, applied FMEA for the risk analysis of six dairy products that are widely consumed in Turkey [37].
- Liu et al., 2013, reviewed 75 FMEA papers published between 1992 and 2012 in various international journals [38].

The literature review indicates that there are no studies about the application of FMEA in marble factories. So this study aims to present the improvement process of OHS-based studies for marble processing. First, marble processing techniques and FMEA are summarized, then a case study was performed on the marble processing plants in Afyonkarahisar, Turkey.

Material and Method

The frame of the study was formed as occupational hazards while processing marble, determination of the most risky stages by FMEA and preparing an improvement program.

Marble processing techniques and occupational hazards

Generally, the marble and natural stone blocks with a uniform geometrical shape and greater volume are selected for production slabs in gang saw or multiwire machines. The others with smaller volume and irregular shape are selected for strip or tile production in block cutter machines.

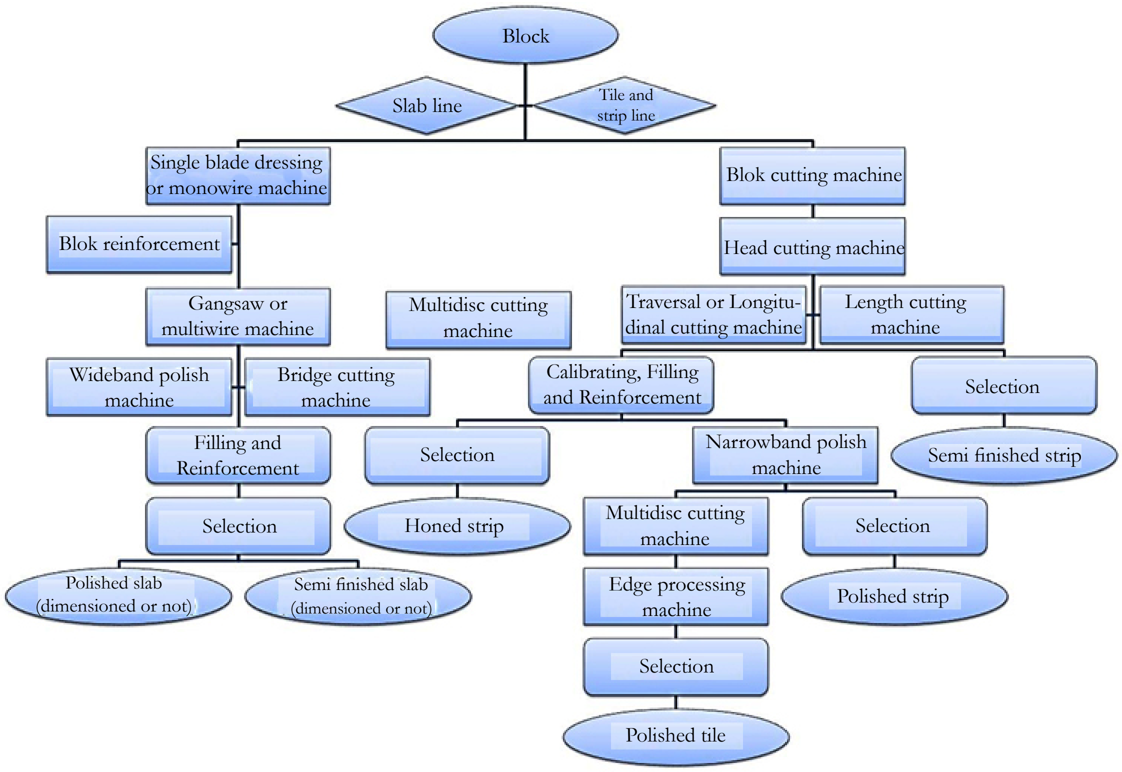
In marble strip production, the blocks are sliced to 2-4 cm thickness with 30-60 cm width using block cutters and lengths are determined by head cutting machine. Some are sent to the market as semi finished strip and the others are proceed to the reinforcement and/or polishing process. The strips can be sold as polished strips after calibrating and polishing by a narrowboat polish machine, or can be taken to the tile production line. At first, the strips selected for tile production are divided into pairs by cutting their thickness to obtain 1-2 cm thickness with a traversal or longitudinal cutting machine. At the tile line, they are filled and reinforced using certain chemicals and sized between 30x30 to 40x40 by a multidisc cutting machine. Then they are taken to the edge processing machine to adjust the borders. Finally the polished tiles ready for sale. Another way to produce tile is by using slabs which are cut by a gang saw machine. The slaps are sized to fit the tile line using bridge cutting or multidisc cutting machines and then taken through the same process.

In marble slab production, the blocks are fixed to trolleys and all surfaces except the bottom are trimmed by single blade dressing or monowire machines. The blocks which have discontunity or cracks are taken to the block reinforcement operation and then they are divided to slabs by agang saw or multiwire cutting machines. At this phase there are four options for slabs. The first one is to sell if as a semi finished product. The second is taking to polish with a wideband polish machine or sizing with a bridge cutting machine and selling as undimensioned polished or honed product. The third is to take to get polished and sized and sell it as a dimensioned polished product. The last is sent it to tile line.

A flow diagram of an ordinary marble factory is given in Figure 1.

At the all stage of the marble prosess, many accident can be occurred. The suddenly appeared occupational accidents can cause physical and psychological damage. The probability and

Figure 1. Flow Diagram of Marble Processing.



severity of accidents can be reduce by examining the process entirely before it happens. However, the perception of people who determine the risks may be different. So the success of determining the risk points and severities depends on the knowledge and experience of the prediction team members. Another factor of analysis is statistical data. Previous accidents and their locations, frequencies and results must be documented [33]. Some of the probable occupational accident risk points and reasons in marble factories are listed below.

Hazards in block and produckt stock areas:

- Untidy stacking the blocks may cause shifting during loading and unloading operations.
- Loading and unloading operations are performed using bridge crane. The operation can be summarized as wrapping the block with steel rope, lifting, and transporting. The block may begin shaking and crash into the surrounding workers due to a fast-moving crane or windy weather.
- The steel rope used in block transportation may break and cause severe ancidents if it is old or faulty.
- Product transpotation is completed by crane or forklifts. A crane is used in closed areas and may cause accidents by crashing into objects or workers. Forklifts are used in both open and closed areas. Forklift transportation may cause accidents when product falls due to overloading or improper loading.
- Not fixing the slabs on palettes in a vertical position may cause them to slide or overturn, and workers standing close get injured by trapp under them.

Hazards in using gangsaw machines:

- A gangsaw machine cuts the blocks with blades and water, so the atmosphere is very humid and dusty. These conditions may cause the respiratory system damages.
- When a gangsaw is running, vibration occurs. Some neurological problems may be observed among workers who experience vibration for a long time.
- The blocks unfixed to trolleys may slide, and the broken slabs can cause damages to the gangsaw machine, i.e. bending the blades.
- The block or machine may be damaged due to some slabs breaking by discontinuites or cracks in the blocks.

Hazards in using blockcutter machines:

- The work area is dusty, noisy and humid. This condition might cause some occupational illness such as deafness, respiratory system damages.
- During the cutting operation, some ruptured pieces may spread around the work area and cause injuries.
- When cutting with the blockcutter, the block is usually not fixed to the trolley because of the low tension between the block and machine. When the cutting operation nears the end, the block slides because of its inadequate weight then the circular saw is skewed.
- Strips that are cut by the blockcutter are manually carried to the head cutting machine by workers. During this action, the ground is wet and slippery. Therefore, the workers may slip and fall.

Hazards in using the dimensioning machines:

- The workers may get an occupational illness because the work area of the dimensioning machines is dusty, noisy and humid.

- Most of the operation is done manually, can cause skeletal problems to the worker.
- Shards of marble may spread around and cause injures during the dimensioning process.
- The careless workers may cut himself.

Hazards in using the polishing machines:

- When polishing, the feeding and taking strips and slabs is performed manually and may cause skeletal damage to workers.
- The rotating parts of the belt conveyor may catch the workers clothes and cause serious accidents.
- The reinforcement operation of blocks, slabs and strips are performed manually using chemicals. The chemicals may cause occupational illness or/and accidents.

Hazards in water purification:

- In the factories which use filterpress for water purification, compressed marble mud (cake) are dropped into a truck standing under the filterpress. Some accidents happen when the trucks maneuver around the areas.
- In the factories used sedimentation pools for purification water, workers can fall into the pool and be drown because of insufficient measures.
- The cleaning of the sedimentation pool is performed manually by workers. If the pool is not completey emptied, the workers may slip, fall or suffocate.
- When the top of the water canals containing dirty water are open, workers may fall or drop somethings into the canal.

The hazards listed above are the most fragment sources of accidents. There are many preventative measures that can be applied. In this study the risk points in marble factories were determined and an improvement program was designed using failure mode and effect analysis method.

Review of Failure Mode and Effect Analysis

The FMEA methodology was developed and implemented for the first time in 1949 by the United States Army [21]. Then first developed as a formal design methodology in the 1960s by the aerospace industry [39], has proven to be a useful and powerful tool in assessing potential failures and preventing them from occurring [19]. FMEA is an analysis technique for defining, identifying and eliminating known and/or potential failures, problems, errors and so on from system, design, process and/or service before they reach the customer [40]. FMEA is an important technique to enhance the reliability and safety of complex systems and is intended to provide information for making risk management decisions. When it is used for a criticality analysis, it is also referred to as failure mode, effects and criticality analysis (FMECA) [34], [38]. FMEA is a systematic process meant for reliability analysis [21, 41], and mainly focuses on failures without outdated over time. Therefore, FMEA repetition during all process stages at all time periods is very important to extract failures.

FMEA implementation stages can be divided into 3 groups as follows: preparation, analysis (system, process, product) and evaluation of outcomes.

An exemplary process of FMEA is applied in the following order:

- Determination of the functions (or system, process stages, product categories)
- Determination of the failures and their possibility (P), severity (S) and detectability (D)
- Calculation of the risk priority numbers (RPN) by multiplying or gathering the possibility, severity and detectability of the failures (RPN=PxSxD).
- Sequencing the risk priority numbers from largest to smallest (RRN).
- Taking the measures to reduce the risks

The risk priority evaluation table given in Table 1, was used to determine the possibility, severity and detectability of failures.

The study is performed on a table and its purpose was not only risk analysis but also further development or improvement of the process. The following components are including the process improvement table;

- Function analysis: The stages and sections of the products or process which will be examined are noted. All stages and sections are defined to show sequentially.
- Risk analysis: Determined failures and risks by calculating and sequencing risk priority numbers.
- Corrective measures: First, measures against the risks are described and the requirements are listed. Then the weights are calculated for each function by dividing quantity of RPN by total RPN to determine the measures and make improving.
- Re-risk analysis: The RPN are re-calculated for the improved process by repeating risk analysis and are compared with the past RPN. In this way, the percentage of improvement or achievement can be calculated.

According to the results of FMEA, the manager tries to eliminate or improve with regards outside factors such as cost, time or labor. A task program is prepared for this purpose and duties are delivered to the improvement team members. The improvement program is cyclical. It aims to reach the perfection through a repeating process for each term or period.

Method

The aim of this study is the idenfication and ranking by priority the failures which threaten occupational health and safety and preparation for process improvement. This study was limited to the accident records of the marble processing factories in Afyonkarahisar province, Turkey, for the last five years (Figure 2). Failure mode and effect analysis method was used in analysing and determining failures.

The FMEA table which is basis of the application was prepared by a decision maker. The main data source was a survey results in the preparation of the table. The survey was conducted with 18 marble processing factories in Afyonkarahisar and consisted of 48 questions related to occupational accidents and illness during marble processing. The averages of the occupational health experts' decisions in these factories were used in FMEA table after completing to integer numbers. These data was studied to identify the process, failures and the solution proposals by determining

Table 1. Suggested ratings for risk priority evaluation [19, 34, 38, 42-49].

Rank	10	9	8	7	6	5	4	3	2	1
Probability (P)	Extremely high: failure almost inevitable	Very high	Repeated failures	High	Moderately high	Moderate	Relatively low	Low	Remote	Nearly impossible
	>= in 2	1 in 3	1 in 8	1 in 20	1 in 80	1 in 400	1 in 2000	1 in 15,000	1 in 150,000	<=1 in 1,500,000
Severity (S)	Hazardous	Serious	Extreme	Major	Significant	Moderate	Low	Minor	Very minor	None
	Failure is hazardous, and occurs without warning. It suspends operation of the system and/or involves noncompliance with government regulations	Failure involves hazardous outcomes and/or noncompliance with government regulations or standards	Product is inoperable with loss of primary function. The system is inoperable	Product performance is severely affected but functions. The system may not operate	Product performance is degraded. Comfort or convince functions may not operate	Moderate effect on product performance. The product requires repair	Small effect on product performance. The product does not require repair	Minor effect on product or system performance	Very minor effect on product or system performance	No effect
Detectability (D)	Absolute uncertainty	Very remote	Remote	Very low	Low	Moderate	Moderately high	High	Very high	Almost certain
	Design control does not detect a potential cause of failure or subsequent failure mode or there is no design control	Very remote chance the design control will detect a potential cause of failure or subsequent failure mode	Remote chance the design control will detect a potential cause of failure or subsequent failure mode	Very low chance the design control will detect a potential cause of failure or subsequent failure mode	Low chance the design control will detect a potential cause of failure or subsequent failure mode	Moderate chance the design control will detect a potential cause of failure or subsequent failure mode	Moderately high chance the design control will detect a potential cause of failure or subsequent failure mode	High chance the design control will detect a potential cause of failure or subsequent failure mode	Very high chance the design control will detect a potential cause of failure or subsequent failure mode	Design control will almost certainly detect a potential cause of failure or subsequent failure mode

Figure 2. Location of Study Area.

the parameters which are used in risk priority number (RPN) calculation, i.e. possibility (P), severity (S), detectability (D).

Application consisted of four stages;

- Identification of the marble processing process and sub-process by function analysis,
- Identification of the risk factors by risk analysis,
- Determination of the possibility, severity, detectability with qualitative values between 1 and 10, then calculation of the risk priority number by multiplying these three values,
- Obtaining the risk ranking of the functions according to their RPN step by step or the proportion in total RPN of the entire process.

Result

Results of FMEA table was given in Appendix 1. According to Appendix 1 the sum of RPN was calculated as 1453 at the beginning of improvement. Improvement aims to decrease the total RPN to minimal level. To reach the goal many methods can be used according to the priorities of factory such as cost, abilities, and legal requirements.

In this paper, the table given in Appendix 1 was evaluated in two methods;

- All failure modes were ranked by their RPN and evaluated from maximum to mininimum (RRN1).
- The proportions of all process failures to total RPN were ranked and evaluated as their importance level (RRN2).

When the first method was used, the study is connecting determine the most important risks and improve the conditions based on their importance levels. In this study, it was seen that the RPN changed between 1 and 162 when all processes were independent evaluated. The "block unloading in block stock area" process was highest with point 162. It was followed by "loading the block to the trolley in the preparation stage of strip cutting" process (144) and "loading the blocks to the trolley in the preparation stage of slab cutting" process (128).

In the second method, the purpose was to determine the weight of main processes risks in total risk weight. The first place at the risk order was "indoor departments" with 27.19%. The "slab sizing and polishing" process followed with 21.20% and the "cutting slabs" process with 15.7%.

The improving stages can be performed as an important base step by step, as stages based stage by stage and as a sub-process base the whole process. It might be impossible to reduce or correct all of the risks in a term due to company abilities, cost or time. In this study, the step by step method was accepted and the first 10 process were selected for improvements for the first period based on their weights and company abilities such as cost and time. During the selection, similar processes under the others with lower risk weights were grouped and added to the first improvement period. The causes of accident risks, planned measures and obtained gains after the improvement period are listed in Table 2.

The selected and determined risks given in Table 2 and Table 3 constitute the first period of the improvement program. In this stage, the theorical improvement rate can be calculated by dividing "total RPN after improvement" by "total RPN before improvement". According to this study, the theoretical improvement was realized as ([1453-715]/1453) 50.08% for the first period.

The risk sequencing, risk prority numbers, and improvement rates at before and after the improvement period for the most risky 10 points are given in Table 3.

Table 2. The Reasons of Accidents, Measures and Gains.

Nr.	Accidents	Reasons	Measures	Gains
2	Falling due to slipping or catching on something. Collision to a moving objects, forklift, product moved by crane, etc.	Use of the same paths by workers and moving objects. Narrow pathways. Failed to perceive moving objects by workers. Employment of non-experienced workers.	Separating the paths used by workers and moving objects. Drawing in different colors the vehicle and crane tracks. Installing audible and visual warnings systems. Widening the pathways. Giving in-service training to the vehicle and crane operators.	The workers and moving objects do not interfere with each other. The moving areas of workers and moving objects are limited. The hazard can be noticed Maneuvering is easier. The employee's abilities improve. Prevention of the possible contact between workers and moving objects and elimination of possible crashes.
10	Collision with moving or stationary objects. Being stuck between two objects.	Breakage or slippage of the steel rope due to incorrect placement. Crane's faults.	Replacement of old and damaged steel rope. Establishing a team responsible for only loading, unloading and transporting.	Ropes are less likely to rupture More experienced team is less likely to have an accident. Preventing the possible breaking and slipping of the steel rope.
11	Collision with stationary objects. Entrapment between two objects. Punched or cut by an object.	Remaining of some workers at unsafe distances. Trolley faults.	Build a safe line around the work area during loading and fixing block to trolley. More frequent trolley maintenance	The workers out of safe line can not be involved in accidents. The trolley faults are reduce.
13	Punched or cut by an object.	Employment of inexperienced worker assembling the blade. Block cutter faults.	Giving in-service training to the montage team. More frequent maintenance to the block cutter.	The blade assemblies are more correct. The block cutter faults will reduce.
14	Collision with moving objects. Falling due to slipping or catching on something. Entrapment between two objects. Punched or cut by an object.	The distance of machine and blocks. Trolley faults. Tidiness around the machine.	Re-design of the block stock area in regarding to the distance of block and machine. Cleaning and tidying around the machine after cutting process.	The possible accidents are reduced by decreasing the transportation distance. Accidents such as falling by slipping or ataching are reduced by cleaning and tidying.
22	Falling due to slipping or catching on something. Punched or cut by an object. Demage to the muscler and skeletal systems due to constant use.	Wet and fractured strips on the production line. Lack of workers due to the production speed. Not using the automatic or robotic systems.	Removing the fractured strips before feeding into the line. Using non-slip gloves. Drying the strips by ventilation. Increasing the amount of workers. Using automatic machines for unloading and stowing.	Preventing accidents by breaking or slipping of the strips during unloading and stowing. The mistakes due to tiredness or boredom are reduced.
32	Falling of lose pieces.	Boxes falling on worker. Mistakes in packing. Unfeasible boxes. Manual loading.	Constracting of boxes more stable materials. Giving in-service training to the packing department. Using a forklift or crane for loading.	Accidents caused by boxes and packing are reduce. Forklift use prevents worker mistakes.
33	Punched or cut by an object.	Unfeasible tools assisted to montage operation. Inexperienced workers.	Using feasible tools in montage. Giving in-service training to the montage team. Using video record system to monitor during the checking and cutting operation.	Modernization of tools and video monitoring reduces the accidents caused by workers.
34	Collision with moving objects. Falling due to slipping or catching on something. Entrapment between two objects. Punched or cut by an object.	Distance of gangsaw and blocks. Trolley faults. Tidiness around the machine. Wrong fixing block to the trolley.	Re-design of the block stock area in regards to the distance of the blocks and machines. Cleaning and tidying around the machine after the cutting process. Reinforcing the contact points of the blocks and the trolley.	The possible accidents are reduced by decreasing the transportation distance. Accidents such as falling by slipping or ataching are reduced by cleaning and tidying. Block moving is prevented.
48	Collision with moving objects. Falling due to slipping or catching on something. Entrapment between two objects. Falling of lose pieces.	Loading slabs manually.	Using a crane with remote control or robotics systems while loading.	A crane with remote control or robotics systems protects the workers from possible accidents.

Table 3. The Risk Levels of before and after Improvement.

Nr.	Section	Process	Sub-Process	Before improvement						After improvement					
				P	S	D	RPN	RPN%	RRN	P	S	D	RPN	RPN%	RRN
2	Department of factory	Transporting	Roads indoors	1	6	9	54	3.72%	8	1	3	2	6	0.84%	33
10		Block stock area	Unloading the block	2	9	9	162	11.15%	1	1	5	3	15	2.10%	21
11			Loading and/or fixing block to trolley	2	6	9	108	7.43%	4	1	6	4	24	3.36%	8
13	Strip cutting by block cutter	Preparation	Assembling blade to the block cutter, calibration, control	1	6	8	48	3.30%	10	1	4	5	20	2.80%	11
14			Feeding block to the block cutter	2	8	9	144	9.91%	2	1	6	3	18	2.52%	13
22	Strip dimensioning, polishing and tile producing	Strip	Unloading and stowing the dimensioned strips	2	4	8	64	4.40%	7	1	4	4	16	2.24%	19
32		Finishing the process	Loading	2	6	6	72	4.96%	6	2	4	3	24	3.36%	9
33	Slab cutting by gangsaw	Preparation	Assembling blade to the gangsaw and checking the tension and stroke	1	6	9	54	3.72%	9	1	3	3	9	1.26%	31
34			Feeding block to the gangsaw	2	8	8	128	8.81%	3	1	6	3	18	2.52%	15
48	Slab dimensioning and polishing	Finishing the process	Loading	2	8	6	96	6.61%	5	1	7	6	42	5.87%	3

* Theoretical improvement rate (1) = 50.08%

Conclusion

The failure mode and effect analysis method can easily be applied to the system for beneficial outcomes during the first stage of product, service, system and process improvement and development.

The provision of occupational health and safety in companies is more important because it increases the value of human life. Furthermore, a company's performance or productivity especially labor productivity can be increased by ensuring occupational health and safety and minimizing, probable accidents and ailments. Thus the companies can also be rid of the negative consequences of accidents fatal or injuries such as ecomic, moral or criminal consequences.

Researchers examined the marble processing process which contains very important risks such as occupational accidents. In order to determine and evaluate the risks, the failure mode and effect analysis method was applied and ten most important risks were selected according to their damages. The first three risks were "block unloading in block stock area" process, "loading block to the trolley in the preparation stage of strip cutting" process, "loading block to the trolley in the preparation stage of slab cutting" process. After that researchers moved to the improvement stage based on occupational health and safety. The measures required for eliminating and reducing of the first ten risks were determined. As a result of the improvement period, the new risk priority numbers and ranks were determined by re-preparing the FMEA table. At the new table, other risks took of priority because the previously important risks were reduced. The theoretical improvement was 50.08% for the first step. Thus, the first period built a background for the next improvement periods.

In this way the marble processing process in marble factories will be safer in regards to occupational health and safety by repeating these periods until all risks are reduced to unimportant levels. As a result of this process, the value of human life, productivity due to less work place accidents, and profitability will increase.

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