

**ÇUKUROVA UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES**

M Sc. THESIS

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**WORLD CLASS MANUFACTURING ON AUTOMOBILE INDUSTRY AND
APPLICATIONS OF AUTONOMOUS MAINTENANCE IN PRESS SHOP**

DEPARTMENT OF MECHANICAL ENGINEERING

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ABSTRACT

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Nowadays international competency is growing fast. In this condition, to be alive the first rule is being a fast runner! To do this, we should follow dynamic structure of this age and we should open for reforms and changes in our work life. Because of that companies have to adapt themselves according to new age technologies and systems, if not, they should be ready to be passed by others. From this reality, Lean Manufacturing system was developed by Toyota. Later from all over the world, so many companies started to implement it. Lean manufacturing with a short explanation is; distinguishing of the waste and value, decreasing or if possible zeroing the waste and making the value more worthy. Autonomous Maintenance (AM) as a subject is one of the most important fundamentals of the application side of lean manufacturing.

In this study, effects of Autonomous Maintenance on the manufacturing productivity have been investigated. It's applications that are the basic of the World Class Manufacturing (WCM) and Total Preventive Maintenance (TPM). So, Firstly WCM system was introduced in this study. Then it replaced by AM applications and it has been studied step by step. In application part, both the effects of the AM applications in working shop and the importance of AM in equipment improvements have been tried to emphasize with the applications realized in Press Production Shop where is from a leader of automotive sector in Turkey.

Key Words: Lean Manufacturing System, Total Preventive Maintenance, Autonomous Maintenance, World Class Manufacturing.

ÖZ

YÜKSEK LİSANS TEZİ

**OTOMOBİL ENDÜSTRİSİNDE DÜNYA KLASINDA ÜRETİM SİSTEMİ VE
OTONOM BAKIM UYGULAMASININ PRES ATÖLYESİNE
UYGULANMASI**

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Günümüzde uluslararası rekabet hızla büyümektedir. Bu rekabet şartlarında var olabilmenin ön koşulu daima en önde koşabilmektir! Bunun için de çağın dinamik yapısına ayak uydurmak, değişiklik ve yeniliklere açık olmak gereklidir. Firmalar bu yüzden yeni sistemleri, teknikleri ve teknolojileri bünyelerine adapte etmek zorundadırlar. Aksi takdirde yarışta gerilerde kalmaya mahkum olurlar. Bu gerçeklerden yola çıkılarak ilk önce Japonya'daki Toyota otomobil fabrikasında uygulanan ve sonraları dünyadaki diğer firmalara da yayılan “Yalın Üretim Sistemi” geliştirilmiştir. Yalın üretim çok kısa bir ifadeyle, üretimde değerle israfın birbirinden ayırt edilmesi, israfın azaltılması, mümkünse yok edilmesi ve bu şekilde de değerlin ön plana çıkartılmasıdır. Yalın üretimin uygulanmasına yönelik temel taşların en önemlilerinden biri de Otonom Bakımdır.

Bu çalışmada Otonom Bakımın ve ekipman iyileştirmelerinin üretim verimliliği üzerindeki etkileri araştırılmıştır. Otonom Bakım Toplam Verimli Bakımın (TVB) ve Dünya Klasında Üretim (DKÜ) Sisteminin temelini oluşturmaktadır. Bundan dolayı bu çalışmada ilk olarak DKÜ sistemi tanıtıldı. Daha sonra Otonom Bakım (OB) uygulamalarına geçildi ve adım adım çalışıldı. Uygulama bölümünde, hem OB uygulamalarının atölyedeki etkileri hem de OB'ın ekipman gelişimindeki önemi Türkiye de otomotiv endüstrisinde lider bir fabrikanın pres üretim biriminde yapılan uygulamalar ile vurgulanmaya çalışılmıştır.

Anahtar Kelimeler: Yalın Üretim Sistemi, Toplam Verimli Bakım, Otonom Bakım, Dünya Klâsında Üretim

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LIST OF ABBREVIATIONS

5w1h	: Who? What? Where? When? Why? How? Techniques
5S	: Seiri-Seiton-Seiso-Seiketzu-Shitzuke Sort Set in Order - Shine –Standardize - Sustain
AM	: Autonomous Maintenance
CD	: Cost Deployment
CIL	: Cleaning, Inspection and Lubrication
ECRS	: Eliminate, Combine, Replace, Simplify
FI	: Focused Improvement
FPS	: Ford Product System
JIPE	: Japanese Institute of Plant Engineers
JIPM	: Japanese Institute of Plant Maintenance
JIT	: Just In Time
KPI	: Key Performance Indicators
MTBF	: Mean Time Between Failures
OEE	: Overall Equipment Effectiveness
OPL	: One Point Lesson
PDCA	: Plan-Do-Check-Act
PM	: Preventive Maintenance (Professional Maintenance)
TIE	: Total Industrial Engineering
TPS	: Toyota Production System
TPM	: Total Productive Maintenance
TQC	: Total Quality Control
WCM	: World Class Manufacturing

1. INTRODUCTION

With globalization all products and brands could be found in domestic and international markets. A lot of models and brands will be chosen by costumers. In addition to this, customers can shop from one country to another via internet. They can find several alternative products. So companies compete with their competitors at the level of global, domestic and imaginary market.

Manufacturing thus becomes a formidable competitive leading edge for the company, providing a major, long lasting contribution to improve customer satisfaction. Manufacturing intends to play a decisive role in maximizing company performance in its competitive priorities such as: quality, price, speed of delivery, flexibility and innovation.

1.1. Production Systems

From history to nowadays lots of systems were used for decreasing the cost, increasing the velocity and flexibility, eliminating the all losses at the machines and increasing the Overall Equipment Effectiveness in their manufacturing systems. These systems have been changed and grown through time and have come up to now these systems have been in the time order as following: Ford Product System (FPS), Just in Time (JIT), Toyota Production System (TPS), World Class Manufacturing (WCM) and ect. Nowadays, many big factories are using at least one of them. Matsui has explained with his time scheduling of the manufacturing systems in Figure 1.1.

According to time scale of those systems beginning about 1910s, Hanry Ford and his right-hand-man, Charles E. Sorensen, fashioned the first comprehensive Manufacturing Strategy. They took all the elements of a manufacturing system people, machines, tooling, and products and arranged them in a continuous system for manufacturing the Model T automobile.

With this new system Hanry Ford was so incredibly successful, he quickly became one of the world's richest men and put the world on wheels. It is even doubtful that Hanry Ford himself fully understood what he had done and why it was

so successful. With time Henry Ford refused to change the system. But the world was changing fast. At the end the Ford system began to break down in the course of time.

For example, Ford Production depended on such a labor force that workers should have sacrificed their dignity and self esteem. The prosperity of the 1920's and the advent of labor unions produced conflict with the Ford system. Product proliferation also put strains on the Ford system. Annual model changes, multiple colors, and options did not fit well in Ford factories.

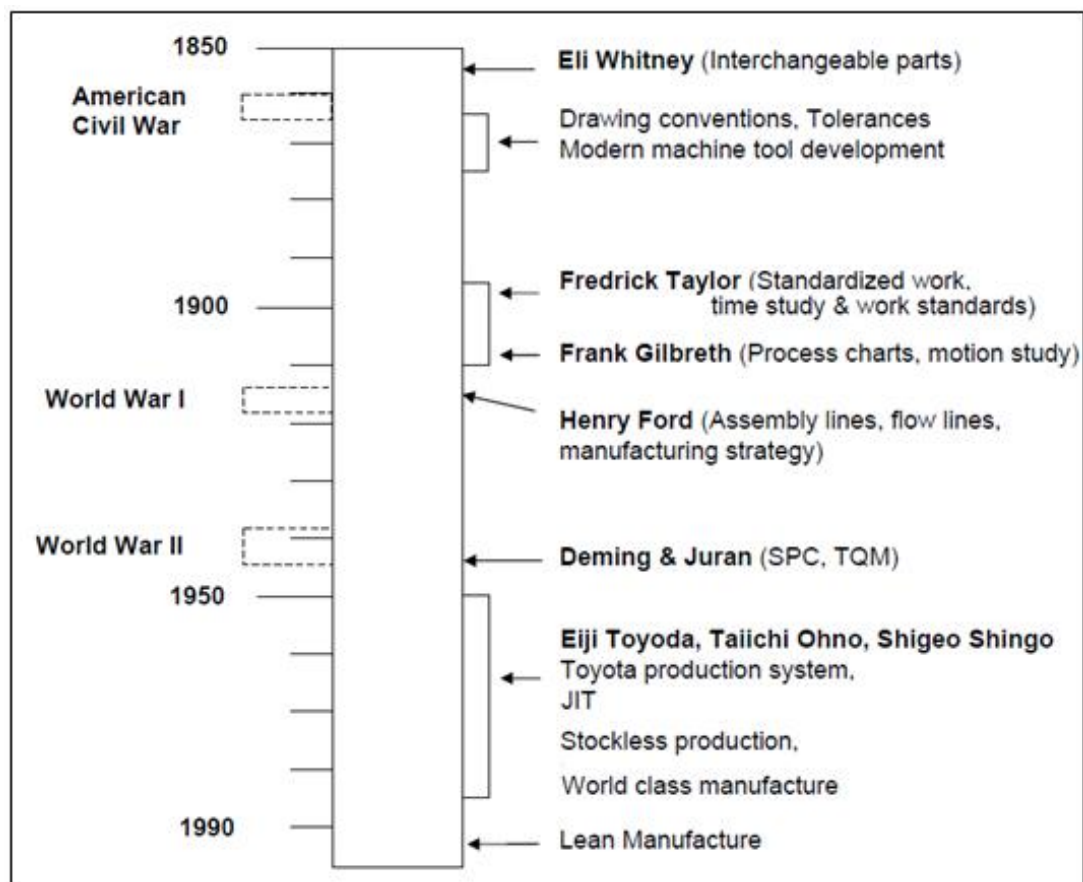


Figure 1.1. Time Scheduling of the Manufacturing Systems (Matsui, 2000)

At General Motors, Alfred P. Sloan took a more pragmatic approach. He developed business and manufacturing strategies for managing very large enterprises and dealing with variety. By the mid 1930's General Motors had passed Ford in domination of the automotive market. Yet, many elements of Ford production were

sound, even in the new age. Ford methods were a deciding factor in the Allied victory of World War II (Matsui, 2000). Nowadays all Ford factories are using the Ford System Method with some TPM's tools supports.

After Second World War, Eiji Toyoda and Taiichi Ohno at the Toyota Motor Company in Japan pioneered the concept of Toyota Production System (TPS). Before they created Toyota Production System, they had visited to Ford factories a few times for benchmarking. They learned flexible production systems from the researches in Ford Factory. They quickly developed it and applied in Toyota factory.

With this application the rise of Japan to its current economic pre-eminence quickly followed, as other companies and industries copied this remarkable system. Manufacturers around the world are now trying to embrace this innovative system, but they are finding the going rough. The companies that first mastered this system were all head-quartered in one country Japan. However, many Western companies now understand Toyota Production System, and at least one is well along the path of introducing it. Superimposing this method on the existing mass-production systems causes great pain and dislocation.

The effort to explain the necessary transition from mass production to revolutionary production is called as Toyota Production System (TPS). Global auto industry has focused on TPS in the course of time. The global adaptation, as it inevitably spreads beyond the auto industry, will change everything in almost every industry-choice of customers, the nature of work, the fortune of companies, and, ultimately, the fate of nations (Matsui, 2000).

The Toyota Production System is also defined as Lean Production in some literature, because it uses less of everything compared with mass production half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time.

The Toyota Production System is a technology of comprehensive production management the Japanese invented a hundred years after opening up to the modern world. The basic idea of this system is to maintain a continuous flow of products in factories in order to flexibly adapt to demand changes. The realization of such production flow is called Just-in-time (JIT) production, which means producing only

necessary units in a necessary quantity at a necessary time. As a result, the excess inventories and the excess work-force will be naturally diminished, thereby achieving the purposes of increased productivity and cost reduction.

The basic principle of JIT production is rational; that is, the Toyota production system has been developed by steadily pursuing the orthodox way of production management. With the realization of this concept, unnecessary intermediate and finished product inventories would be eliminated. However, although cost reduction is the system's most important goal, it must achieve three other sub-goals in order to achieve its primary objective.

TPS includes some important case. First one is quantity control, which enables the system to adapt to daily and monthly fluctuations in demand in terms of quantities and variety. Other one is quality assurance, which assures that each process, will supply only good units to the subsequent processes. Finally there is respect-for-humanity, which must be cultivated while the system utilizes are the human resource to attain its cost objectives.

From the beginning of the 1990's to now World Class Manufacturing (WCM) has focused all employees, waste and losses, standards and methods. WCM is the main subject of this work. Therefore, the detailed information about the fundamental principles and its applications are given in the following sections.

1.2. World Class Manufacturing

World Class Manufacturing production system builds under the four main pillars. These are Workplace Organization, Quality, Maintenance and Logistics. In addition to this, all major pillars are supported with management pillars, international methods and some tools. Ketter's modern World Class Manufacturing model is given in Figure 1.2. Nowadays, lots of automobile factories are using this model.

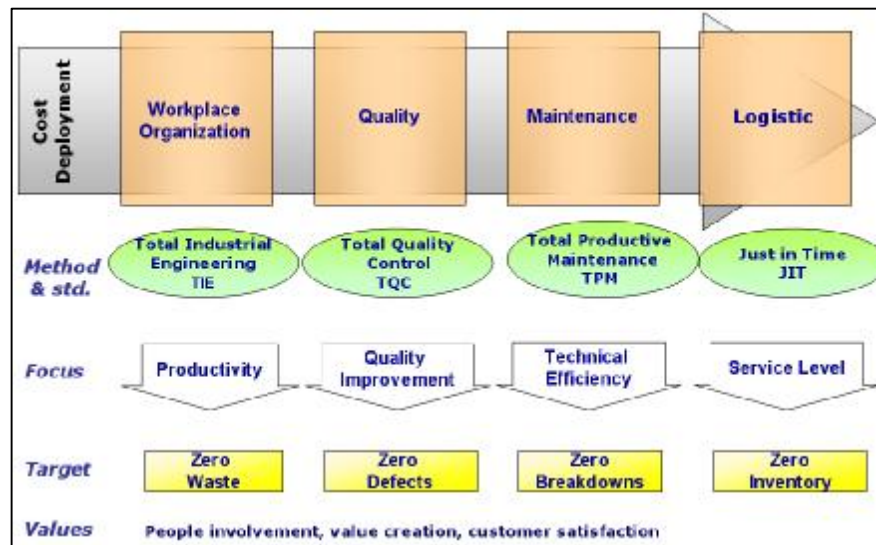


Figure 1.2. World Class Manufacturing Objectives (Ketter, 2006).

Total Industrial Engineering (TIE), raising the employees' performance! Eliminate unnatural operations, disordered motions, works and unvalued processes. Target of TIE is zero waste. Employees are major focus point of WCM. With trainings, all employees' skill matrix rise and they will start to look of problems. They solve all problems fast and continuously. Second big piece of WCM is a description of losses and waste. At the end of the description, the solutions will be immediately found. But for looking of losses and waste, employees must be careful; they must look carefully to their working areas. If positive results are founded at the end of the kaizen (any WCM tools), standards, methods, visual cards, one point lessons, operation card etc are prepared. They will be helped to understand to other people clearly. If same problems are occurred, employees will understand the problem rapidly (Ketter, 2006).

Total Quality Control (TQC), eliminate quality problems from design to all manufacturing levels. Target of TQC is zero defects.

Total Productive Maintenance (TPM), they are muscles of Manufacturing. TPM target is zero breakdowns for continuously manufacturing.

Just in Time (JIT), they are nervous system of factory. Short transport time and JIT's target is zero inventory (Chand and Shirvani, 2000).

All tools yield money. There is a benefit between kaizens and results. This is provided by Cost Deployment Method. In other words WCM encloses all things. So that continuous benefits are provided with practical solutions and systematical approaches.

The level reached by each company is certified by external experts and is achieved through continuous improvement of performance and constant involvement of all levels of the company.

WCM is introduced and deployed top down with the constant commitment of the management, and it is based on the constant, widespread contribution of all those who work at the company (and not consultancy driven). In addition to these, WCM is a way of working (and not a project) and it is reinforced and developed with the involvement of all concerned. It requires some methods, tools, standards and rigorous application of these. WCM results in the setting up of a visible, transparent system and it is effective as it aims to 'keep it simple'.

An integrated model is that optimizes all production-logistic processes and promotes continuous improvement of essential factors such as quality, productivity, safety, delivery and etc. Application of the system is supported by an Audit System and it is structured according to objectives, achievement of which is measured on the basis of suitable Key Performance Indicators (KPI's).

Principle of WCM;

1. World Class Safety is the foundation of World Class Performance,
2. WCM Leaders have a passion for standards,
3. In a World Class Company, customer voice can be heard in the plant,
4. WCM does not accept losses of any kind (The goal is always Zero: accidents, service & quality defects, inventory, breakdowns),
5. A rigorous application of WCM methods guarantees the elimination of losses,
6. In a World Class plant all abnormalities are immediately visible (Dust & contamination free, tracking, control charts ...),
7. WCM takes place in the workplace, not in the office,
8. WCM is most effectively learnt by practicing the techniques with the plant teams,
9. The power of WCM comes from the involvement of people,

10. World Class companies create the energy of a crisis in the face of continued success (Yamashina, H., 2006.).

The purpose of the WCM is maximizing production system performance in accordance with logistic plans and defined quality objectives through;

1- Improvement of processes,

2- Improvement of product quality,

3-Control and gradual reduction of production costs,

4- Flexibility in meeting market and customer requirements,

5-Involvement and motivation of people who operate on industrial processes (Yamashina, H., 2006).

WCM uses ten methods to achieve the targets. These methods are; 1-Safety, 2-Environment, 3-Customer Service & Logistics, 4-Focused Improvement, 5-Autonomous Maintenance, 6-Professional Maintenance, 7-Early Equipment Management, 8-Quality Control, 9-People Development and lastly is 10- Cost Deployment (Jetley et all and Catalan et all, 2001).

Although all methods (pillars) are managed by different teams and they are working only on these tools in a factory, they are connected with each other. For example maintenance teams are interested in Professional Maintenance (PM) tools but they are supporting to Autonomous Maintenance (AM) groups. And all groups have to implement the rules of safety. Individual development is related with all members of the groups. In addition to this, production operators are using Autonomous Maintenance tool in production line.

Autonomous Maintenance is recognized as a key concept in lean manufacturing and world class manufacturing models. Autonomous Maintenance is a methodology that aims to increase the availability of existing equipments, increase the quality and tidy work place. Also, Overall Equipment Effectiveness increases with AM activities. Autonomous Maintenance is a system that plays major roles just after the beginning. The most important reason is the first three steps of AM which are the beginning maintenance activities.

Autonomous Maintenance aims zero breakdowns and zero defects at machine. Before starting to AM the causes of losses are identified. Primarily they are a matter

of equipment breakdowns. Quality defects are also caused by problems with equipment, especially in an automated plant. Furthermore, equipment is designed, fabricated, installed, operated, and maintained by human beings. From this standpoint, it might be acknowledged that result from human thought patterns and behavior.

Therefore, without dramatic changes in conventional way of thinking, zero breakdowns and zero defects can never be attained. The attitude most acutely required of today's manufacturers is an innovative approaches those products breakthrough countermeasures.

Zero defects have existed traditionally only as a slogan in campaigns promoting quality. It is, nevertheless, impossible to achieve zero defects easily and assuredly in any plant. To paraphrase, one may ask, " Is there some good method applicable to any factory for succeeding regardless of present technical levels and expertise of frontline personal, if everyone from top management to floor workers is sufficiently committed to this goal? " The answer to this question is the seven step Autonomous Maintenance program.

The first stage of AM program consists of Step 1, 2 and 3. It focuses on creating the foundation of AM by establishing proper cleaning, lubrication and inspection of equipment. The AM activities in the first stage are the various remedial actions to restore deteriorated parts in equipment. The major objectives are: "establish basic equipment conditions," and "under stand what autonomous supervision is."

Establish basic equipment conditions means, by concentrating all efforts on cleaning and lubricating, the basic equipment conditions are established. As a result, an adequate system can be organized to maintain concurrent operating condition. From an equipment perspective, it aims at restoring deteriorated parts and preventing forced deterioration.

Understand what autonomous supervision means, the activities just mentioned can never be satisfactorily achieved on the shop floor unless all employees are involved. Throughout these three steps, in the first stage of the program, all personal

involved learn about the Plan, Do, Control, Act, (PDCA) cycle by practice. Operators then can understand that rules must be set by those who must be following the rules.

The second stage of AM consists of two steps: Step 4 and 5. The major activities to be carried out here are an over all category by category inspection and the establishment of operators' routine maintenance system. This stage focuses on achieving a dramatic reduction of breakdowns and minor stoppages, along with training knowledgeable operators through the repetition of education and subsequent practice of inspection. The activities programmed in the second stage are the various remedial actions used to inspect for and restore all minute deteriorated and defective parts in equipment so as to attain zero breakdowns.

The third stage of AM is Step 6 and Step 7. In this stage, work piece flow in shop floor and work place are focused. Operators continuously realize and maintain optimal shop conditions by setting the rules that they must follow.

2. PREVIOUS STUDIES

In order to maximize the effectiveness of equipment throughout its entire life, Total Productive Maintenance which is based primarily on the Productive Maintenance concept imported from the United States, was initiated in 1971 and promoted by the Japan Institute of Plant Maintenance (JIPM). TPM is the foundation of the World Class Manufacturing (WCM). Thereafter, it continued in a relatively small number of factories without achieving remarkable success. In those days, Japanese manufacturers were faced with severe economic challenges caused by a series of oil crises. Therefore, they were searching seriously for effective measures to survive in the marketplace.

In the meantime, a step by step small group activity was begun in the Chuo Spring Company in the late 1970s. In 1981 a prototype of the seven-step program to implement an operator's routine maintenance system on the shop floor was developed in the Tokai Rubber Industries and produced significant benefits. Since then, the number of factories implementing the TPM system has been growing year by year, because the system actually achieves improved operating conditions in existing plants and increases employess' knowledge and skill. TPM concepts have been ewpending continuously with the accumulation of wisdom created on the shop floor (Tajiri and Gotoh, 1995).

Japanese manufacturers, furthermore, faced other serious difficulties in business, such as sudden and frequent change in oil prices and currency exchange rates. Many of them foun an escape from the challenging problems of those trying times thtough the automation of repetitive manual work that was possible by significant progress in microelectronic and computer technologies. Therefore, they have succeeded in maintaining their position in the worldwide marketplace. Under these circumstances, TPM, since the late 1980s, has been rapidly recognized by a growing number of campanies as a highly effective methodology for dealing with matters of not only maintenance, but also plant engineering and product design (McCloud, 1998).

The principle activities of TPM & WCM are organized as ‘pillars’. Depending on the author, the naming and number of the pillars may differ slightly; however, the generally accepted model is based on Nakajima’s eight pillars for TPM as presented in Figure 2.1.

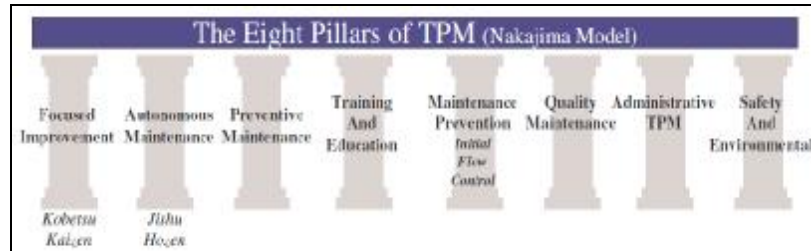


Figure 2.1. TPM Pillars (Nakajima 1988),

After 1970’s lots of tools and pillars have been added to TPM. With time TPM has transformed to WCM. This transformation is presented in Table 2.1. After this transformation new pillars have been created (Nakajima, 1984; Nakajima, 1988).

Table 2.1. The Growth Of Techniques And Factors Associated With The Concept Of World Class Manufacturing (Yamashina, H., 2006).

				JIT/Kanban	JIT/Kanban	JIT/Kanban	JIT/Kanban	JIT/Kanban
				TPM	TPM	TPM	TPM	TPM
				Cellular Manuf	Cellular Manuf	Cellular Manuf	Cellular Manuf	Cellular Manuf
				rQc	rQc	rQc	rQc	rQc
				TUM	TUM	TUM	TUM	TUM
				MRPII	MRPII	MRPII	MRPII	MRPII
				CIM	CIM	CIM	CIM	CIM
				Empowerment	Empowerment	Empowerment	Empowerment	Empowerment
				Training	Training	Training	Training	Training
				Kaizen	Kaizen	Kaizen	Kaizen	Kaizen
				Technology Management	Technology Management	Technology Management	Technology Management	Technology Management
				Design Management	Design Management	Design Management	Design Management	Design Management
				Manufacturing Strategy	Manufacturing Strategy	Manufacturing Strategy	Manufacturing Strategy	Manufacturing Strategy
				Perform Measurs	Perform Measurs	Perform Measurs	Perform Measurs	Perform Measurs
				Benchmarking	Benchmarking	Benchmarking	Benchmarking	Benchmarking
				Structure & Culture	Structure & Culture	Structure & Culture	Structure & Culture	Structure & Culture
				Innovation Strategy	Innovation Strategy	Innovation Strategy	Innovation Strategy	Innovation Strategy
				Corporate Strategy	Corporate Strategy	Corporate Strategy	Corporate Strategy	Corporate Strategy
				Group Technology	Group Technology	Group Technology	Group Technology	Group Technology
				Batch Size Reduction	Batch Size Reduction	Batch Size Reduction	Batch Size Reduction	Batch Size Reduction
				Set up Reduction	Set up Reduction	Set up Reduction	Set up Reduction	Set up Reduction
				Non Financial Measures	Non Financial Measures	Non Financial Measures	Non Financial Measures	Non Financial Measures
				Supplier Partnership	Supplier Partnership	Supplier Partnership	Supplier Partnership	Supplier Partnership
YEAR	1980	1986	1989	1991	1996			
	TPM →				WCM			

WCM has been applied with its 10 methods. These are called WCM pillars such as Safety, Environment, Customer Service, Logistics, Focus Improvement, Early Equipment Managements, Quality Control, People Development, Autonomous Maintenance & Work Place Organization and Professional Maintenance, Figure 2.2. All of these 10 pillars have 7 application steps.

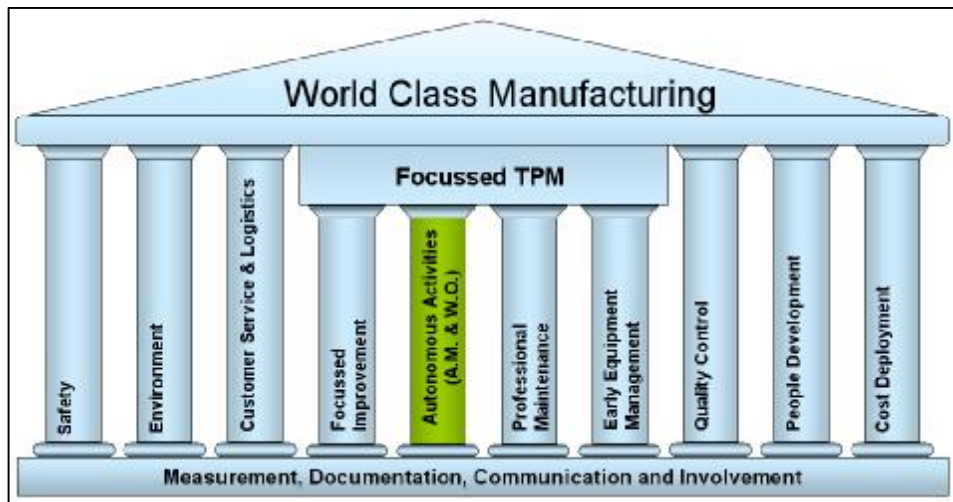


Figure 2.2. WCM Pillars (Yamashina, H., 2006)

Also, Autonomous Maintenance is the one of the WCM pillar, too. It has two aims. From a human perspective, it fosters the development of knowledgeable operators in light of their newly define role. From an equipment perspective, it establishes an orderly shopfloor where any departure from normal conditions may be detected at a glance.

Autonomous maintenance is the process by which equipment operators accept and share responsibility (with maintenance) for the performance and health of their equipment (Robinson and Ginder, 1995).

The driving concept of Autonomous Maintenance is the creation of ‘expert equipment operators’ for the purpose of ‘protecting their own equipment’ (Shirose, 1996). “Autonomous Maintenance is the cornerstone of TPM activities.” (Komatsu, 1999). The paradigm shift that AM addresses are a transition in the operator perception from ‘I run the equipment, Maintenance fixes it’, to ‘I own the performance of this equipment’.

In this Autonomous Maintenance environment, “The greatest requirements for operators are, first, to have the ability to ‘detect abnormalities’ with regard to quality or equipment, based on a feeling that ‘there is something wrong’.” (Shirose, 1996). Autonomous Maintenance is closely linked with Focused Improvement in that both TPM and WCM pillars support equipment restoration and sustaining basic equipment conditions.

Through autonomous activities in which the operator is involved in daily inspection and cleaning of his or her equipment companies will discover the most important asset in achieving continuous improvement its people (Society of Manufacturing Engineers, 1995).

Autonomous Maintenance has two aims, 1) to foster the development and knowledge of the equipment operators, and 2) to establish an orderly shop floor, where the operator may detect departure from optimal conditions easily (Tajiri and Gotoh, 1992).

Autonomous Maintenance offers a significant departure from Taylorism (Taylor, 1911) where operators are required to repeat simple structured work tasks with little understanding and knowledge about the equipment they run or the products they manufacture.

“Autonomous Maintenance involves the participation of each and every operator, each maintaining his own equipment and conducting activities to keep it in the proper condition and running correctly. It is the most basic of the eight pillars of TPM. If autonomous maintenance activities are insufficient, the expected results will not materialize even if the other pillars of TPM are upheld.” (Komatsu, 1999).

From history to today Autonomous Maintenance has been applied in all department of automobile factory. (pres, body, paint, die...etc). Because equipment is often in deteriorated conditions and machine efficiency does not comply with objectives. In addition to these the people’s motivation can certainly be improved.

At 1971, Nippon Danse, as a Japan company was applied TPM methodology as the world first. Also first AM application was applied in this factory. This was the begening of TPM and AM applications in the world (Kotze, 1993). Firstly, it was seperated to automobile industries quickly. Toyota, Nissan, Mazda and some their

suppliers were used in a short time. With time, it has separated to another industries as mikro electronic, machine parts, plastic, white house goods, film and etc. In recent years chemical, medical, gas, paper, iron, cement and other some industries adopted this system (Dal, Tugwell, and Greatbanks, 2000).

These systems have been recognized quickly all over the world. AM began to be recognized as TPM with in time. American and European countries have been widely adopted by these systems. At the beginning of 1990, this system has been accepted in Turkey. In many companies, especially Pirelli, Brisa, Kordsa, Tofaş, Netaş, Arçelik and Beko began to apply this system.

Development of the system in Turkey according to date; Türk-Pirelli factory has applied TPM and its pillar AM applications firstly in 1994. At the same year, Pirelli was awarded prize by JIPM. In 2001, Beko Elektronik was awarded with perfect TPM application prize. After one year later, Arçelik Çayrova Washing Machine Factory was awarded with prize as a third factory in Turkey. In 2003, TetraPak, Unilever Algida and Elida (OMO) factories were awarded prizes because of their successes. At the same time, Arçelik Eskişehir Refrigerator ve Compressor Company was started to apply this system. In 2004 Eti Food Factory was started to apply this system in their factories. In parallel with this development, some studies have been completed by Çulfaz (2001), Nas (2001), Aksu (2003), Kaya (2003), Kekezoğlu (2006) and Sarıçoban (2006).

Çulfaz studied Optimal Utilization of Electrical Energy in Enterprises and The Studies Required for It's Saving. In this work, it has been showed that total productive maintenance and autonomous maintenance are systems in which reliability engineering and productive maintenance have been integrated (Çulfaz, 2001).

Nas has published an article named "Total Preventive Maintenance Management or To Create of Effectiveness and Competitiveness". In this article, the historical development of TPM was examined and it was summarized some implementation in Erkunt San. A.Ş. All workers joined to company targets with this application. Increase productivity, zero safety accident, zero stock, zero breakdowns

and zero scrap were focused in this study. It has been started to achieve the targets for tree years (Nas, 2001).

Aksu described TPM and AM system in his study which is called “Total Preventive Maintenance and the Application in Industrial Enterprises’’. Then, TPM and AM applications steps and their results were given for BMC A.Ş. in Turkey. For active AM applications, joining of workers, support of top management, effective engineering support and stable working were determined as basic conditions in this study. Also, it is stated that initially adopting the measures to increase the reliability of equipment and work practices shall have a positive impact on labor force participation (Aksu, 2003).

Maintenance Management and Creating TPM model in One Company has been studied by Kaya. Kaya emphasized the importance on the elimination of the losses and wastages. So, TPM is introduced as the most effective approach to prove this target. He studied on the medium-sized manufacturing company to create the appropriate system (Kaya, 2003).

Kekezoğlu studied Total Productive Management Process and Applications in Total Quality Management and Lean Manufacturing System. With the spread of just in time production, increasing importance of lean manufacturing system was examined in this study. He has described that; resources of company must be used most effective for the system to be strong. In this study, it was explained that the efficiency of the use of resources were possible with total productive maintenance which were accepted at managerial strategy. He asserted that total productive maintenance is the best way to be lean in manufacturing. Concrete examples were given with researching in Beko A.Ş. (Kekezoğlu, 2006).

Sarıçoban examined the system of TPM and its prior step-5S applications in detail. In his study ‘The importance of 5S in Total productive maintenance study and its application’ has been investigated. Also, 5S was explained one of the tool of Autonomous Maintenance. The importance of 5S was explained that it was preparing for improving opportunity in TPM system. After this applied study in Dönmez Debraj San. Tic. A.Ş. He stated that clear and tidy working areas have positive

impact in terms the job security, regular work atmosphere, productivity, quality and motivation (Sarıçoban, 2006).

In addition to these, Ljungberg has performed a work on the “Measurement of Overall Equipment Effectiveness As a Basis for TPM Activities”. In this study, it was stated that the base of Total Preventive maintenance had been created by OEE, and OEE which were determined from TPM application, were given as most importance indicator for development (Ljungberg, 1998).

Dal, Tugwell ve Greatbanks have studied “Overall Equipment Effectiveness (OEE) as a Measure of Operational Improvement: a Practical Analysis”. They have revealed that, OEE is the most suitable criterion which could be used to monitor operational improvements in the company. Obtained results were summarized at the end of their case study (Dal, Tugwell, and Greatbanks, 2000).

Nowadays, WCM and TPM are used in lots of Japanese, American, European factories. Also AM applications are used, too. Seven steps have been used in these applications. The first stage of AM program consists of Step 1,2 and 3. It focuses on creating the foundation of WCM by establishing proper cleaning, lubrication and inspection of equipment. The second stage of AM program consists of step 4 and 5. The major activities to be carried out here are an over all category by category inspection and establishment of operators’ routine maintenance system. This stage focuses on minor stappages, reworks and scraps. The last stage of AM consists of step 6 and 7. At this stage Work Place Organization tools are applied on shop floor (Yamashina, H., 2006).

3. MATERIAL AND METHOD

3.1. Material

In this study, Autonomous Maintenance which is one of the pillars of WCM has been used in Press Shop of one of the leader main automotive company in Turkey.

In the Press shop, 24 white collar and 233 blue collar employees are working in 20.000 m² closed area with two shifts. There are 7 press lines and 3 blanking lines (800 Ton SCH, 500 Ton SCH and RBK) in this area. Two of the press lines (Line 1 and Line 2) are working manually with 650 ton capacity. Other lines are robotic (Line 3, Line 4, Line 5, Komatsu and Line 7) and have the capacity of between 1300 tons and 2100 tons. Materials are purchased in coil forms, cut and shaped on the blanking lines. All lines are shown in press shop layout in Figure 3.1.

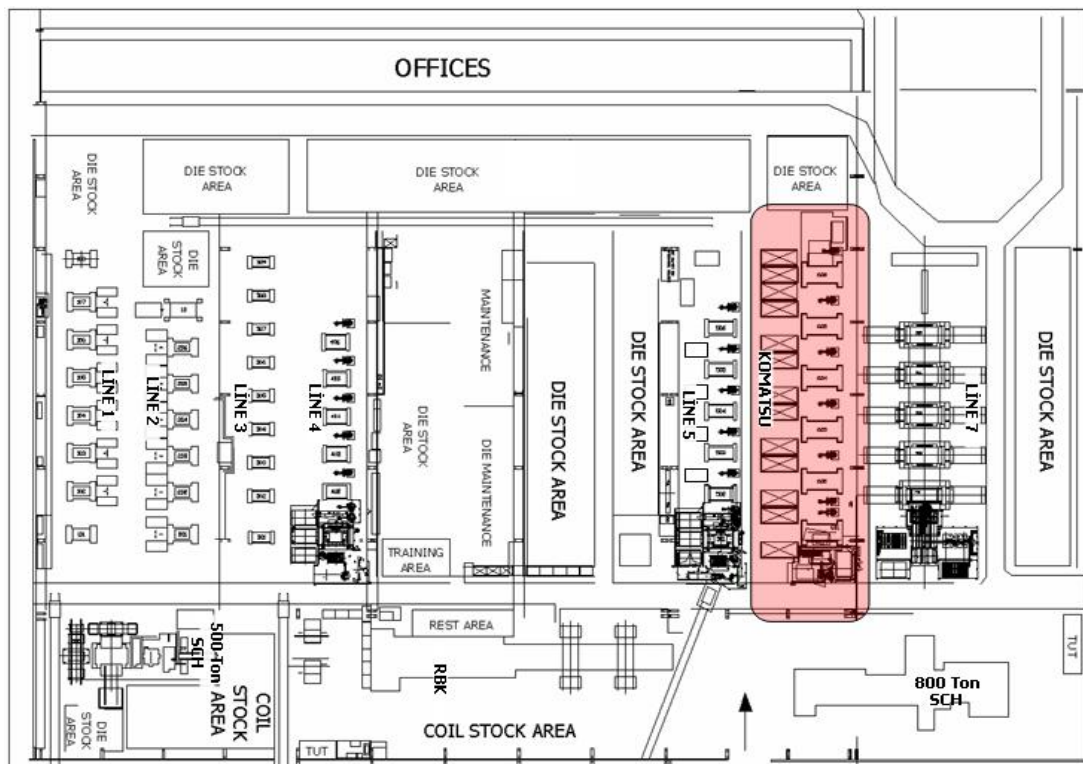


Figure 3.1. Press Shop Layout

Losses of the shop are tracked by a system which is identified daily and all losses are accounted as cost by this system which is called Press Capacity System. Then the areas which need the urgent improvements are identified. Professional maintenance team take care of breakdown losses, die maintenance team take care of all losses related to dies, all team members take care of set up losses and production team take care of minor stoppage losses due to Autonomous Maintenance. All losses are analyzed and monitored on Cost Deployment (CD) analysis. These analyses are done every month.

In this study, Pilot line was chosen to make the AM applications with looking to Press Shop Cost Deployment analysis and ABC Line Classification table. Cost deployment analysis indicates that Komatsu Press Line has too many breakdown losses. Therefore, this study has been applied in Komatsu Press Line.

This line is working with two shifts. In one shift 9 blue collar employees and one white collar employee are working in this line. White collar has been selected from mechanical engineer. He is interesting with managerial works in this line. One auto control operator is working in this line for one shift. He has to give okey to first part of production. He must control the production parts with their identified frequency. There is one external set up operators in this line. While line is working, he prepares the dies and line for next production. One robot arm responsible operator is working in this line. He interests the robot arms during the line is working, as external set up operators. Stocking operations are made by four operators. Lean team leader was selected from blue collars operators. He is entering the all line losses to capacity programs. He is looking to lean team works. He can prepare one point lessons. In addition to this, he can prepare some quick and standard kaizens. When line is stopped for internal set up, all operators are working for set up. They have specific duties for internal set up.

There are 6 presses, 9 robots, 12 moving blasters and 2 desteckers in the press line shown in Figure 3.2. Also, when line is working all employees' locations are given in this figure.

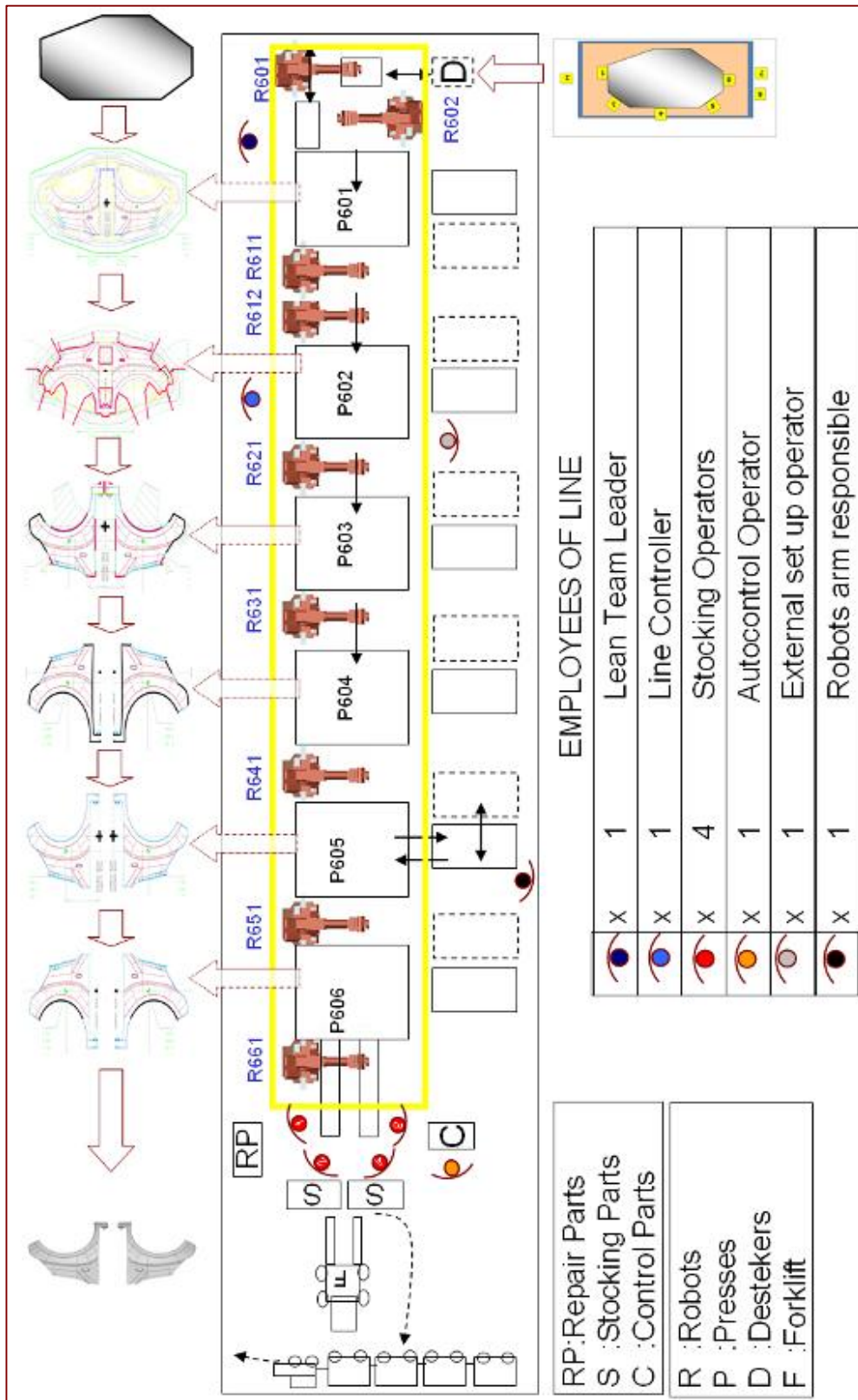


Figure 3.2. Komatsu Press Line Layout and Employees of Line

This line was built in 1998 with robots by a Japan company. This line has a double effect mechanical press which has 2100 tons metric units' capacity (Figure 3.3). In automobile industries press line is called with first press capacities. First press capacities must be greater than others. Because, the first shapes are given to sheet parts under the first press. It is called deep drawing press. Big parts can be shaped with high capacity press. For example, side panel parts of car can be produced with greater than 1500 tons capacity press. Other presses are single effect mechanical presses which have 900 tons capacity in this line. First form is given on part by first press. Other presses are cutting, are bending and are flattening the part. At this line all presses have got moving bolster (moving table). These moveable tables are used for easy die changing operation in less than ten minutes.

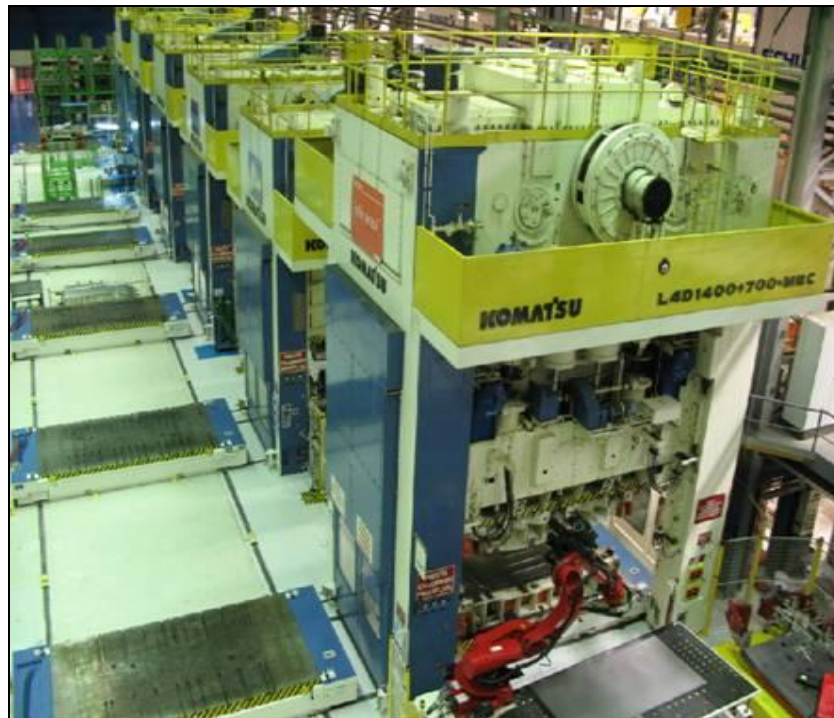


Figure 3.3. Komatsu Press Line

The maximum capacity of this line is 18 stroke / minute. It means, with maximum effectiveness 18 parts can be produced per minute in this line. Several automobile models' sheet metal part productions are performed in this press shop. These parts are used in firms own products and also they are exported to many

foreign countries. Especially in Komatsu press line different sheet metal automobile parts, from 0,3 meters to 2 meters, are produced (Figure 3.4).

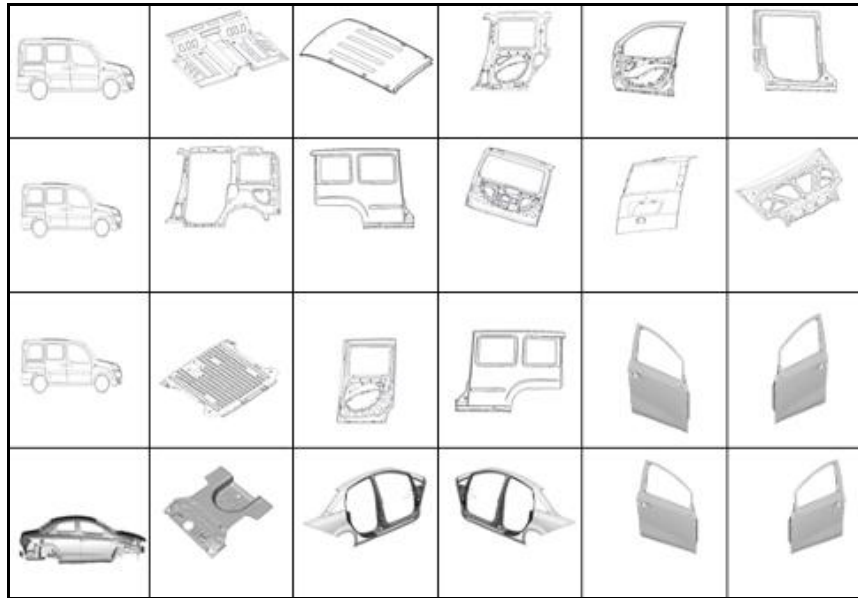


Figure 3.4. Some of Automobile Parts Produced in Komatsu Line

Also, this line is a robotic production line. All robots are produced by COMAU, an Italy company; type SMART NH1-100-3.2p (Figure 3.5). Each robot consists of an anthropomorphic structure with 6 degrees of freedom. On the fixed base a column with the axis 2 gear reducer and balancing assembly rotates around the vertical rotation axis (axis 1). Axis 2 is balanced by compression springs in a suitable housing; this solution does not require maintenance. An arm connects axis 2 to the forearm that includes the gear motors of axes 3-4-5-6. The wrist which is spherical is located at the end of the forearm.

While the sheet metals are formed in this press line, parts are transformed from press to press by robots. The first and the second robots are positioned on front side of the first press. All parts are come to line with desteckers. The first robot is transforming the sheet metals from destecker to the centering table. Parts come to a similar position on this centering table. Because, parts have to enter dies with same position all time for quality production. Then, the second robot is transforming same part from centering table to into the deep drawing dies in the deep drawing press (in

the first press). After the giving initial shape to the part in this press, part is transformed to the second press with using the third and the fourth robots. They are positioned between the first and the second press. For this operation, two robots are used, because according to die designs when part is taken from the first press it has been rotated 180 degrees on its x axis. The first cutting operation is made in the second press by using cutting dies. Then, part is transformed from the second press to the third press by using the fifth robot. So, the fifth robot is positioned between the second and the third press. The second cutting operation is made in the third press. For some bending operations part is transformed from the third press to the fourth press by using the sixth robot. Also, this robot is positioned between the third and the fourth press. Generally, ironing operations are made in the fifth press and the sixth press. So, the seventh robot is used for transforming from the fourth press to the fifth press, it is positioned between these presses. The eighth robot is used for transforming part from the fifth press to the sixth press. It is positioned between the fifth and the sixth presses. And the last robot is positioned at the end of the line. It is used for transforming part from sixth press to stocking band. Finally part is stocked from stocking band to its defined stand by operators.

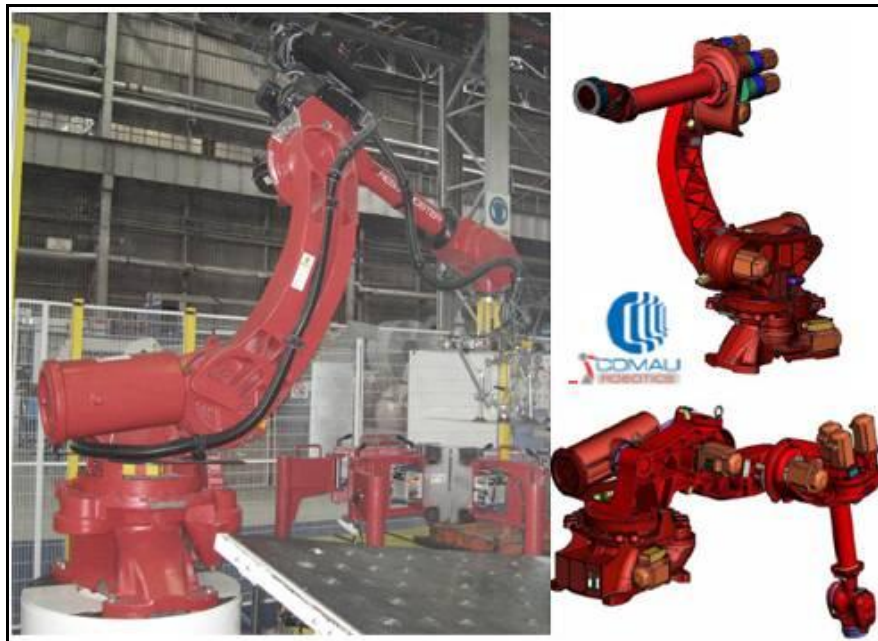


Figure 3.5. Comau Smart NH1-100-3.2P Robots

3.2. Method

Line effectiveness is keeping under control with line Overall Equipment Effectiveness. Overall Equipment Effectiveness (OEE) of a factory is very important for competitive manufacturing. Cost, velocity and flexibility are the main factors that affect the OEE. OEE is created using data entered by the lean team leader.

In addition to this, manufacturing thus becomes a formidable competitive leading edge for the company, providing a major, long lasting contribution to improve customer satisfaction. Manufacturing intends to play a decisive role in maximizing company performance in its competitive priorities such as: quality, price, speed of delivery, flexibility and innovation. OEE has 3 types of losses such as equipment downtime, equipment performance and defect losses.

Equipment Downtime Losses include equipment failure loss, changeover loss, set-up & adjustment loss, cutting blade (option) change loss, start-up loss / shut down loss and other downtime losses.

Sudden and unexpected equipment failures or breakdowns are obvious cause of loss, since an equipment failure means, that the machine is not producing any output. For example breakdown is an equipments failure loss. There is an equipment stoppage greater than 10 minutes due to a component failure or breakdown.

A changeover is determined by a planned variation in the production plan or replacing tools / dies due to wear and tear or being broken.

Most machine changeovers require some period of shutdown so that internal components can be exchanged or adjusted. The time between the end of the last good product produced and the first good product produced of the following production run is downtime. This downtime loss often includes substantial time spent making adjustments until the machine gives acceptable quality on the required product. These losses are called Setup-Adjustment losses.

Different types of parts can be produced with the same die. According to production plan, passing the one option to another option you can change some die equipments. During this operation machine must be stopped. These stoppages are option change losses.

In addition to these, the start up loss occurs for the period of time preparing the line for starting up and running in the equipment until conditions have been stabilized. Yield losses occur when production is not immediately stable at equipment start-up, so the first products do not meet specifications. This is a latent loss, often accepted as inevitable, and it can be surprisingly large.

Second main loss of OEE is Equipment Performance Loss. It is divided by two groups as minor stoppage, idling losses and speed loss.

When a machine is running and stopping / starting frequently, it will lose speed and obstruct a smooth flow. The idling and stoppages in this case are not caused by technical failures, but small problems such as product(s) that block sensors or get caught in chutes. Even though the operator can easily correct such problems when they occur, the frequent stoppages can significantly reduce the effectiveness of the equipment.

Minor stoppage means, an equipment stoppage due to a failure or error in automatic handling, processing or assembly of parts or work pieces which are often within specification. Restoring normal conditions normally requires action by the operator to reset and/or reactivate the equipment in less than 10 minutes, and that is usually all that is required to overcome the equipment stoppage. The loss can also be manifested as a yield or usage issue.

Reduced speed operation refers to the difference between the actual operating speed and the equipment's designed speed (also referred to as theoretical). There is often a gap between what people believe is the "maximum" speed and the actual designed (theoretical) maximum speed. The aim is to eliminate the gap between the actual speed and the designed speed. Significant losses from reduced speed operation are often neglected or underestimated.

Final main loss of the OEE is the defect loss. It occurs when products do not meet quality specifications, even if they can be reworked to correct the problem. The goal should be zero defects to make the product right first time, every time.

On the other hand, other losses occur in production shop. These are Shutdown and Unused time losses. These are forming Equipment loading time loss. They don't effect to OEE negatively.

Equipment Downtime losses form the Availability Rate, Performance losses form the Performance Rate and Defect losses form the Quality Product Rate. Finally OEE is calculated with Availability Rate x Performance Rate x Quality Product Rate. All OEE losses and calculation method is given in Figure 3.6.

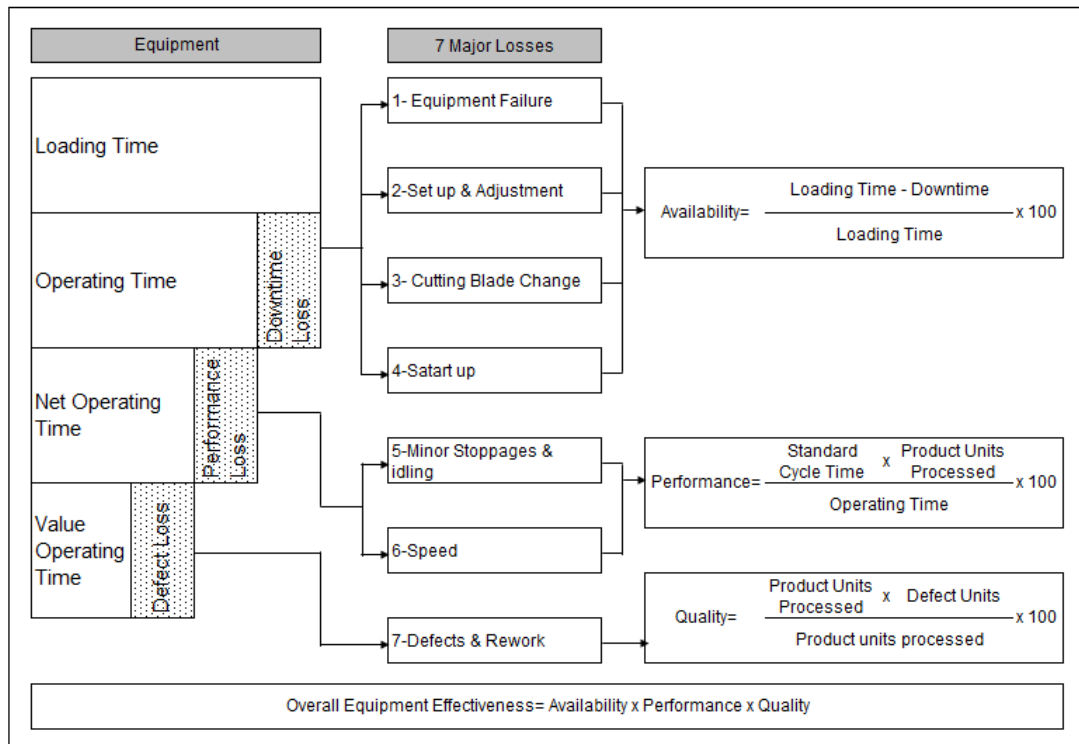


Figure 3.6. Overall Equipment Effectiveness Calculation (Nakajima,1988)

The first aim of this study is to reach 85% OEE, with to achieve zero minor stoppages and breakdowns which are caused by lack of autonomous maintenance. In addition, other aim of this study to achieve minimum 90% improvement on line cleaning, control and lubricating (CIL) times which was determined in first step of the Autonomous Maintenance.

In this study, first 4 step of AM was applied in Komatsu press line by using Figure 3.7.

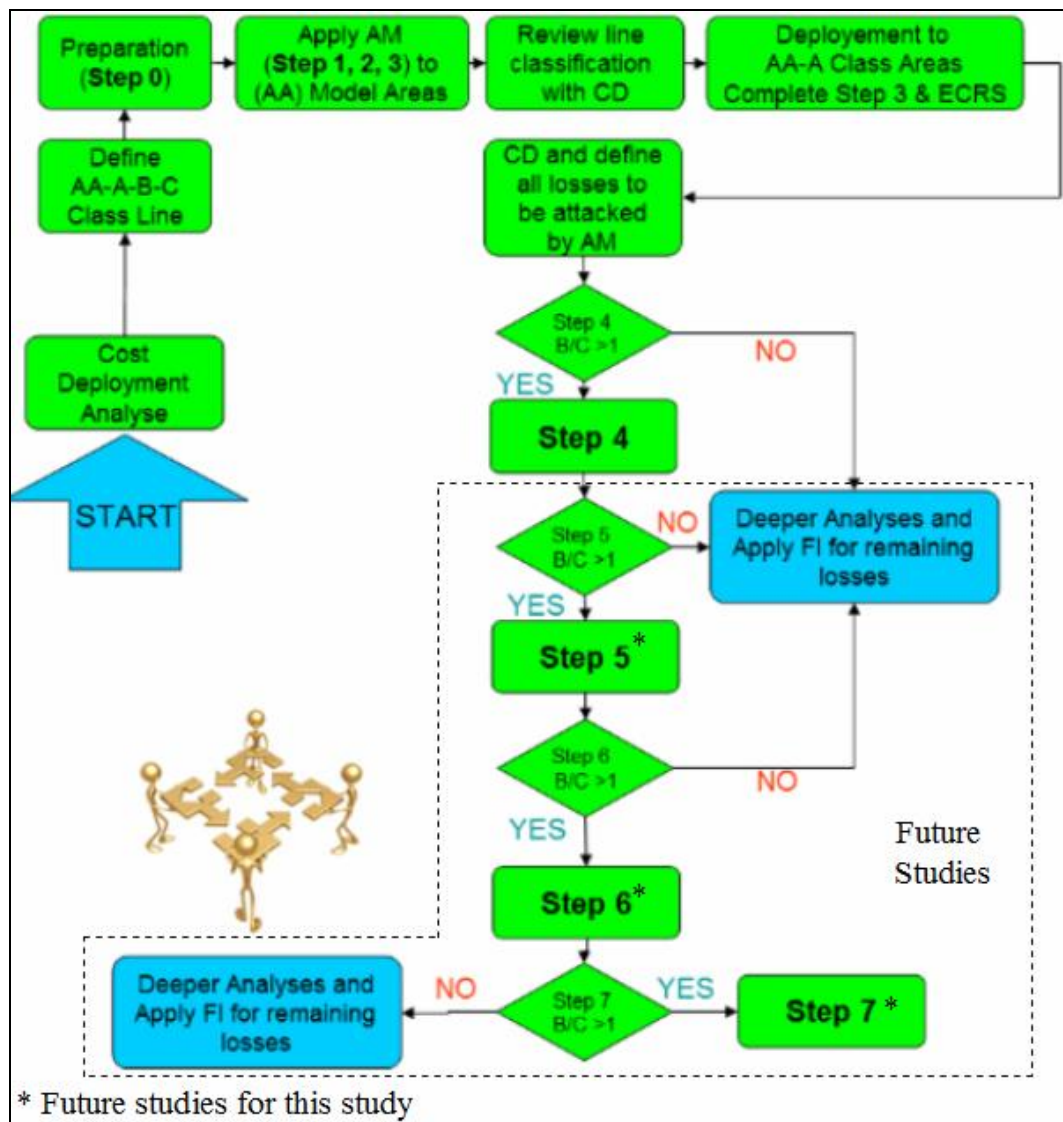


Figure 3.7. Autonomous Maintenance Flow Chart

Next steps are taken for future studies. Before the starting AM steps, preparations must be completed. So, firstly preparation step (step 0) is applied in line. First three steps of AM involved activities to keep the state of equipment deteriorating. These included reestablishing basic equipment operating conditions through regular cleaning, inspection and lubrication. Step 4 and Step 5 are focusing on quality losses. Operators are interesting equipments in step 4. Process is interested at step 5. The work piece flowing and workplace organization are focused at last steps. All works and used method were given below step by step.

3.2.1. Step 0 Preparation

At step 0, it is installed an understanding of how forced deterioration occurs and why AM is necessary now with the AM program participants. This is ensured that safety is paramount in AM activities. An understanding has been developed to see How the Machine Works for the participants in the AM program. All safety risks have to eliminate before AM activities. One point lessons are generated for using all training given to operators. Existing operator's skills are determined at step 0. According to their skills new training plan is developed. A question list is generated on specks of the machines workings and AM systems.

As it given before, Cost deployment analysis indicates that Komatsu Press Line has too many breakdown losses. In addition to this according to prepared ABC Machine Classification of Press Shop Komatsu press line which was the single AA class line.

Safety risks had to be eliminated before starting to future steps. So, all safety risks were determined during preparation step at pilot line. Safety trainings were given to line operators with One Point Lessons (OPL) and some classroom trainings.

One Point Lessons (Figure 3.8.) were used for a simple but effective training instrument. OPL was prepared with texts that were easy to understand, with sketches, drawings and photos. In addition to safety subject, they were described the best practices of a plant. OPL was used in three types. Firstly, basic knowledge of operators has been improved with technical and management information. Operators have been taught how to carry out o certain activity and how a plant component works, etc. Then, some specific situations in order to avoid errors, faults, defects or accidents were given with OPL. Sketches or photos were prepared to describe the problem and clearly indicated the steps to be taken to prevent it from occurring again. Finally, OPLs were used to give some before and after improvements. It was used for know-how applications.

On the other hand properties of AM and some works which were transformed form Professional Maintenance to Autonomous Maintenance have been given with OPLs. First OPLs were prepared by white collar, and then lean team leaders started

to prepare them. With time, all AM operators have prepared OPLs. OPLs have been monitored and have been managed with One Point Lesson Plan Matrix (Figure 3.9.). In this matrix, all prepared and given OPLs and operators which were taken these OPLs could be seen.

At this step, a question list was generated (Table 3.1.), too. All team members of line could ask about their line specifications and AM systems. Supports, technical members or white collar of line provide answers in the form of OPLs. Question list was the most useful means for operators to share questions and know-how, and to understand equipment gradually without dropping out. Questions on the list were crossed off and the completion date was recorded when all group members understand the answers by way of adequate materials, such as one point lessons. A time limit was set for finding an answer, in order to prevent going on with regular activities without having resolved operators' problems.

Meanwhile, everyone might be aware that some people confuse of basic knowledge with the basis for asking a question. The term of question referred inquiry about something unusual, which was not evaluated as defective by means of routine technical knowledge and skill. On the other hand, the inability to name a part was simply a lack of knowledge and did not constitute a "question". An example of a legitimate question arises from a situation in which a pressure gauge, which was marked between 4,5 and 5,5 kg/cm² with blue in order to indicate the range of normal operating pressure, points instead at 4,4 kg/cm². Operators were encouraged to respond with questions to such matter.

While knowledge of operators was improving with technical and management information, their skill levels had to monitor. So, the Skill Matrix (Figure 3.10.) of operators was prepared according to their duties and their technical skills. The current and wanted statuses of operators could be seen in this matrix. This matrix could be monitored with Operator Skill Radar Chart Graph (Figure 3.11.). They have been prepared and have been followed by white collar employee. In addition to this, development plan was prepared by white collar of line.

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MÜDÜR/DURUMBAŞI/BAŞKANI/BAŞKANI/BAŞKANI		EĞİTİM İÇERİĞİ		YARIN		EĞİTİM YERİNİ		EĞİTİM ALAN	
HAZIRLAYAN: BAKURAN ÖZALP		EĞİTİM TÜRÜ		EĞİTİM YERİNİ		EĞİTİM ALAN		EĞİTİM ALAN	
		<p>DİKKAT!</p> <p>*** POMPASIZ AĞIZLI İSE KULLANMA</p> <p>*** KAPAĞI KAYBUNYOR İSE KULLANMA</p> <p>*** İÇERİĞİ KIRILMIŞ GÖZ VE CİLD İLE TEMAS BÖLGESİ SÖL SU İLE YIKAVIMLI</p> <p>% 95 ORANINDA SEBEKE SUYU DOLDUR.</p> <p>% 5 ORANINDA TEMİZLİK MADDESİ DOLDUR.</p>		<p>Yeni Döviz</p> <p>Mehmet YILDIZ</p> <p>Sakir YILMAZ</p> <p>H. BAKKAYA</p> <p>M. H. H. H.</p> <p>AL. D. D. D.</p> <p>İ. K. K.</p> <p>Z. S. S.</p> <p>T. S. S.</p> <p>A. S. S.</p> <p>İ. S. S.</p> <p>B. S. S.</p> <p>A. S. S.</p> <p>S. S. S.</p>		<p>Yeni Döviz</p> <p>Mehmet YILDIZ</p> <p>Sakir YILMAZ</p> <p>H. BAKKAYA</p> <p>M. H. H. H.</p> <p>AL. D. D. D.</p> <p>İ. K. K.</p> <p>Z. S. S.</p> <p>T. S. S.</p> <p>A. S. S.</p> <p>İ. S. S.</p> <p>B. S. S.</p> <p>A. S. S.</p> <p>S. S. S.</p>			

Figure 3.8. One Point Lesson Example

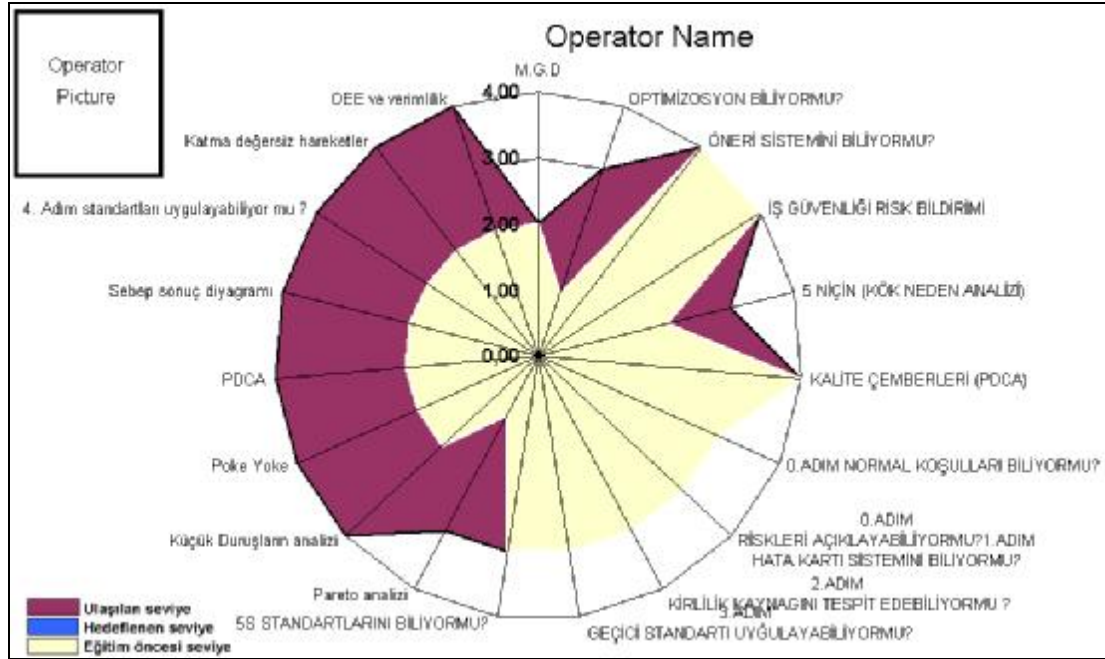


Figure 3.11. Operator Skill Radar Chart

In other words, operators developed the habit of observing and distinguishing carefully between normal and abnormal conditions. In summary, operators were encouraged to generate questions and then provided the answers that fellow operators could understand. As a result, they slowly developed a greater ability to discover more essential problems. When all employees were actively looking for questions, serious hidden defects in equipment could frequently be exposed.

At the end of preparing step, Autonomous Maintenance Activity Board (Figure 3.12.) has been prepared for successful team activities near the line. All AM steps' documents, key performance indicators and one point lessons can be found at this board. Using the AM activity board helped everyone work together, give team members a sense of accomplishment and showed everyone the progress they were making.

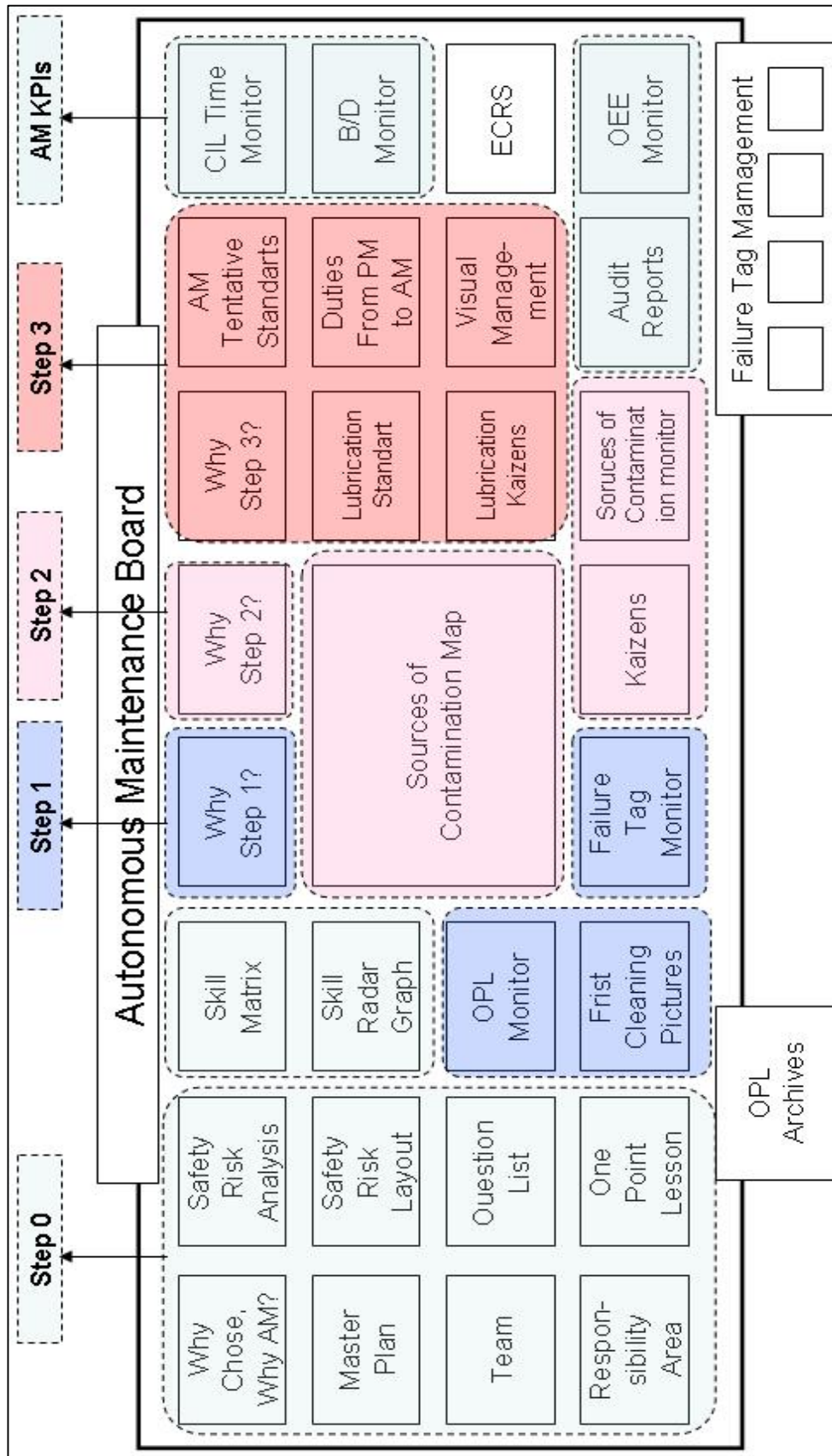


Figure 3.12. Autonomous Maintenance Activity Board

3.2.2. Step 1 Initial Cleaning

This is a crucial step, at which the ‘cleaning is inspection’ concept is put into practice. It is not a matter of just making the equipment look clean on the surface; the process of cleaning exposes abnormalities, such as leaks, loose fastenings, or damaged parts.

The aim of this step is to get to grips with the equipment, getting our hands dirty and removing every last bit of dust or grime and keeping our eyes open as we do so, because this is by far the best way of discovering problems. Since initial cleaning is a key step in which the equipment is cleaned thoroughly in order to make any abnormalities visible, it is also called ‘Checking through Cleaning’. By carrying out this step, operators not only got their equipment cleaned and found out what is wrong with it; they also experienced for themselves, in a very practical way, that cleaning and inspection are actually the same thing.

Also, operators have started to use failure tag for anomaly situation, contaminations sources and hard to access areas. In addition to these, Quick Kaizens applications are started to solution of failure tags. Also, daily meetings are started near the line with step 1. Anomaly tags and daily losses are reviewed at these meetings. In addition to these, first cleaning, inspection and lubrication (CIL) times are determined at this step. With this step all activities were applied for reducing this time.

In this study, firstly all operators have learned the meaning and importance of cleaning. Cleaning the equipment means exactly what it says: removing all foreign matter, such as dirt, dust, oil stains, sludge, and so on, from the machinery, moulds, dies, tools, jigs and other equipment used to make the product. Getting every last corner of the equipment thoroughly clean is the best way of revealing hidden defects, as emphasized by the slogan ‘cleaning is inspection’. It was not a cosmetic exercise; only a real ‘deep clean’ would did the job. Less-than-thorough cleaning leads to a lost of harmful such as breakdowns, quality defects, forced deterioration and speed losses.

In addition to this, it was described this approach as ‘Cleaning is Inspection’ because its aim was to discover as many equipment abnormalities as possible. Painstakingly cleaning the equipment like this, touching every nook and cranny, often reveals hundreds and hundreds of minor defects. Figure 3.13. illustrates the overall workflow for this step.

At Komatsu Press Line, when starting to Step 1, firstly there was given the basic instruction required for carrying out Step1. Operators have been trained so that they properly understand the safety requirements in preparing step. They learned that how their equipment is constructed and how it works, and how to perform tasks such as checking, lubricating and tightening in step 1. This training has been kept practical, through the use of one-point lessons or shop-floor practice sessions using the actual equipment.

A cleaning plan was created by drawing up a cleaning map and using some kind of ranking scheme to decide what order the equipment should be cleaned in, a cleaning plan can be prepared showing the cleaning procedure to be followed. The plan was covered 5S activities, and lists the tools and materials that would be required. 5S is “a systematic method to organize, order, clean, and standardize a workplace and keep it that way.” (Productivity, 1999) 5S is based on a Japan’s approach to establishing and maintaining an organized and effective workplace.

The elements of 5S include the following (Willmott, 1994). Westernized views of 5S are also common (Productivity Press Development Team, 1996).

5S;

1. Seiri (Organization).....1. Sort (Organization),
2. Sieton (Orderliness)..... 2. Set in Order (Orderliness),
3. Seiso (Cleaning)..... 3. Shine (Cleanliness),
4. Seiketsu (Cleanliness).....4. Standardize (Standardized Cleanup),
5. Shitsuke (Discipline).....5. Sustain (Discipline).

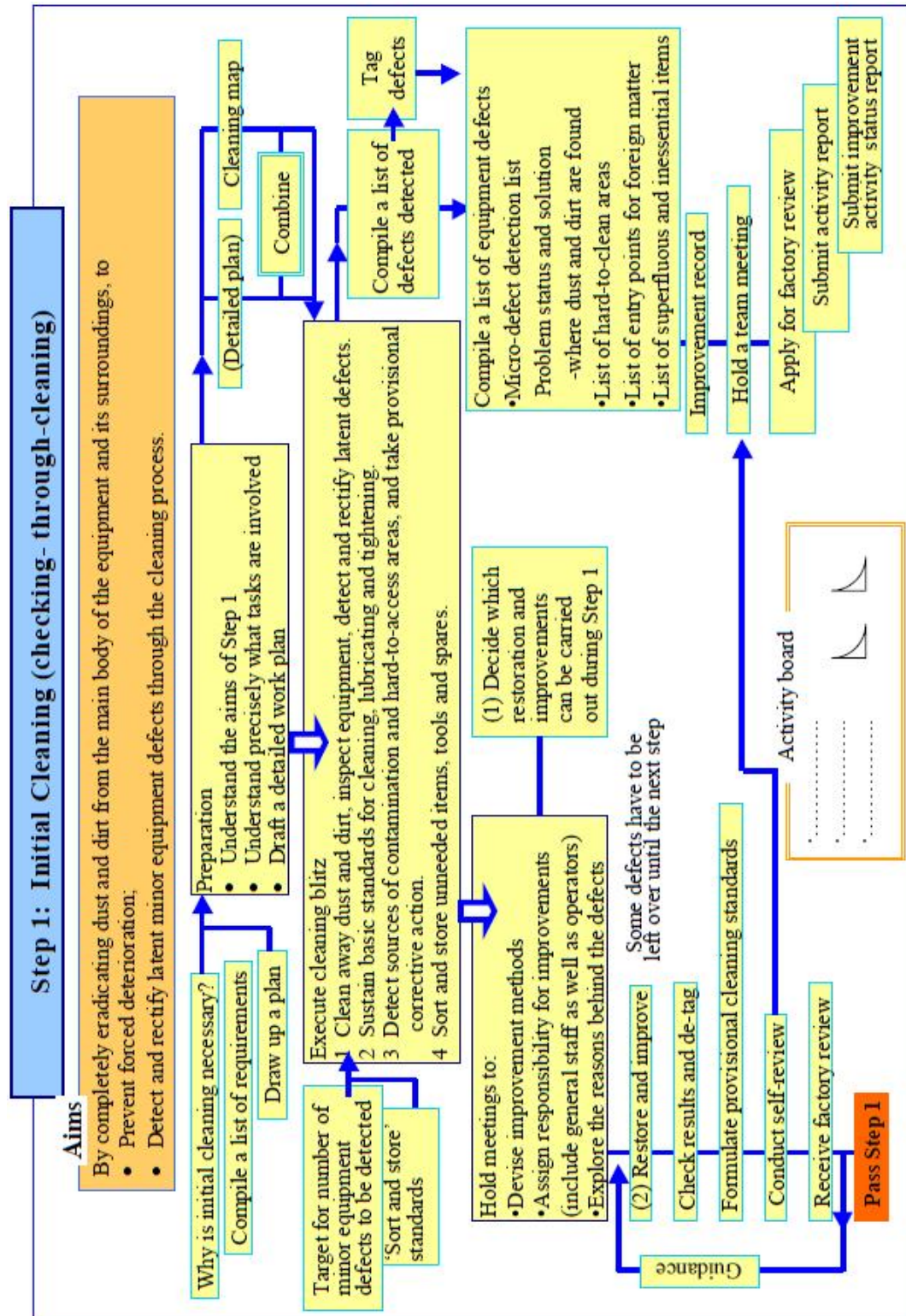


Figure 3.13. Work flow for Step 1 (Initial Cleaning) (Japan Institute of Plant

For the sake of definition identification, operators have used AM failure tags (Figure 3.14.) each defective area of equipment, such as deteriorated parts, inadequately or mistakenly assembled parts, malfunctioning components and any other discrepant areas which are discovered during the initial cleaning. Relevant information was simultaneously written on the defective area list as shown in Table 3.2. Operators then decided whether to remedy the problem by themselves or to ask maintenance department to deal with it. They also put the scheduled completion date on the list.

After the condition was corrected, operators collected the identification tag and write the actual completion date on list. Different colored tags were prepared according to the action taken by the production or maintenance departments. Red card means that the maintenance department can be solve the problem, blue means that the production departments members can be solve the problem, and green card means that that is potential safety risk. The green card has to resolve prior because of safety risk. All tips of tag cards are shown in Figure 3.15. The tag is compiled by the person who has identified the problem and consists of 2 copies. The first is inserted in the specific pocket on the board for subsequent recording, analysis and action planning, and the second remains on the machine close to the defect until the problem has been definitively solved.

All prepared and solved AM tags were shown on line layout with different collar stickers. This layout was put near the line. Failure points could be seen easy on this layout. Prepared and used AM failure tag layout is shown in Figure 3.16.

To solve the AM failure tags, operators have used Quick Kaizens. Quick kaizens would be used at every step. During the this improving Deming's cycle Plan (P), Do (D), Check (C) and Act (A) (PDCA cycle) was used. One quick kaizen example about die losses is given in Figure 3.17.

The diagram shows a red AMFT form with the following fields and labels:

- Card Number**: Points to the top header area.
- Who will Solve**: Points to the **BAKIMCI** (Maintenance Worker) section.
- Line**: Points to the **Hatt** (Line) field.
- Machine**: Points to the **Makina** (Machine) field.
- Definition of Fault**: Points to the **HATA NEDİR:** (What is the fault?) section.
- Solution Proposed**: Points to the **Çözüm Önerisi:** (Proposed solution) section.
- Perform Responsible**: Points to the bottom control section.
- Name of Prepared**: Points to the **İsim** (Name) field.
- Date**: Points to the **Tarih** (Date) field.
- AM Step**: Points to the **AM Adım** (AM Step) field.
- Priority**: Points to the **Öncelik** (Priority) field.
- Control**: Points to the bottom control section.
- Start Date**: Points to the **Başlangıç Tarihi** (Start Date) field.
- Finish Date**: Points to the **Bis Tarihi** (Finish Date) field.

Figure 3.14. Autonomous Maintenance Failure Tag

The figure displays three different AM Failure Tags:

- HATA KARTI BAKIMCI** (Maintenance Worker Tag): Red header, includes fields for Name, Date, Line, Machine, AM Step, Priority, and a section for fault definition and solution.
- HATA KARTI OPERATÖR** (Operator Tag): Blue header, includes fields for Name, Date, Line, Machine, AM Step, Priority, and a section for fault definition and solution.
- POTANSİYEL RISK BİLDİRİMİ** (Potential Risk Report): Green header, includes fields for Name, Date, Line, Machine, AM Step, Priority, and a section for fault definition and solution.

Figure 3.15. AM Failure Tags Tips

Table 3.2. Defective Area list (Failure Tag Card List)

KOMATSU HATA KARTI KAYIT FORMU													
Kart No	Kart Açan Adı Soyadı	Hata Kategorisi				Kart Açılış Tarihi	Hata Tanımı	Alınacak Önlem/Yapılan İş	Öngörü Tarihi	Aman Önemli Kategorisi			Kart Kapama Tarihi
		Yapılan İş	Yapılacak Olan	Kişi	Adı Soyadı					Yapılan İş	Yapılacak Olan	Kişi	
346	F. YILMAZ					08.10.10	603 pres arıza türü tespit edildi yeniden bakım.	Kayıp edilmiş.	08.10.10				08.10.10
347	F. YILMAZ					11	603 pres arıza türü tespit edildi yeni den bakım.	Yapıya dönüldü.	11				08.10.10
348	F. YILMAZ					11	605 pres arıza türü tespit edildi yeniden bakım.	Makineyle değiştirildi.	11				08.10.10
349	E. ÖZGEN					12.01.10	606 sulaj sisteminde milin kırılması nedeniyle arıza meydana geldi.	Dış milinle.	12.01.10				12.01.10
350	C. COŞKUN					15.02.10	606 milin parçaları sıkıştırdı arızanın nedeni tespit edildi.	Bilinmediği için değiştirildi.	15.02.10				
351	A. MURAT					18.02.10	607 sulaj sisteminde milin kırılması nedeniyle arıza meydana geldi.	Çarkların değiştirildi.	04.02.10				04/02/10
352	R. İZCAN					20.02.10	606 presin arıza türü tespit edildi yeniden bakım.	Contaların değiştirildi.	26/02/10				04/02/10
353	F. YILMAZ					18.02.10	601 presin arıza türü tespit edildi yeniden bakım.	Rolinge kontrolü.	18.02.10				
354	M. ALA					20.02.10	603 sulaj sisteminde milin kırılması nedeniyle arıza meydana geldi.	2. yarıda arıza tespit edildi.	20.02.10				
355	M. ÖZGEN					10.02.10	603 sulaj sisteminde milin kırılması nedeniyle arıza meydana geldi.	2. yarıda arıza tespit edildi.	10.02.10				
356	M. ÖZGEN					10.02.10	601 sulaj sisteminde milin kırılması nedeniyle arıza meydana geldi.	Kilbin değiştirildi.	10.02.10				
357	E. ÖZGEN					15.02.10	603 sulaj sisteminde milin kırılması nedeniyle arıza meydana geldi.	Sensörlerin kontrol edildi.	15.02.10				

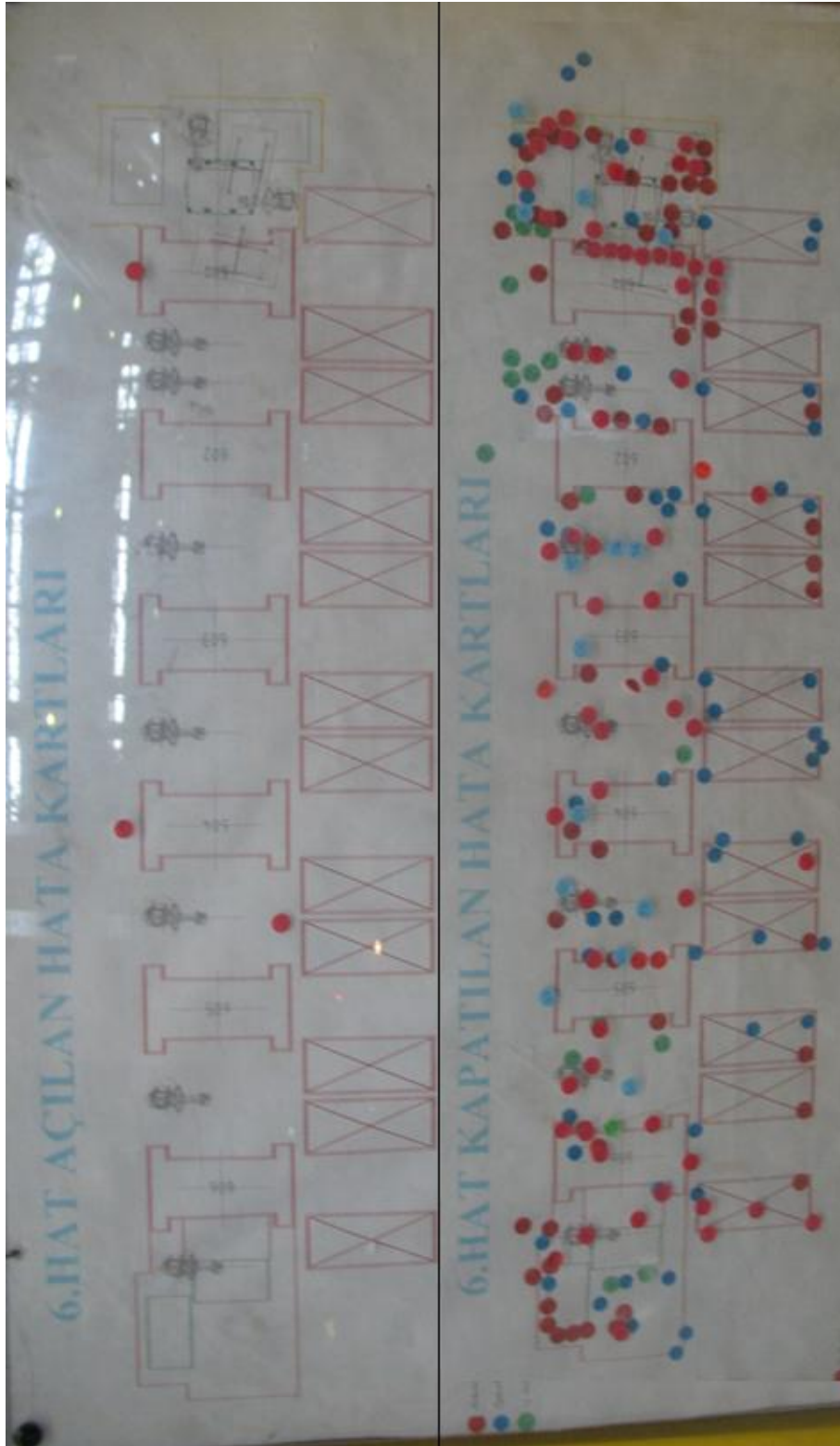


Figure 3.16. AM Failure Tags Layout

On the other hand, during the initial cleaning all sources of contamination and difficult work area could be found by operators. These points were collected at Defective Area List (Table 3.2.), too. These sources of contamination points would be eliminated at step 2. Any sources of contamination that cause the equipment to become dirty again after cleaning were be clearly identified, and everyone would be impressed with the need to deal with these so that the equipment stays clean.

Also, daily meetings were performed at this step. Line leader, PM and AM specialists, maintenance leader were talking about results of losses, AM tags and customer complaints.

10 weeks later, step 1 was finished. At the end of the step 1 AM board and area were audited by WCM officers. This audit was the first and most important audit in the seven step program and deeply influences the future development of all AM activities. Most operators felt extremely uncomfortable. But auditors presented serious questions in a humorous vein to create a relaxed atmosphere. It was essential to help especially those operators who have no experience with presentations to express their opinions clearly.

Prior to the audit was practice the procedure by trial, using the manager's modal as a guide. Managers also had remembered that the audit was only the final assessment in confirming of the completion of a step as well as an important opportunity for educating operators. Also, auditors checked whether every single operator understands group activity and is willing to participate in it. In addition, it has be established that operators understand well how to identify defective areas of equipment, sources contamination, and the saying, "cleaning is inspection".

3.2.3. Step 2 Tackling Contamination Sources and Hard to Access Areas

Aims of step 2 are elimination of sources and contaminations which were defined at step 1, are eliminated by using Quick Kaizens. Also, hard to access and hard to inspect area are focused and are eliminated. According to this aims, sources of contamination and difficult work areas (hard to access areas) were focused by line operators. Figure 3.18. shows the overall workflow followed for this step.

A source of contamination refers to any particular area in a piece of equipment which generates any foreign substances, such as metal chips in machining, flashes in molding, dirt and dust caused by malfunctioning equipment, leakage of lube oil and raw material, etc. Among these sources, as an instance, leakage from deteriorated parts such as a rubber hose or packing were easily remedied by simply replacing or repairing the parts during step 1.

Countermeasures to eliminate such sources, however, had be put off until step 2 if the mechanism for generating foreign substances was completed and needs to be studied in more detail. Detected sources of contamination were recorded in Defective Area List (Failure Tag Card List) as was given in Table 3.2. In the early stage of an AM program, the source of contamination list was most useful in having operators understand “clean is inspection” in step 2. Also hard to access areas (difficult work areas) were focused at this step. A difficult work area refers to a particular area of equipment where operators experience trouble with any kind of task, such as cleaning, lubrication, inspection and other routine operations.

In Komatsu Press Line contamination sources and hard to access areas had been identified in Step 1, and AM failure tags were put on these areas. By using the PDCA lots of quick and standard kaizens were made to solve these identified points. In addition to step two, a map of contamination sources was drawn up showing each point where contamination or leakage is occur, where hard to access area is, so that could be addressed systematically, starting with those that have the greatest effect on quality , equipment performance, and the general work environment. Komatsu Press Line contamination sources and hard to access area map is shown in Figure 3.19. Some before and after improvements were shown on this map for how-know.

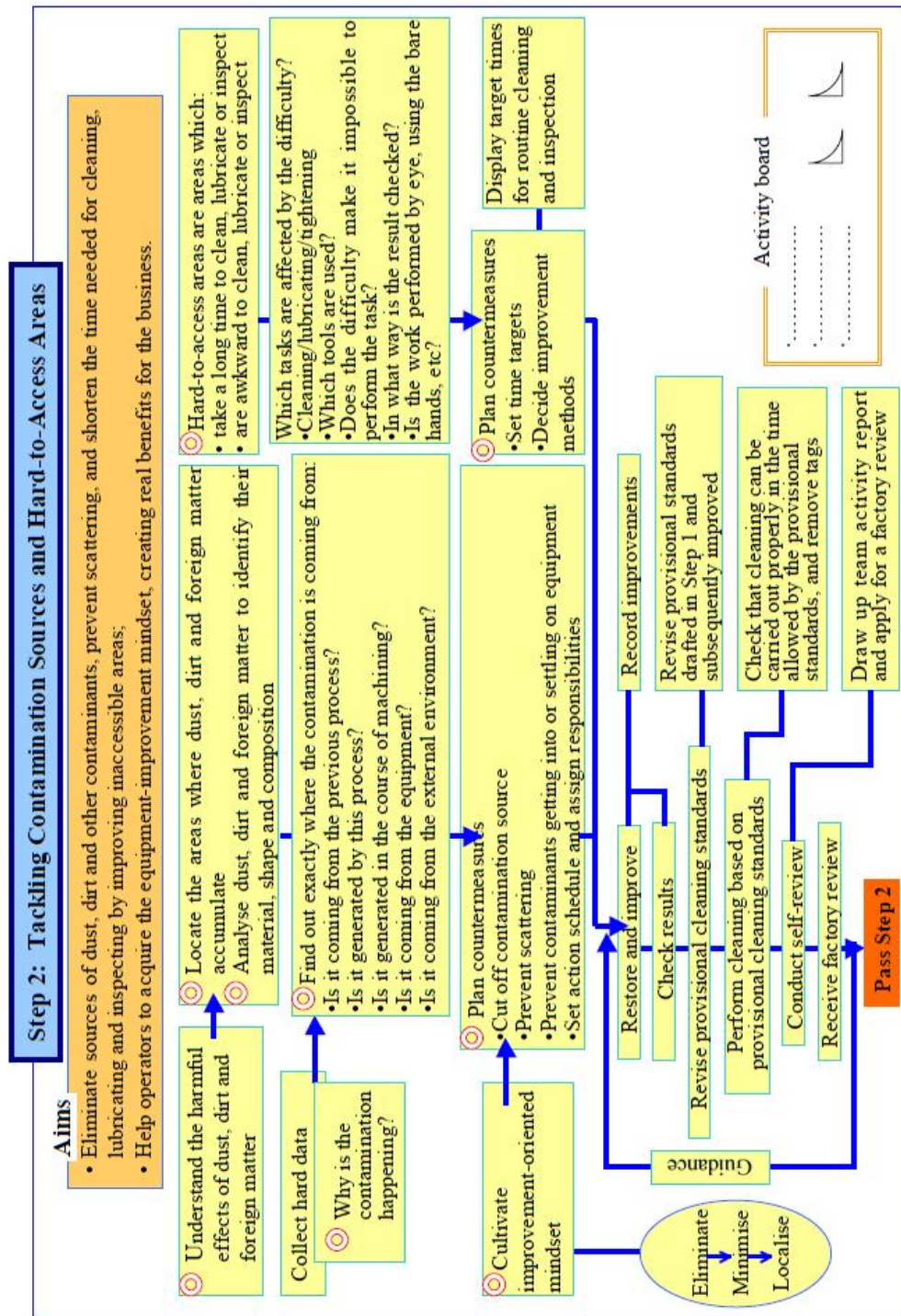


Figure 3.18. The Overall Workflow for Step 2 (Japan Institute of Plant Maintenance, 2003).



Figure 3.19. Komatsu Contamination Sources Map

About 11 weeks later, step 2 was finished, too. At the end of this step AM board and area were audited by WCM officers again. In the audit, it was more important to confirm the following points than whether or not cleaning time targets were met. Some check points had to satisfy for auditors. Such as;

What did operators learn about matters such as stricture and function of equipment, influences of contaminants, and so on?

How thoroughly did operators survey for harmful effects and related causes?

How substantial were operators' efforts by way of trial and error?

How effective were the operators' countermeasures in terms of safety, quality, breakdowns, minor stoppages, set up and adjustment?

If the above checkpoints were not satisfied, the PM group involved was judged as having failed in spite of its having completed cleaning within the given time target. The true aim of the activities of Step 2 exists in developing knowledgeable operators who resolve problems by themselves.

3.2.4. Step 3 Establish Cleaning, Inspection and Lubrication (CIL) Standards

The Step 3 is an important step in which operators use the experience they have acquired in Steps 1 and 2 to clarify what the ideal conditions for their equipment should be, and devise standards for the actions necessary to sustain those conditions (standards specifying the 5Ws and 1 H, i.e. who is to do what, where, when, why and how).

At step 3, the standards are established with CIL cards. Lubrication system is reviewed and is optimized. Visual management tools are used with step 3. Some inspections points are transferred from PM to AM with Standard Maintenance Procedures or OPL's. At the end of the step 3 eliminate, combine, review, simplify (ECRS) methodology is applied to CIL standards with its seven sub tools. More details for Step 3 are given in Figure 3.20.

Also, provisional standards for cleaning, checking and lubricating were formulated in this study. Lubrication standards were drawn up by checking current lubrication practice and the state of lubrication of the equipment; identifying any

problems, or areas that are hard to lubricate or check properly; and taking action to rectify these. Some lubrication standards have passed from PM to AM with technical trainings. The aim was taken to improve equipment reliability and maintainability by creating easy-to-follow standards.

All duties were written with details and all duties which are given inside of the standards. Duties were identified with OPLs, map or other trainings documents. Equipment details were given clearly with their pictures inside of the standards. Responsible operators were identified with their shifts. Also, during the AM activities the machine condition has to identify inside of this standard. Duties' frequency and their duration were given on this standard. Also, mini schedule can be given. Operators could see the activity days on this schedule easily.

According to these, AM standard' cards were created and they are used for all presses, robots and other equipments at this step. It can be seen a Robot AM standards (CIL check list) in Figure 3.21. This check list was used by operators in this study. When operators started to AM activities, they were using these check lists. After their duties they marked on this.

Also, CIL points were shown on equipments in the shop. And task rout were drawn on floor. The relationship between checklist and shop is given in Figure 3.22. All points in the area and all checklists helped to operators during the AM activities.

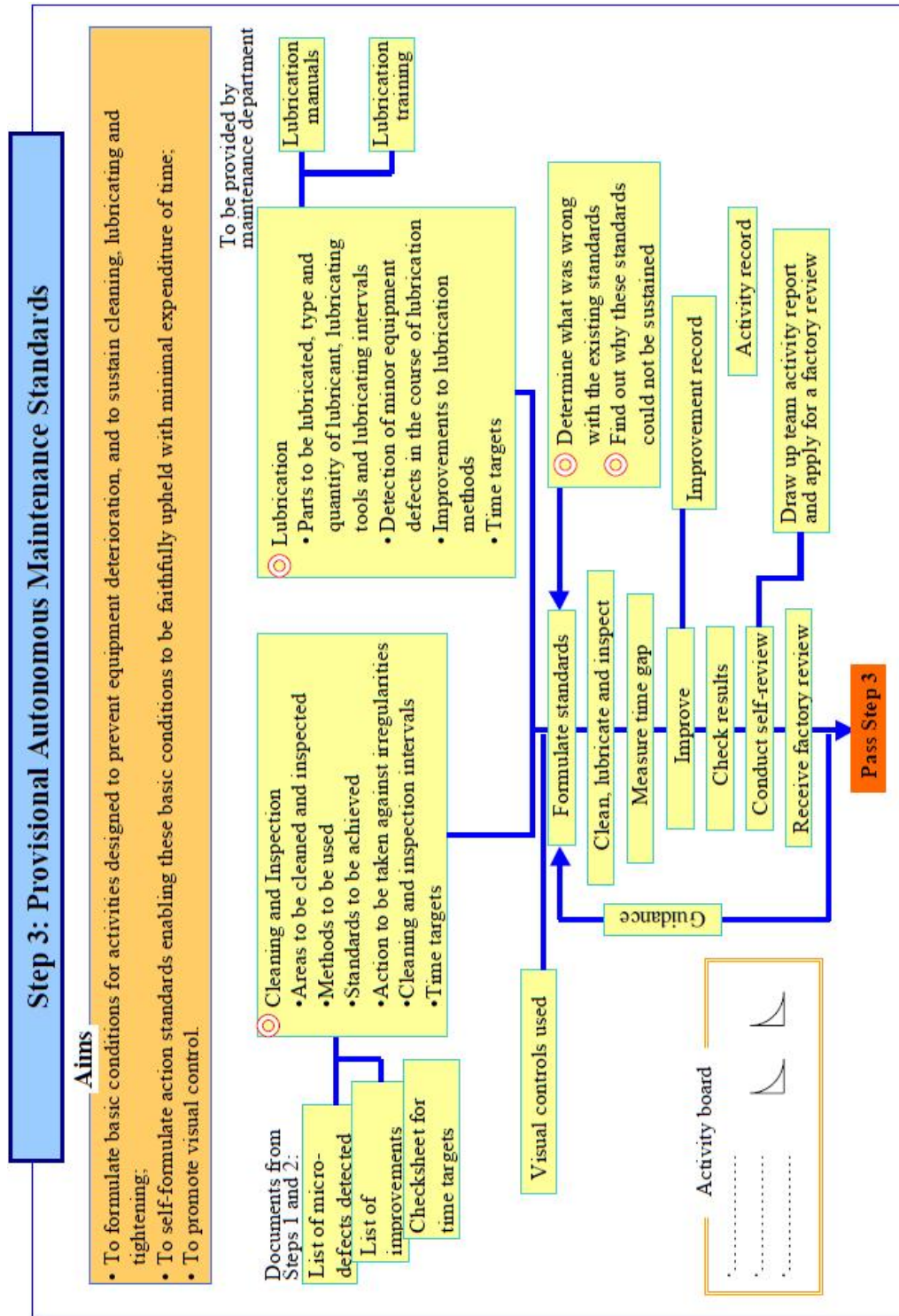


Figure 3.20. Workflow for Step 3 (Japan Institute of Plant Maintenance, 2003).

At the end of the step 3 all standards were reviewed. The target was 90% improvement at CIL time which was determined at first cleaning operation at step 1. The ECRS method was used for improving to reach the CIL time goal. ECRS stands for: E: eliminate, C: combine, R: replace, S: simplify

This methodology had to apply by a group of professional maintenance and autonomous maintenance teams. After their confirmations new checklist could be used. One ECRS application is given in Figure 3.24. One operation was reviewed, and then its frequency was improved from 2 times per month to one time per month.

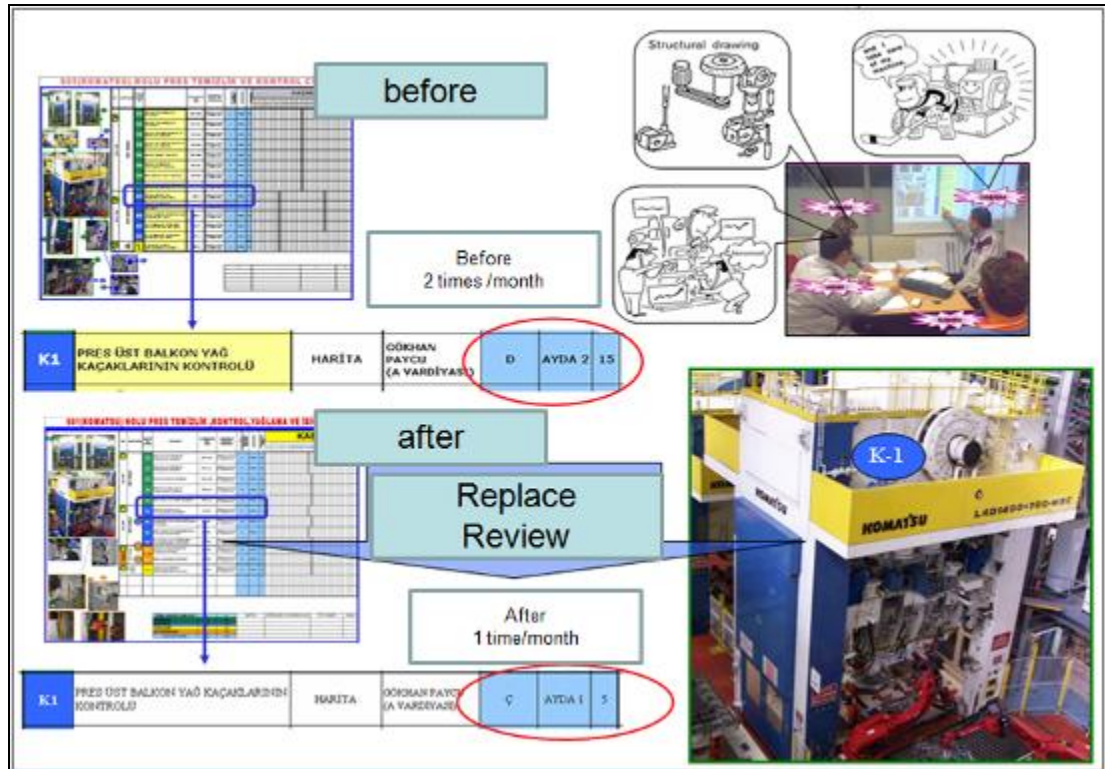


Figure 3.24. ECRS Method on Komatsu Standard Checklist.

About 3 months later, AM board and press line area were audited by WCM officers for step 3. Firstly step 1 and step 2 were reviewed quickly. The aim of step 3, activity plan and safety matters were examined. AM check lists and AM calendar usability were controlled. Tentative lubrication standards, lubrication educations and all skill matrixes were controlled by them. Also CIL time following and visual managements were viewed on AM board and on shop floor.

3.2.5. Step 4 Conduct General Equipment Inspections

Some factories don't apply next steps. Because much money must be spend at next steps. So, benefit and cost ratio must be estimated at the beginnings of the next steps. If the ratio is greater than one, the next steps can be applied at shop. With step 4 all future steps show different characteristic properties according to production type of factory. With this step more technical training about their equipments and process are given to operators. Operators are started to change from normal operator to engineer operator.

Equipments of line are focused and some control points are created in step 4. When the checking equipment, it is very important to pay close attention to minor abnormalities that could lead to breakdowns, quality problems and other chronic losses, identifying them precisely and taking effective action to eliminate them. To be able to do this, operators need to use the process of Step 4 to learn how to measure deterioration and predict when breakdowns and quality defects are likely to happen. Step 4 has two aspects which are equipment and human.

The first task of Step 4 in General Inspection is to establish the appropriate categories (fasteners, lubrication, pneumatics, hydraulics, drives, electrics, and so on). The next is to use the relay teaching method, one category at a time, to teach operators the structure and functions of their equipment, how to check it, and what criteria to use to assess how far it has deteriorated.

Having learned about a category, the operators use their knowledge to check their equipment, restore it, and make improvements. At the same time, they introduce visual controls and improve hard-to-check areas in order to make the checking easier and more efficient. They then incorporate their findings into standards for that category that will enable them to keep the equipment in its restored condition through a simple daily maintenance routine. They repeat this process until they have completed all the categories.

The aim of General Inspection training is to develop operators who are able to check their equipment effectively, recognize when parts have deteriorated or something is going wrong, and perform easy maintenance tasks. Through training

and hands-on experience, General Inspection lays the groundwork for developing operators who are thoroughly conversant with their equipment. Their self management skills progressively improve as they proceed through the categories one by one, spending two to three months on each.

If operators know and understand their equipment properly, they can learn all about its common elements and understand the basics of element components. Step 4, operators receive basic training in areas such as mechanical elements, bolts and nuts, lubrication systems, pneumatics, hydraulics, electrics, drive systems, equipment safety, and process conditions, and by applying this knowledge when inspecting the equipment, they become able to spot even the smallest defects. More details and basic workflow for step 4 is given in Figure 3.25.

In this study, the estimated benefit cost ratio of Komatsu has been greater than one (Figure 3.26). So, Step 4 has been started on this line. Line losses were focused in this calculation. Minor stoppages, causing some quality losses, were selected for improvements.

In this calculation, cost came from all theoretical and practical trainings, all meetings, some used equipments in kaizens, documents preparing, check list durations and etc in one year have been considered. All losses, in this category, were eliminated to equalize the benefit to all losses value.

After estimating the benefit cost ratio, robot arm minor stoppage losses were attacked by AM in Komatsu Line at Step 4. Robot arm were used at the end of the robots. They are used to keep parts with vacuum power during the part transfer from one location to another location (Figure 3.27).

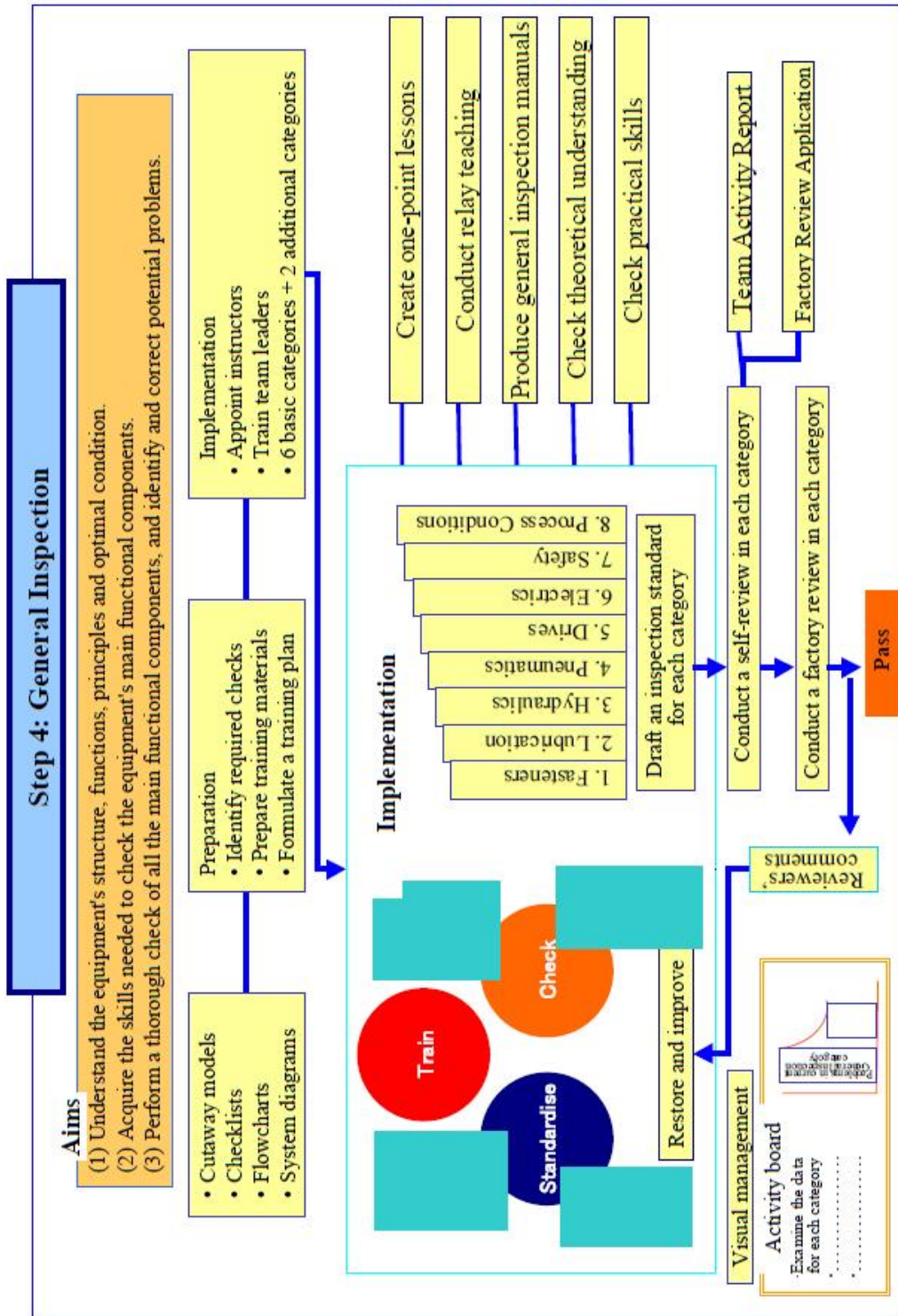


Figure 3.25. Workflow for Step 4 (Japan Institute of Plant Maintenance, 2003).

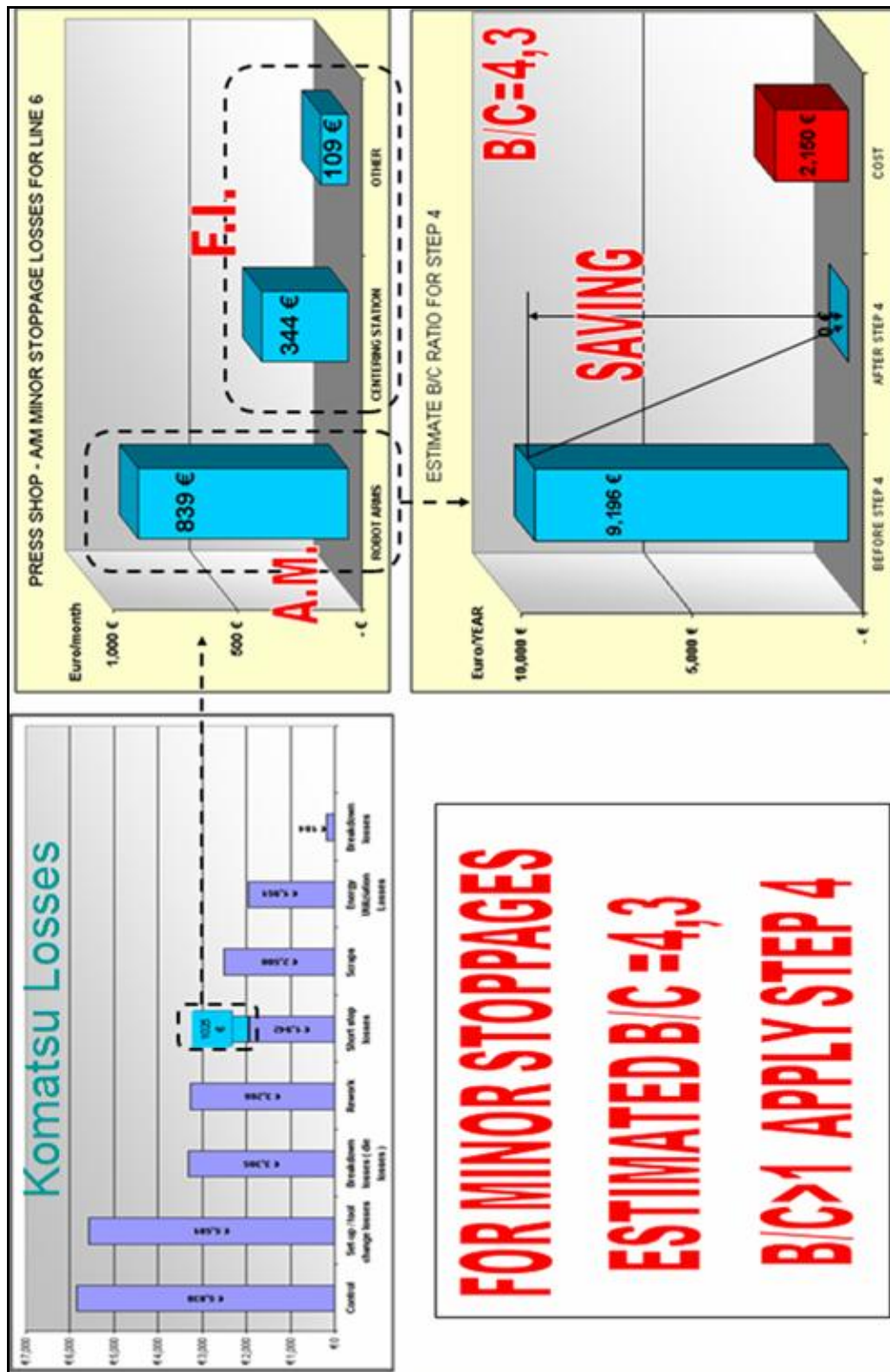


Figure 3.26. Estimated Benefits / Cost Ratio of Komatsu Line

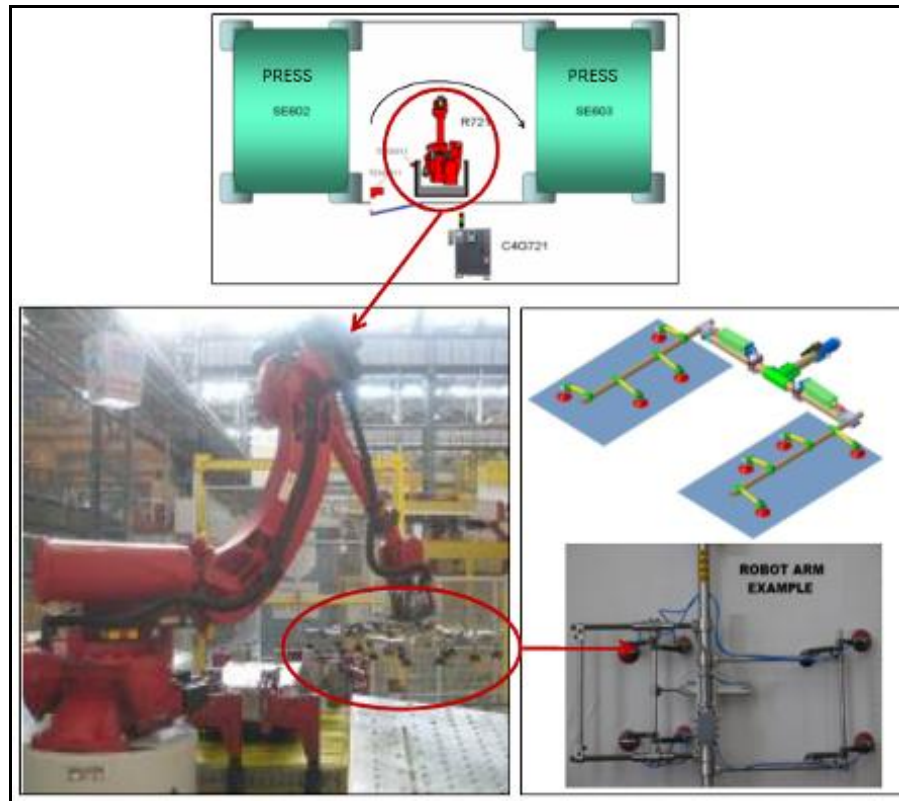


Figure 3.27. Part Transfer with Robot Arm

The key points in this process were followed to lean team leaders learned all things about the robot arm basic mechanisms and functions. They passed on this knowledge to their teams. The line operators used their experience obtained during training period to discover problems in the workplace. Visual controls were introduced wherever they could be.

The training program was prepared with PM groups. It was depended on the following two cases. Operators were learned to know about running their equipment correctly setting conditions, operating, doing changeovers, etc. Everyone might have understood their machines by Standard Maintenance Procedures. It is shown in Figure 3.28. They were prepared the summaries of the principles of operations and abnormal conditions of the machines. These must be learned and explained that wrong and abnormal conditions and control and inspections which must be carried out to keep the machines in good conditions.

STANDART BAKIM PROSEDÜRÜ			
Konu:	ROBOT KOLU ELEKTRONİK KONTROLLER		
Birim:	PRES Ü.M.	SBP no:	PRES-SBP K202
Ekip man ismi:	KOMATSU	Hazırlayan:	İBRAHİM BOZAĞAÇ
Ekip man no:	TÜMR601 ROBOT KOLLARI	Tarih:	12.04.2009
Bakım tipi:	<input type="checkbox"/> Arızı onarım <input checked="" type="checkbox"/> Periyodik kontrol <input type="checkbox"/> Periyodik değişim		
Bakım frekansı:	<input type="checkbox"/> Günlük <input type="checkbox"/> Haftalık <input type="checkbox"/> Aylık <input type="checkbox"/> 3 aylık <input type="checkbox"/> aylık <input checked="" type="checkbox"/> Üretim		
Kullanılacak Malzeme / Ekip man	Bakım süresi:	7	
GÖZ KONTROLÜ			
EL KONTROLÜ			
ÇELİK CETVEL			
Metod:			
	Süre (Dk)		
1- ÇİFT SAC SENSÖRÜNÜN VANTUZUNUN SAĞLAMLIĞINI KONTROL ET. PROBLEMLİ İSE DEĞİŞTİR	1		
2- ÇİFT SAC SENSÖRÜNÜN ELEK SOKETİNİN SAĞLAMLIĞINI KONTROL ET. PROBLEMLİ İSE DEĞİŞTİR	1		
3- GÜVENLİK SENSÖRÜNÜ VE KAPLOSUNU KONTROL ET. PROBLEM VAR İSE DEĞİŞTİR.	1		
4- ÇİFT SAC SENSÖRÜNÜN KOLA BAĞLANDIĞI SOKET GİRİŞİNİ KONTROL ET. PROBLEMLİ İSE DEĞİŞTİR	1		
5- ÇİFT SAC SENSÖRÜNE GİREN SOKETİ KONTROL ET. GEVŞEK İSE SIK	1		
6- ÇİFT SAC SENSÖRÜNÜN VANTUZU DİĞER VANTUZLARA ANZARAN 15 MM 20 MM DAHA AŞAĞIDA (PARÇAYA YAKIN OLMALI)	2		

STANDART BAKIM PROSEDÜRÜNÜ UYGULUYORKEN İŞ GÜVENLİĞİ KURALLARINA RIAYET EDİLMELİDİR

Figure 3.28. Standard Maintenance Procedure

For teaching the system better to the operators, robot arm was separated to its sub system as mechanic, pneumatic and electronic as shown in Figure 3.29. All sub systems were explained to operators step by step.

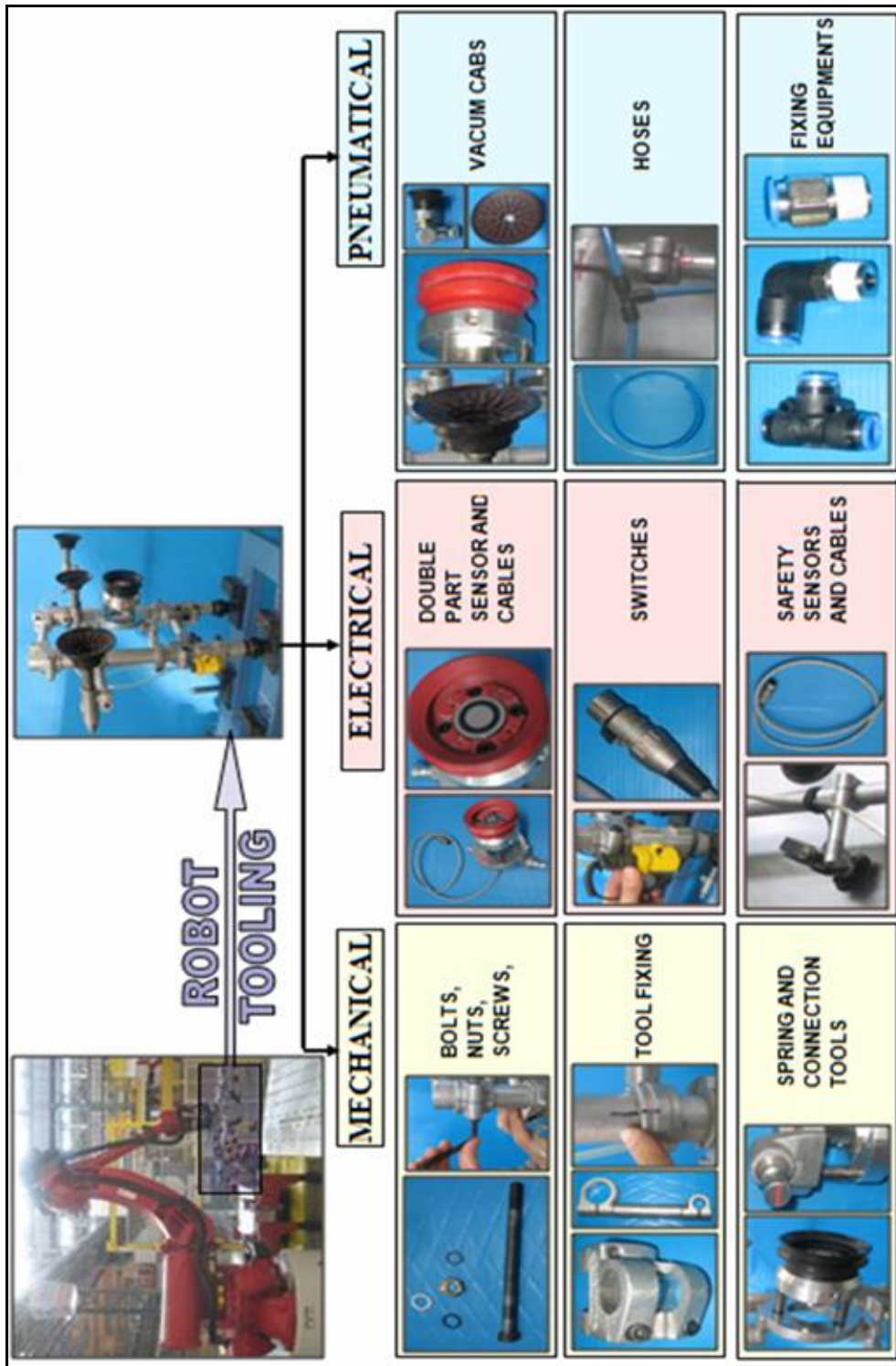


Figure 3.29. Robot Arm Sub System

Check points have been designated for mechanic sub system, electronic sub system and pneumatic sub system. Mechanic sub system check points card is shown in Figure 3.30. With this check sheets, it is started to survey existing maintenance records on quality defects, breakdowns, minor stoppages and other problems in order to identify in detail all the five-sense checks that it was considered necessary for the operators.

Civata, Somun ve Mekanik Parçalar İçin Kontrol Noktaları		
Civata ve Somun		<input type="checkbox"/> •Gevşek bir somun veya civata varmı_? <input type="checkbox"/> •Herhangi bir somun veya civata eksikmi?
Civata Uzunlukları		<input type="checkbox"/> •Tüm civatalar ve somunlar sıkıldıktan sonra 2-3 diş dışı çıkıntıları varmı_?
Rondela ve somunlar		<input type="checkbox"/> •Uzun deliklerde rondela kullanılmışımı_? <input type="checkbox"/> •açılı millere ve deliklerde konik rondela kullanılmışımı_? <input type="checkbox"/> •Titreşimli ortamlarda kullanılan yaylarda rondela kullanılmışımı_? <input type="checkbox"/> •Tanımlanan rondelalar tanımlanmış parçalarda mı kullanılıyor_?
Civata, somun Bağlantıları		<input type="checkbox"/> •Civataların altlarına somunları takılıımı_? Dışardan rahatça görülebiliyormu_? <input type="checkbox"/> •Swichler gibi sınırlayıcılar en az iki civata ile mi bağlanmış_? <input type="checkbox"/> •Yaylarda herhangi bir problem varmı_?

Figure 3.30. Mechanical Sub System Check Points

Also, lots of improvements were done and new standards were added to their standards according to result of check list. One improvement detail is given with standard kaizen in Figure 3.31. In addition to these, some new AM check list were prepared by using identified check points. Also, robot arm minor stoppages losses were monitored on AM board.

About 4 months later, AM board and press line area were audited by WCM office for step 4 again. Firstly passed steps were reviewed quickly. They questioned about all discovered defective parts were corrected. Then, all sub systems and their control points were controlled by them. Training documents, operators training plan and their skill matrix were controlled.

Until now, the next steps of WCM has not been implemented anywhere. This company wants to learn all details of AM application. So, they have decided to apply all next steps on Komatsu press line step by step. Then, they will expend to other lines.

Since Step 5, Step 6 and 7 have not ben applied, but some theoretical information is given in the future studies section of this study. This information includes step's activities, hardware (shop) goals, human goals and roles of managers and staff (fostering motivation, ability, and opportunity).

4. RESULTS AND DISCUSSION

As it was given in material method section, press shop in Komatsu Line has been selected by looking at two criteria. One of them was ABC line classification, the other one was cost deployment analyses diagram. Prepared ABC line classification table is shown in Table 4.1. This table was prepared with PM groups. The effect of production, quality of parts which are produced, cost and safety were important criteria's for line classifications. From 1 point to 10 point was given to lines at all categories with maintenance group. Then, all points were collected with each other. If the collected point is between 80 and 100 points, this line class is called AA.

Table 4.1. ABC Classifications of Lines

ABC CLASSIFICATION OF LINES														
NO	LINE	EFFECT TO PRODUCTION					QUALITY		COST		SAFETY		TOTAL	CLASS
		TOP OF THE LINE	WASTE	REWORK	CONTROL	MATERIAL	DEFECTS	REWORKS	PERCENTAGE	PERCENTAGE	PERCENTAGE	PERCENTAGE		
1	1	1	5	1	10	5	10	5	5	10	1	53	B	
2	2	1	5	1	10	5	10	5	5	10	1	53	B	
3	3	1	5	1	10	5	10	5	5	10	1	53	B	
4	4	10	1	5	10	10	10	5	10	10	5	76	A	
5	5	10	10	1	10	5	10	5	10	10	5	76	A	
6	6	10	10	5	10	10	10	5	10	10	5	85	AA	
7	BEKUM	1	10	1	10	5	10	5	5	10	5	62	A	
8	RBK	1	10	1	10	5	10	5	5	10	5	62	A	

In addition to this, The results of Cost Deployment analysis is given in Figure 4.1. All line losses which are breakdown, set up, rework, die losses, control losses and material losses values were shown in this diagram. Then all breakdowns were separated according to line type as shown in Figure 4.2. Komatsu line which is called line 6 had maximum breakdown losses in this press shop. These breakdown losses included the lack of AM and PM maintenance. So, Komatsu press line has been selected as a pilot line for this study.



Figure 4.1. Press Shop Cost Deployment Diagram

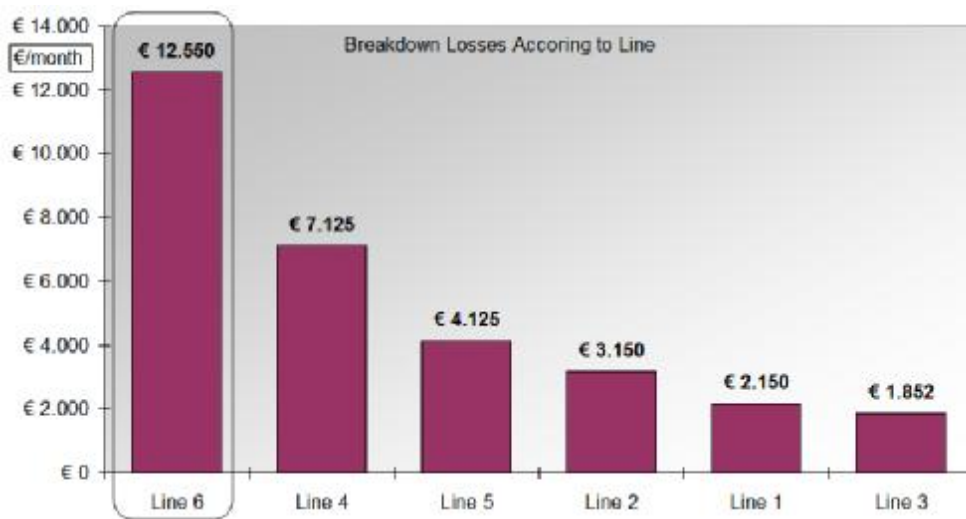


Figure 4.2. Breakdown Losses According to Line

Also, OEE is used a major key performance indicator at factories. OEE introduces availability, performance and quality. Therefore, it has been used as a key metric in this study. The aim is to get a consistent way to measure the effectiveness of AM and other initiatives by providing an overall framework for measuring production efficiency. Komatsu line's OEE was calculated for one shift at the beginning of this study. Referenced shift duration distribution is given in Table 4.2.

Table 4.2. One shift duration distribution of Komatsu Press Line

Item	Data
<i>Shift Length</i>	540 minutes
<i>Short Breaks</i>	20 minutes
<i>Meal</i>	30 minutes
<i>Down Time</i> (breakdown + minor stoppages + set up + adj.)	120 minutes
<i>Ideal Run Rate</i>	10 pieces per minutes
<i>Total Pieces</i>	3,250 pieces
<i>Reject Pieces</i> (repairs + scraps)	223 pieces

At the beginning of this study, press shop was working 2 shifts with 9 hours, so
 $9 \text{ hours /shift} \times 2 \text{ shift/day} = 18 \text{ hours/day}$.

One shift length was taken 9 hours => $9 \text{ hours} \times 60 \text{ minutes} / 1 \text{ hour}$
 $= 540 \text{ minutes}$

They were 2 short breaks with 10 minutes => $2 \times 10 \text{ minutes} = 20 \text{ minutes}$

Meal Break was given 30 minutes.

45 minutes breakdown, 28 minutes minor stoppages, 26 minutes set up and 21 minutes adjustment occurred in this shift. Down time was calculated as;

Down time=Breakdowns losses + Minor Stoppages losses + Set up losses +
 Adjustment losses = $45 \text{ minutes} + 28 \text{ minutes} + 26 \text{ minutes} + 21 \text{ minutes}$
 $= 120 \text{ minutes}$

10 pieces can be produced per minute in Komatsu line. So, ideal run time was taken 10 pieces /minute.

In addition to these, at the end of the reference shift totally 3,250 pieces were produced in this line but 223 reject pieces were found in these parts.

Initially, OEE was found by using the following relationship;

OEE= Availability x Performance x Quality (Nakajima, 1988).

Where;

Availability took into account Down Time Loss, and is calculated as:

Availability = Operating Time / Planned Production Time

Planned Production Time = [Shift Length - Breaks] = [540 - 50] = 490 minutes

Operating Time = [Planned Production Time - Down Time] = [490 - 120] =

370 minutes

The result found for the Komatsu press line availability value at the beginning of AM:

Availability = 370 minutes / 490 minutes = 0.7551 (75.51%)

Performance takes into account Speed Loss, and is calculated as:

Performance = Ideal Cycle Time / (Operating Time / Total Pieces)

Ideal Cycle Time was the minimum cycle time that the process and it could be expected to achieve in optimal circumstances. Since Run Rate was the reciprocal of Cycle Time. Performance could also be calculated as:

Performance= (Total Pieces / Operating Time) / Ideal Run Rate

The result found for the Komatsu press line performance value at the beginning of AM:

Performance = [(3,250 pieces / 370 minutes) / (10 pieces /minute)]
= 0, 8783 (87, 83%)

Quality takes into account Quality Loss, and is calculated as:

Quality = Good Pieces / Total Pieces

Good Pieces = [Total Pieces - Reject Pieces] = [3,250-223] = 3,027 pieces

The result found for the Komatsu press line quality value at the beginning AM:

Quality = 3,027 pieces / 3,250 pieces = 0, 9314 (93, 14%)

Also, Komatsu OEE was calculated,

OEE = Availability x Performance x Quality

OEE= 0, 7551 x 0, 8783 x 0, 9314 = 0, 6177 (61, 77%)

In practice, generally the World-Class OEE has been accepted 85.00 % (Nakajima, 1988). Detail of this OEE is given in Table 4.3. At the beginning of this study, it was targeted to reach the accepted World Class OEE value.

Table 4.3. World-Class OEE (Nakajima, 1988)

OEE Factor	World Class
<i>Availability</i>	90.0%
<i>Performance</i>	95.0%
<i>Quality</i>	99.9%
<i>Overall OEE</i>	85.0%

Preparing and first four steps have been applied in this study and emphasis has been given on eliminating forced deterioration and sustaining basic conditions with autonomous maintenance.

All safety risks were collected in Table 4.4. , and they were shown on line layout. This layout is given in Figure 4.3. Before and after safety risk effects, safety risk probabilities, safety discernible and its ranks were given on this list. They have been eliminated by operators and line engineer with kaizens. Before starting to AM steps totally 37 safety risks points were determined at preparation steps.

Table 4.4. Komatsu Press Line Safety Risk List

OTONOM BAKIM ÇALIŞMALARININ RİSK DEĞERLENDİRMESİ													
MAKİNA NO	KONİMATSU YAPILACAK İŞ	TEHLİKE	TARİH :		RİSK	RİSK	ÖNLEM	ÖNLEM SONRASI		RANK			
			ETKİ (1)	OLASILIK (2)				ETKİ (3)	OLASILIK (4)				
1	P801 Presin zemin temizliğinin yapılması	Jüstiye	2	1	2	4	RİSKLİ	Hata Gözlel uyarı tırtili zaidi. Kırıy an. İş avaklar. ve a şıfı n b. anlık uyarı tırtili uyarı olmasına dikkat edilicek. (İMF -P-801K)	2	1	1	2	İHMAL EDİLEBİLİR
			3	3	1	9	TEHLİKELİ	Hata Gözlel uyarı tırtili zaidi. Kırıy an. İş avaklar. ve a şıfı n b. anlık uyarı tırtili uyarı olmasına dikkat edilicek.	2	1	1	2	İHMAL EDİLEBİLİR
			1	1	2	2	İHMAL EDİLEBİLİR	İHMAL EDİLEBİLİR	1	1	2	2	İHMAL EDİLEBİLİR
			2	2	2	8	TEHLİKELİ	Hata Gözlel uyarı tırtili zaidi. Kırıy an. İş avaklar. ve a şıfı n b. anlık uyarı tırtili uyarı olmasına dikkat edilicek.	2	1	1	2	2
2	Platform ve bariyer temizliğinin yapılması	Duşum	2	1	2	4	RİSKLİ	Hata Gözlel uyarı tırtili zaidi. Kırıy an. İş avaklar. ve a şıfı n b. anlık uyarı tırtili uyarı olmasına dikkat edilicek.	2	1	1	2	İHMAL EDİLEBİLİR
			2	1	2	4	RİSKLİ	Hata Gözlel uyarı tırtili zaidi. Kırıy an. İş avaklar. ve a şıfı n b. anlık uyarı tırtili uyarı olmasına dikkat edilicek.	2	1	1	2	İHMAL EDİLEBİLİR
			2	1	1	2	İHMAL EDİLEBİLİR	İHMAL EDİLEBİLİR	2	1	1	2	İHMAL EDİLEBİLİR
			2	1	1	2	İHMAL EDİLEBİLİR	İHMAL EDİLEBİLİR	2	1	1	2	İHMAL EDİLEBİLİR

ETKİ:	OLASILIK:	FARK EDİLEBİLİRLİK:	RANK:
BELİRGİN 3	YÜKSEK 3	MÜMKÜN DEĞİL 3	ÇOK TEHLİKELİ 18-27
ZAMAN KAYBI 2	ORTA 2	DÜŞÜK OLASILIK 2	TEHLİKELİ 8-12
ZAMAN KAYBI YOK 1	DÜŞÜK 1	YÜKSEK OLASILIK 1	RİSKLİ 2-6
ETKİ YOK 0	YOK 0	KEBİNLİKLE 0	İHMAL EDİLEBİLİR 0-2

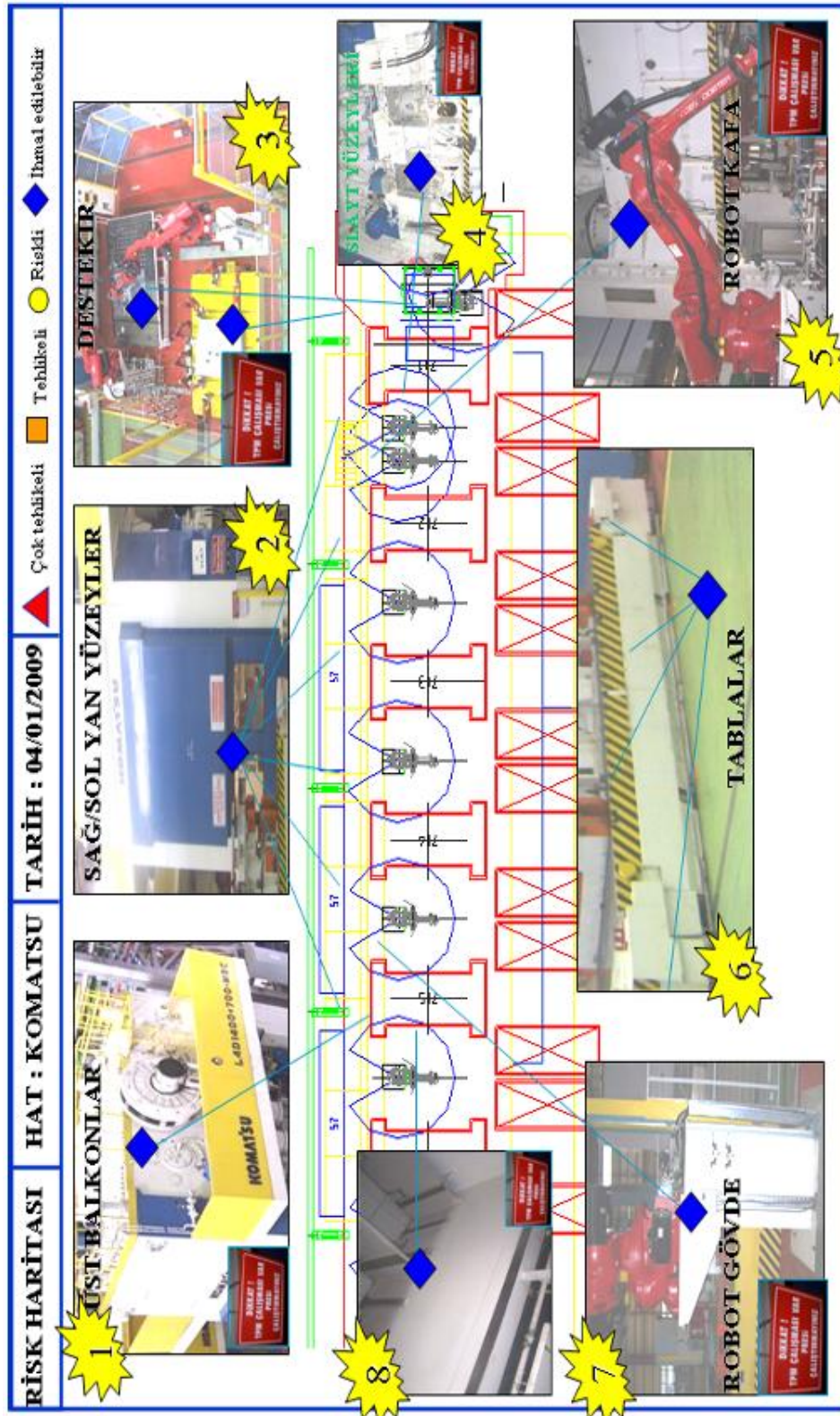


Figure 4.3. Komatsu Press Line Safety Risk Layout

After the preparation step, operators searched out and eliminated equipment abnormalities, instituted counter measures against contamination sources and hard-to-access areas, and developed provisional cleaning, checking and lubricating standards in first three steps. Then step 4 applied for reducing quality losses by using equipment control and some improvements.

Step 1 was an initial cleaning step of AM application. Initial cleaning of equipment was the heart of autonomous maintenance. As operators cleaned, they inspected the equipment for abnormalities that could cause bigger problems in the future. When they were noticed abnormalities so that problems didn't happen again.

All operators recognized that cleaning in autonomous maintenance means deep cleaning and inspection of every part of the machine. This inspection would naturally reduced abnormalities and problems. These abnormalities and problems were exposed by attaching failure tags to each problem. If operators could fix the problem easily, they might do it their selves, or they might need to ask for maintenance assistance. OPLs were used as major education tools in this study. 225 one point lessons have been created and they have been given to Komatsu Press Line operators. Step by step, given number of OPL for Komatsu line is shown in Figure 4.4.

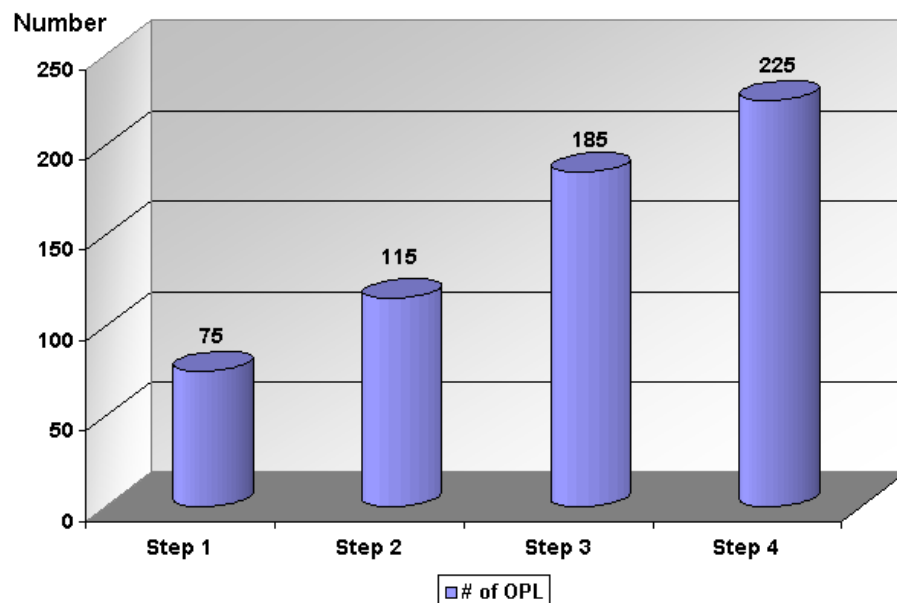


Figure 4.4. Number of OPL for Komatsu Line

From step 1 to the end of step 4 they have been managed more than 300 tags within this period. AM failure tags were attached by line operators and they were removed by PM and AM operators. Lots of potential problems uncovered in each category, lots of major defects discovered and eliminated with tags management. Opened and closed failure cards were followed on AM Failure Card Following Graph in Figure 4.5. This graph was filled by lean team leader with hand weakly. Also open and closed card types, the groups who have closed (AM or PM) the cards were followed with this graph. This graph was shown on AM activity board, too.

Number of opened and closed tags used in each step is shown in Figure 4.6. As it is seen in this figure, attached and removed failure tags number was increasing with step 2 and step 4. Because, lots of contamination sources and hard to access areas have been described with tags and they have been eliminated at step 2. In addition to this, operators learned more specific details about their machines at step 4. So, they used autonomous maintenance tags commonly at step 4.

During inspection, operators looked not only for static problems that were visible even when the machine was not running, but also for dynamic problems that appear during operation. Some important problems could be found during the inspection. For example dirt or grime, leaks or spattering, sagging or play, missing or removed parts, warping or wear, rust or scratches, tilting or off-center parts, abnormal movement, vibration or shaking, unusual sounds or abnormal heat, unusual smells or discoloration could be found by operators.

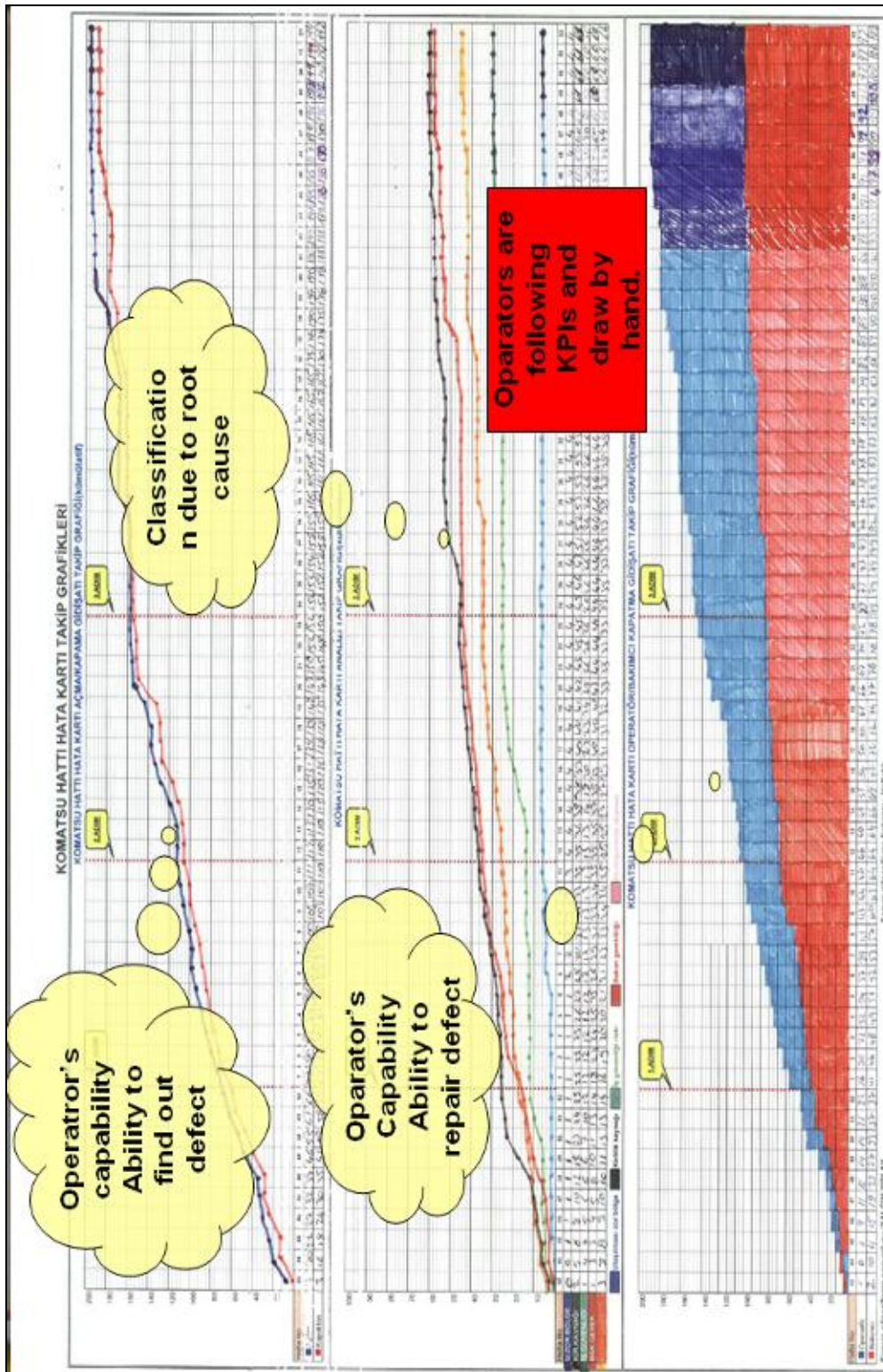


Figure 4.5.. AM Failure Card Following Graph

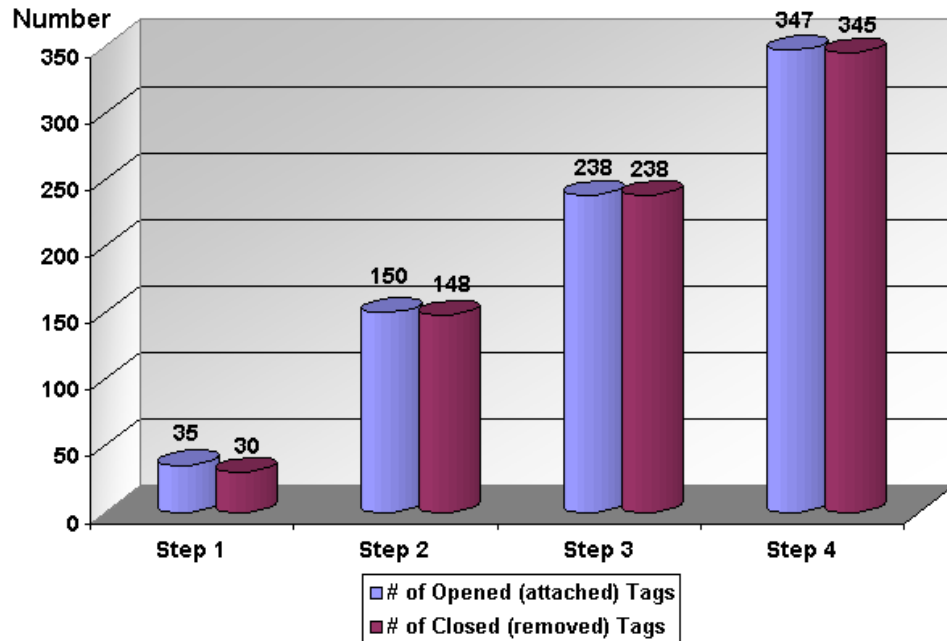


Figure 4.6. Komatsu Press Line Failure Tag Management Diagram

Initial cleaning time was measured immediately. First cleaning, inspection and lubrication (CIL) durations were determined with its. At future steps operators would work to decrease this duration. It has been monitored at each step as shown in Figure 4.7. This indicator has been shown on AM board. The reasons of improving were shown on this graph with their kaizens numbers. Every week it has been filled by lean team leaders.

Four senses were used during cleaning and inspection, including seeing, listening, smelling, and touching the machine. It was a hands-on process that should reach every area of the machine, using simple checklist to cover various parts and system. Operators who discovered and tagged equipment problems had be ones to fix them and removed the tags. Sometimes it was helpful to have diagnostic team that includes managers and maintenance and engineering specialist review that tags to help determine what to do about them.

On the other hand this joint approach helped operators develop equipment skills by focusing attention on problems and by offering examples and guidance. Some of the problems found due to abnormal conditions in Komatsu line are shown in Figure 4.8.

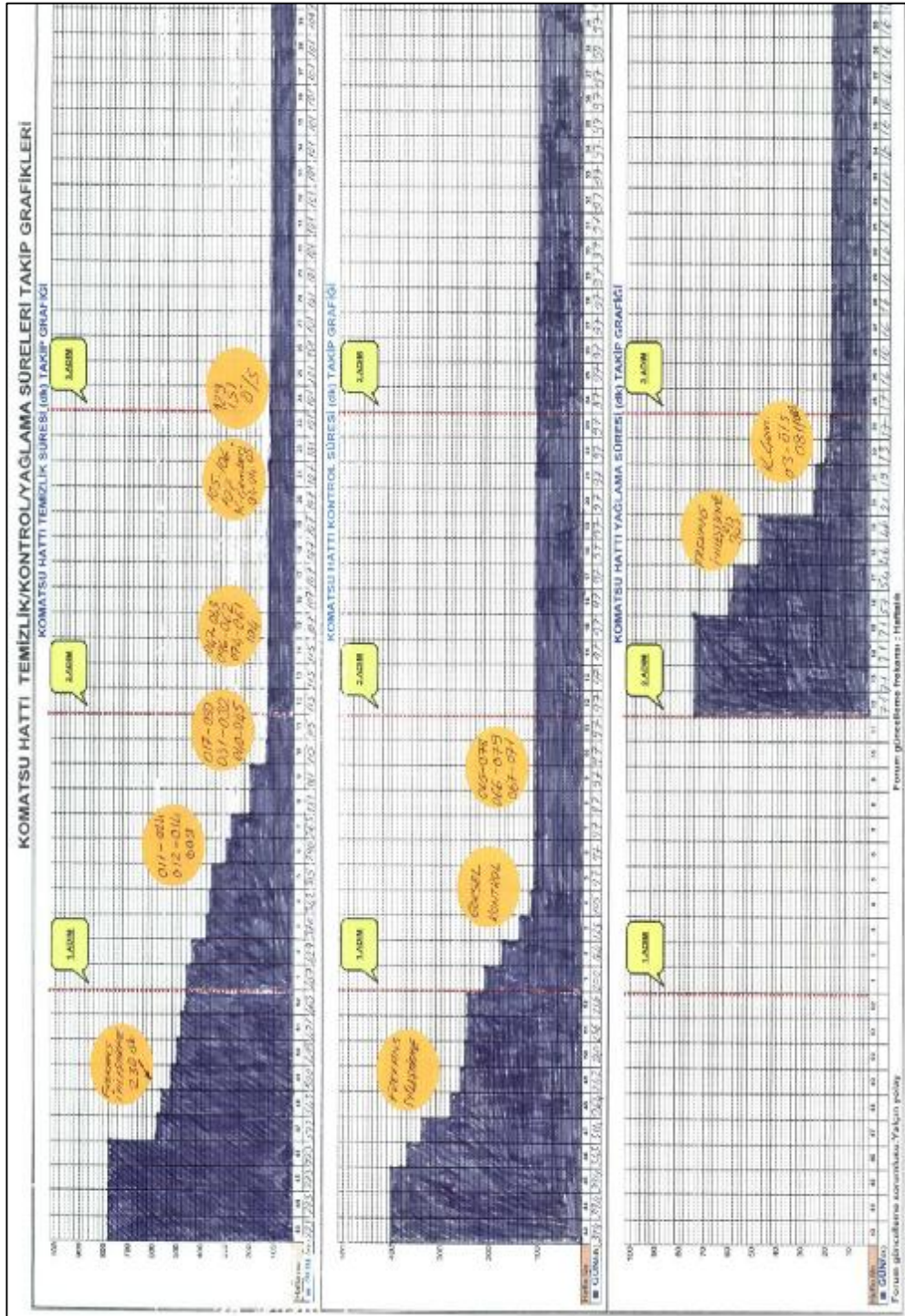


Figure 4.7. CIL Duration Follow Graph

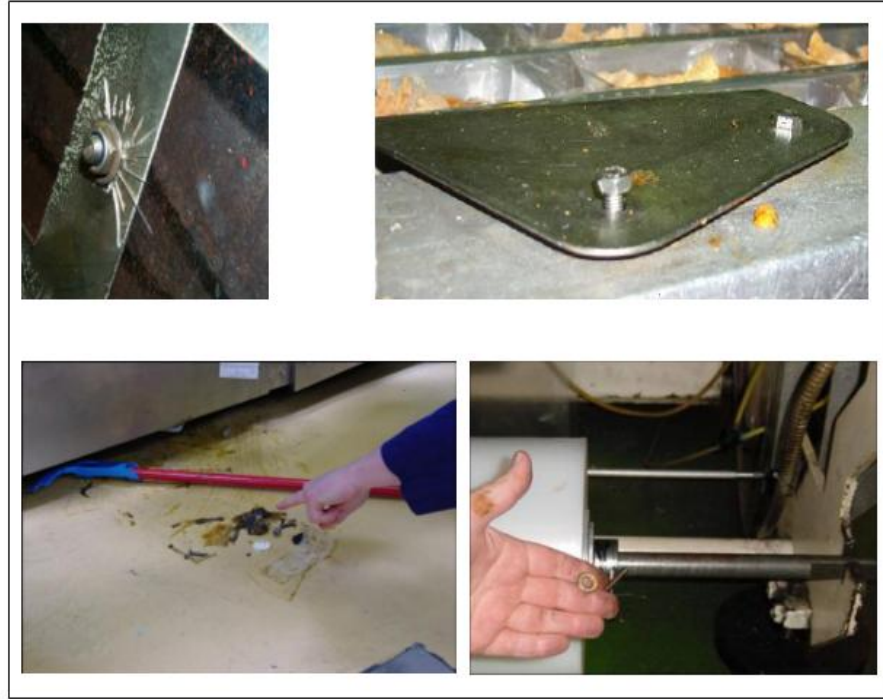


Figure 4.8. The Abnormal Conditions in Komatsu

At the end of the Step 1 applications, line was audited and Step 1 Audit Report (Figure 4.9.) has been given to AM group. Also this report was put to AM board.



Figure 4.9. Step 1 Audit Report

At Step 2, preventing accelerated deterioration was taken as a key purpose of AM. Operators learned about deterioration that referred to wear that eventually causes equipment to break down or produce defects by using OPLs. Some deterioration was natural, even when equipment was used correctly. Accelerated deterioration was deterioration that happens sooner than it naturally would. It usually resulted from failure to do something operators ought to do- for example, not keep parts clean and lubricated. Keeping the working area clear of scattered debris such as cutting sheet metal parts from dies and oil from presses were taken as important concepts in reducing accelerated deterioration.

Localized containment was a more effective approach for controlling scattered debris. This is done by making guards as small as possible (localization) and by bringing them as close as possible to the source of contamination (containment). Localized containment was a key strategy in step 2 of AM, which has focused on removing the sources of problems and eliminating inaccessible areas. Totally 49 points of remaining contamination sources and hard-to-access areas were improved at step 2. As it is given in Figure 4.10, these improvements were continued at the end of step 4.

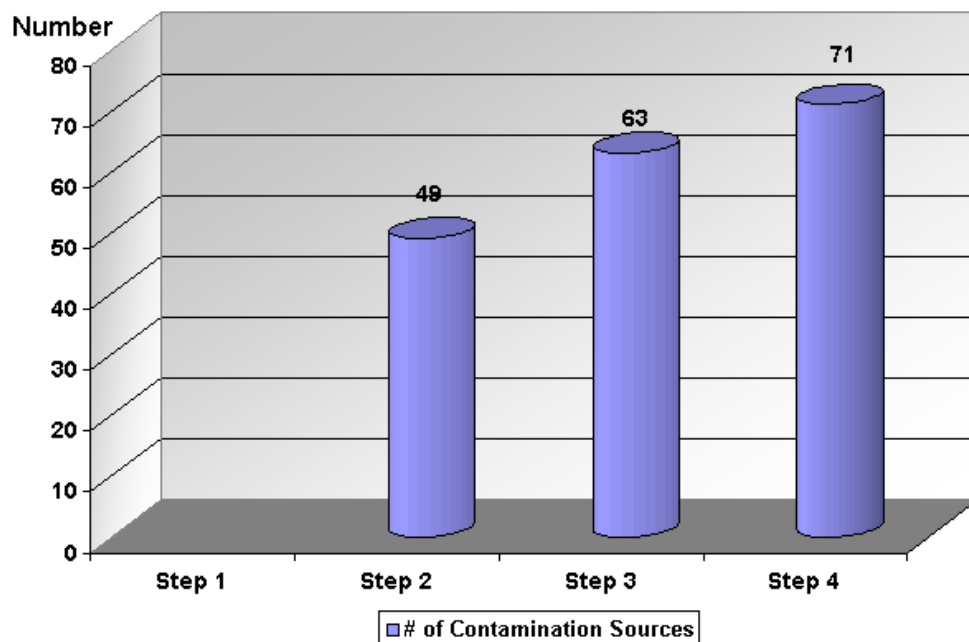


Figure 4.10. Eliminated Contamination Sources and Hard to Access Areas

Dirt and grime didn't penetrate to the critical functional parts of equipment. So, deterioration because of contamination sources dropped with improving at step 2. This reduced breakdowns considerably. It made cleaning, lubrication and inspection quicker and more through. Oil application and other machining conditions could be checked easily. Some examples of contamination sources and hard to access areas from Komatsu Press line are given in Figure 4.11.

As localized containment was installed to control scatter, natural deterioration patterns replace accelerated deterioration, and the number of machine breakdowns usually dropped dramatically. When breakdowns became rarer and take up less time, quality defects from of scrap and rework typically drop as well.

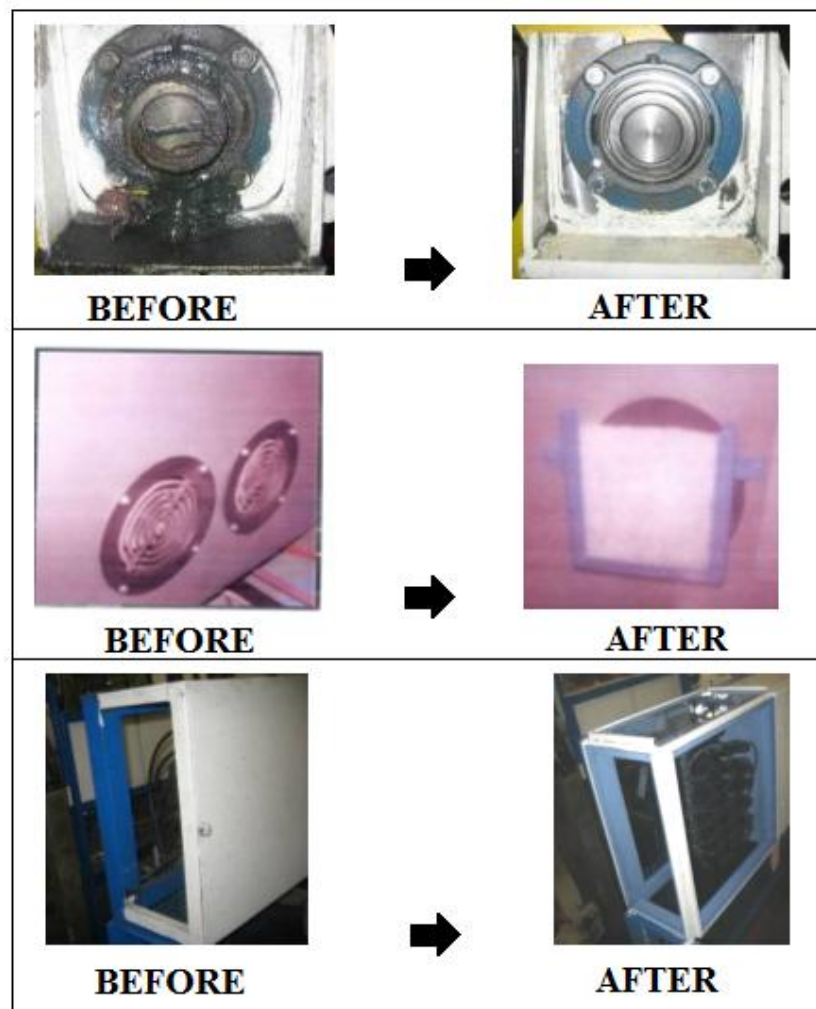


Figure 4.11. Contamination Sources and Hard to Access Areas Examples

After the Step 2 audit, Step 2 Audit Report (Figure 4.12.) has been given to AM group. Also this report was put to AM board, too.

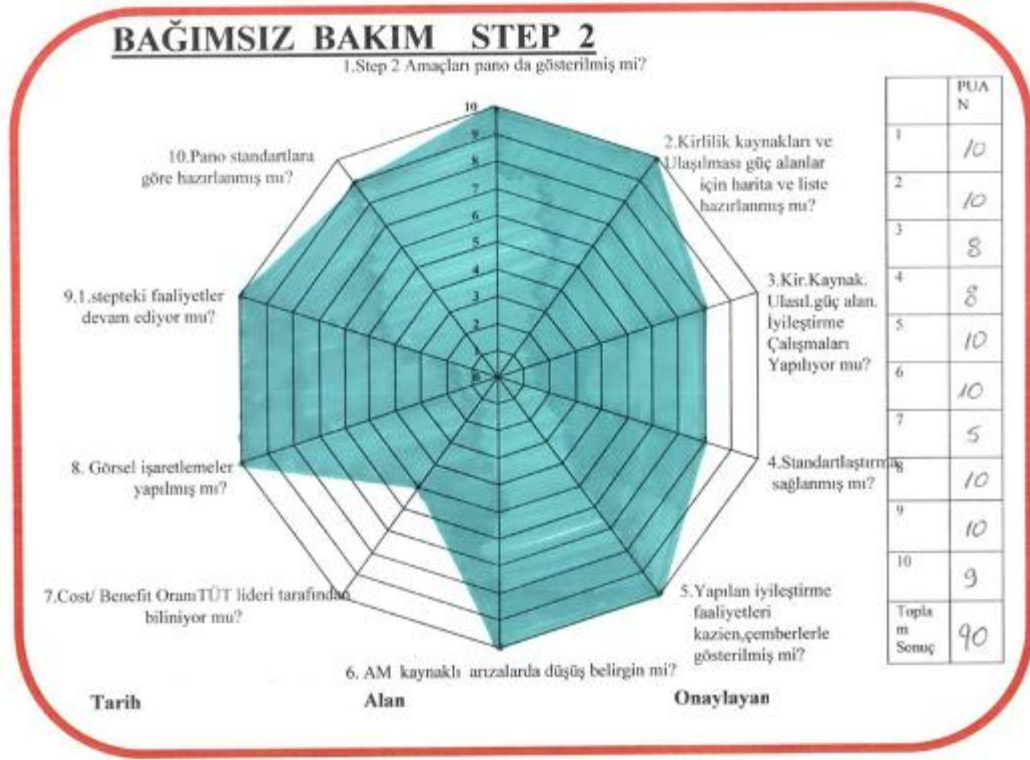


Figure 4.12. Step 2 Audit Report

At Step 3, according to breakdown analyses at Komatsu line, poor lubrication caused about 60 percent of all breakdowns. So, some simple lubrication duties have been transferred from PM to AM. One point has been found in robot, one point has been found in press, one point has been found in moving table, one point has been found in destecker, and one point has been found in equipment in basement. According to equipment number, totally 35 lubrication duties have passed to AM group. Lubrication trainings were given to operators from PM to AM group for these duties. One lubrication OPL example is given in Figure 4.13. During general inspection and lubrication training, operators learned about lubrication management and how to add just right amount of right lubricant at the right time.

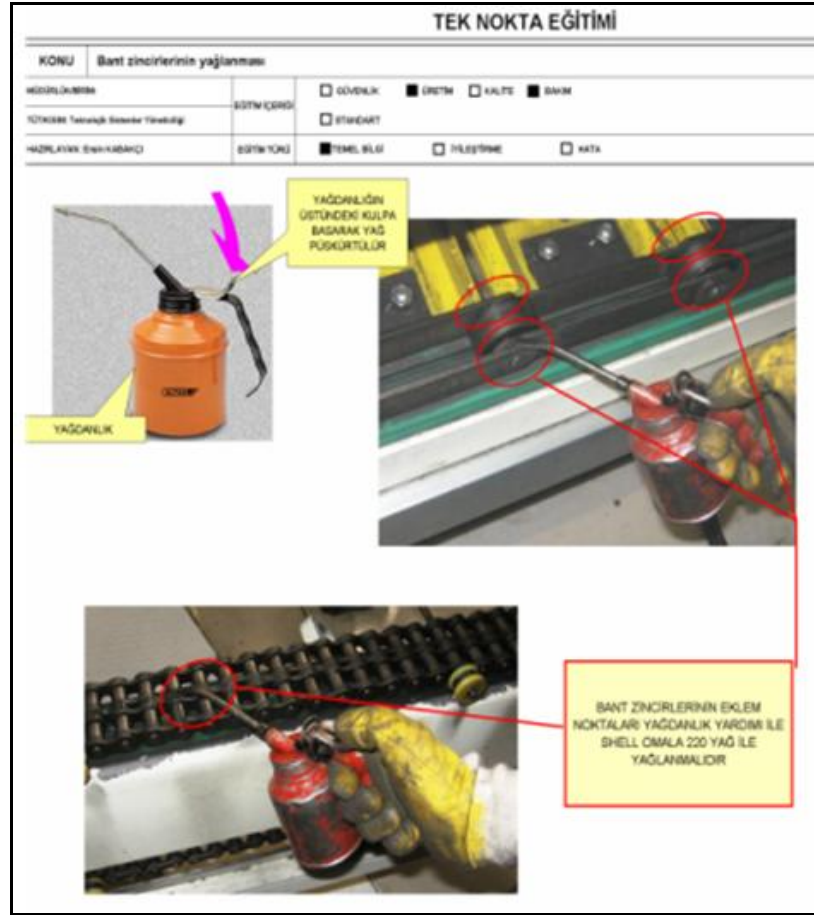


Figure 4.13. Lubrication OPL Example

Lubricants reduce the friction resistance caused when physical objects move in contact with one another. Lubrication reduces wear and eliminates heat caused by friction. It is also used to prevent rusting caused by moisture and to wash away debris. Therefore, various types of lubricants were used for different purposes. So, lubrication station was prepared near the line as shown in Figure 4.14.

Adding lubricant at the right time was crucial at this study. Hence, a lubrication schedule should be established in accordance with the equipment operating manual. Using the right amount of lubricant was also important. Too much lubricant could cause leaks, lower viscosity, and lead to deterioration of the lubricant. Too little lubricant could reduce the effect of lubrication by reducing film of oil and cause scuffing and burning. Using the right method to add lubricant assures that right

amount was applied at the right time. Specified tools and inlets were used with clean lubricant and, fluid level was checked in accordance with type of lubrication system.



Figure 4.14. Lubrication Station of Komatsu Line

Also, visual management was helped to avoid lubrication errors. Color codes used in the lubricant containers, inlets on the equipment, and lubrication tools were used in area to ensure that the use of right type of lubricant.

After determining the standard of lubrication, autonomous maintenance standards were prepared. Standards were created for all equipments in Komatsu Line. They have included cleaning, inspection and lubrication activities. 351 standards were determined for 9 robots, 6 presses, 12 moving tables 2 desteckers and equipment in basement. Numbers of standards for all equipments are shown in Table 4.5.

Table 4.5. Komatsu Press Line Standards According to Equipments

EQUIPMENT	NUMBER	STANDARS				TOTAL POINTS
		The Number of Cleaning Points	The Number of Inspection Points	The Number of Lubrication Points	The Number of Safety Control Points	
Robots	9	2	5	1	1	81
Presses	6	5	4	1	2	72
Moving Tables	12	3	6	1	1	132
Desteckers	2	3	5	1	0	18
Equipment in Basement	6	2	5	1	0	48
					TOTAL	351

With first three steps operators have discovered some rules in their work life such as; ‘Cleaning is inspection’ (cleaning should not just be cleaning for its own sake, but ‘cleaning with meaning’; i.e. cleaning for the purpose of finding problems), ‘Inspection is detection’ (careful inspection of the equipment while cleaning it will reveal all kinds of imperfections), ‘Detection is correction’ (discovering a problem provides the motivation for correcting it and making further improvements).

All standard’s duration has been monitored as CIL time on AM board. This was carried out for finding and eliminating contamination sources and hard to access areas. To apply the standards have reduced CIL time step by step. On the other hand the application of ECRS methodology has caused reduction in CIL time from 1450 minutes / month to 167 minutes at the end of step 4. As a result of this operation, 90 %, 91, 5 % and 83 % improvements were obtained respectively in cleaning, inspection and lubrication times respectively as shown in Figure 4.15.

In addition to these, AM breakdowns have been monitored on AM board too. These breakdowns have been rapidly reduced from 350 minutes to 45 minutes at the end of the step 3 with applying standards and preparing kaizens. Reduced AM breakdowns are shown in Figure 4.16. Beginning AM breakdowns was taken from Breakdown Analysis According to Line which had been given in Figure 4.2.

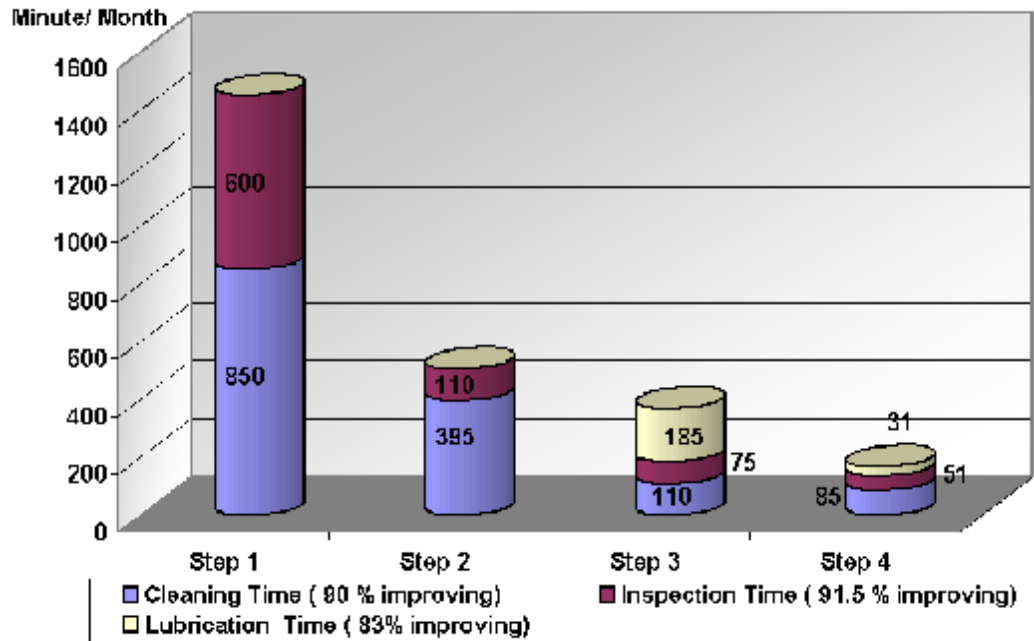


Figure 4.15. Reduction in CIL time of Komatsu Line

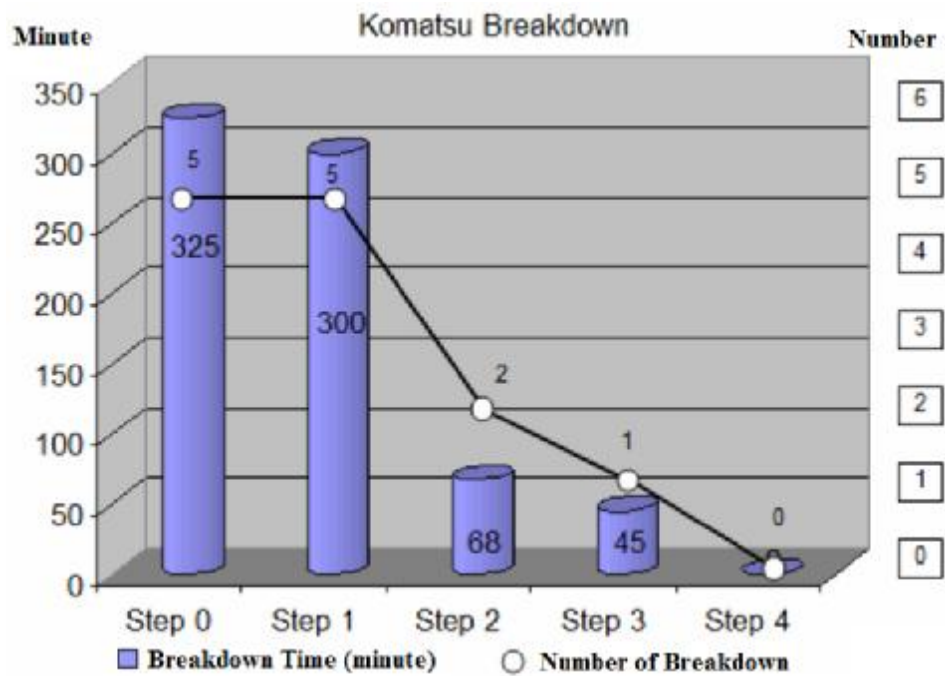


Figure 4.16. AM Breakdowns at Komatsu Line

After the Step 3 audit, the successful audit report shown in Figure 4.17, was given to Komatsu line for step 3. Also this report was put to AM board, too.

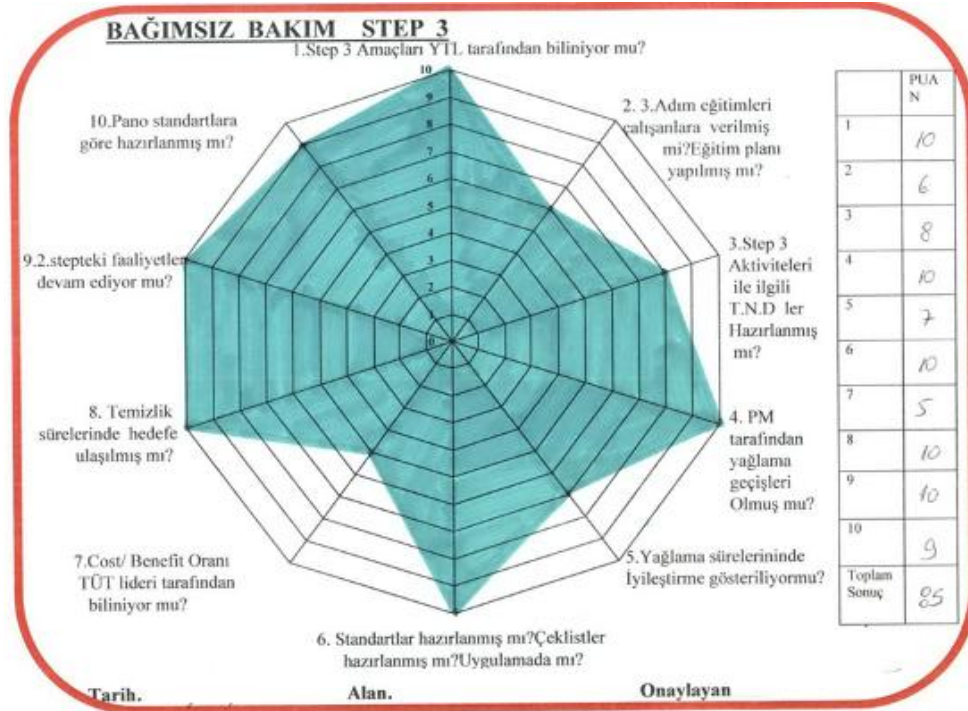


Figure 4.17. Step 3 Audit Report

Lots of repair and scrap parts were produced because of equipment failures. Normally, to prevent losses of quality, line was stopped and the equipment was being repaired. So, minor stoppages were created in line. Therefore, efforts has been focused the elimination of these types of minor stoppages in step 4.

Losses were analyzed by PM group in order to clear the minor stoppages from the robot arm as targeted in step 4. 130 minutes / month (839 € month = 9,196 € / year) robot arm losses were found in the line. Before step 4, benefit cost ratio had to be calculated. If the calculated ratio is greater than one, the step 4 could be applied, if the calculated ratio is less than one, these losses could be attacked by FI (Figure 3.7). It has been estimated that these losses would reset all. So, 9,196 €/year was taken as benefit. Also, estimated cost was taken 2149 € / year. Estimated cost details are summarized in Table 4.6.

Table 4.6. Estimated Cost Details for First Benefit / Cost Ratio Calculation

COST	Number / Yaer	Blue Collar Number	White Collar Number	Duration (hour)	Blue Collar Euro / 1 hour	White Collar Euro / 1 hour	Kaizen Equipment Euro / 1 Kaizen	Check List Euro / year	Total
Class Training	2	18	2	2	10	15			372 C
Practical Training	2	18		3	10				108 €
Meeting	4	2	2	1	10	15			308 €
Kaizens	15	8		1	10		50		830 €
Check List Application	3							177	531 C
TOTAL COST / YEAR									2.149 C

Benefit / Cost ratio was calculated as $9196 \text{ €} / 2149 \text{ €} = 4,3$. So, these losses were attacked by AM groups with step 4. Firstly, totally 15 Standard Maintenance procedures were prepared about equipment and their control points by line engineers. These procedures were told to operators with trainings. Then equipments were divided by sub systems such as mechanical, electronically and pneumatically. And check lists were prepared for all equipment by line engineers and then they were applied to line by operators.

When the abnormal conditions were found in the line, operators prepared kaizens for improving them in step 4. Totally 18 improving kaizens were prepared by operators. Also, robot arm minor stoppages losses were monitored in graph with Figure 4.18 on AM board. Lean team leader were filling it weekly. At the end of the step four, robot arm minor stoppages were came to zero.

Realized cost was calculated 2,960 Euro in Table 4.7. Then, realized benefit/cost ratio was calculated as $9,196 \text{ Euro} / 2,690 \text{ Euro} = 3,42$. This value was satisfactory for step 4 application. Because, 2,690 € was spent, 9,196 € was gained in step 4. The net gain of Step 4 was calculated as;

Gain of Step 4 = Benefit - Cost = $9,196 \text{ €} / \text{year} - 2,690 \text{ €} / \text{year} = 6,506 \text{ €} / \text{year}$

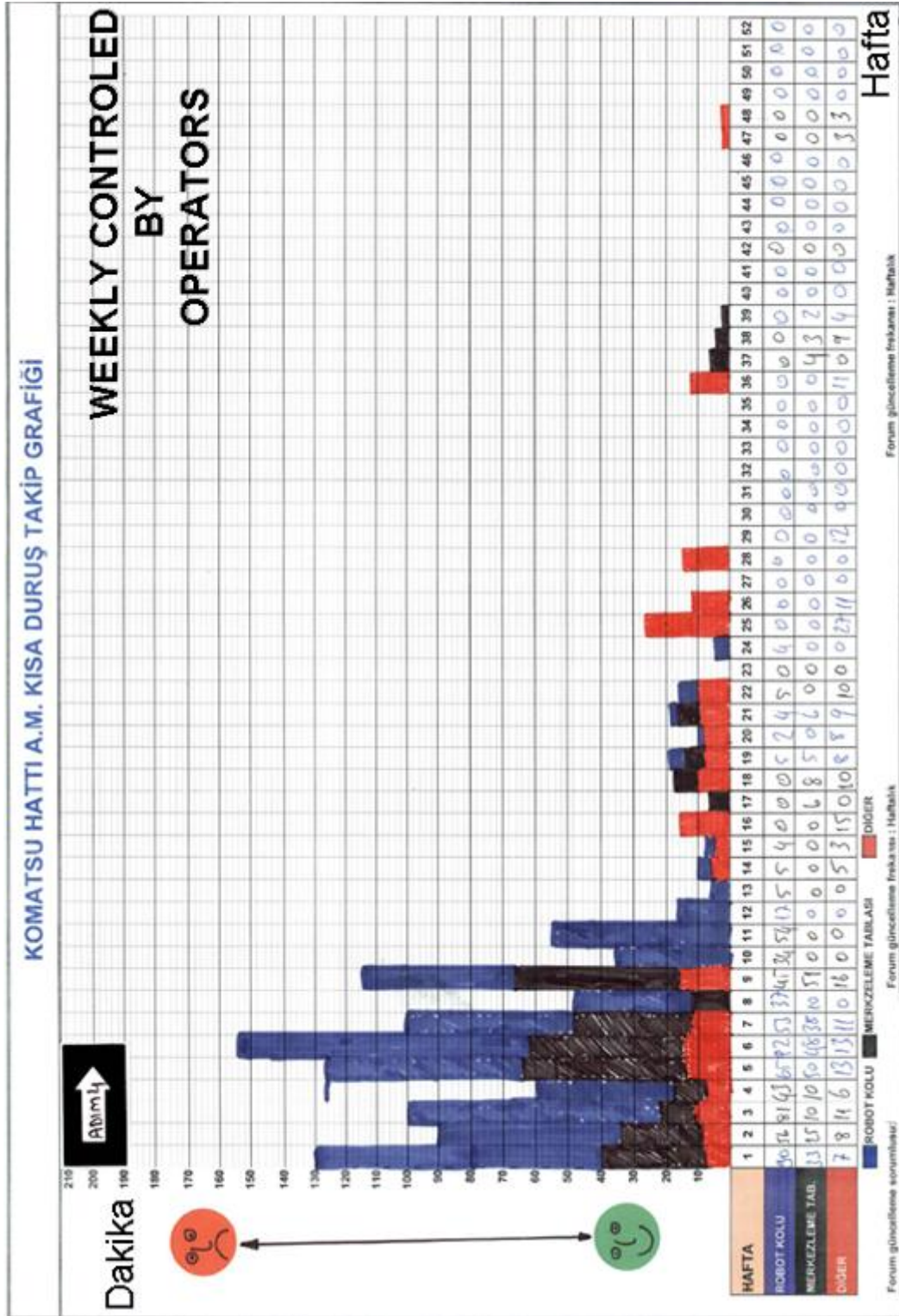


Figure 4.18. Minor Stoppages Monitor

Table 4.7. Realized Cost Details for Benefit / Cost Ratio

COST	Number / Yaer	Blue Collar Number	White Collar Number	Duration (hour)	Blue Collar Euro / 1 hour	White Collar Euro / 1 hour	Kaizen Equipment Euro / 1 Kaizen	Check List Euro / year	Total
Class Training	3	18	2	1,5	10 €	15 €			381 €
Practical Training	3	18		2	10 €				108 €
Meeting	3	2	2	1	10 €	15 €			306 €
Kaizens	18	8		1	10 €		65 €		1.250 €
Check List Application	3							215 €	645 €
TOTAL COST / YEAR									2.690 €

With step 4, operators have discovered some rules in their work life such as; ‘Correction is perfection’ (reversing deterioration and making improvements brings good results), ‘Perfection is satisfaction’ (getting good results gives a feeling of accomplishment), ‘Satisfaction is further action’ (a feeling of accomplishment makes people want to achieve even more).

Line’s OEEs were calculated after all steps. Also, one shift was analyzed at the end of the step 4 in Table 4.8. Final line’s availability, performance, quality and OEE were calculated with using this data.

Similar to the initial condition, press shop was working 2 shifts with 9 hours, so $9 \text{ hours /shift} \times 2 \text{ shift/day} = 18 \text{ hours/day}$ at the end of this study. One shift length was taken 9 hours $\Rightarrow 9 \text{ hours} \times 60 \text{ minutes} / 1 \text{ hour} = 540 \text{ minutes}$

Similarly they were 2 short breaks with 10 minutes $\Rightarrow 2 \times 10 \text{ minutes} = 20 \text{ minutes}$ and one meal break was given as 30 minutes.

Different to the initial condition, 0 minute breakdown, 18 minutes minor stoppages, 26 minutes set up and 8 minutes adjustment occurred in this shift at the end of step 4. Down time was calculated as;

Down time = Breakdowns losses + Minor Stoppages losses + Set up losses + Adjustment losses = $0 \text{ minute} + 18 \text{ minutes} + 26 \text{ minutes} + 8 \text{ minutes} = 52 \text{ minutes}$

Similarly, 10 pieces can be produced per minute in Komatsu line at the end of this study. So, ideal run time was taken 10 pieces / minute.

At the end of the reference shift totally 4,150 pieces were produced in this line. 105 reject pieces were found in these parts.

Table 4.8. One Shift Duration Distribution of Komatsu Press Line After Step 4

Item	Data
<i>Shift Length</i>	540 minutes
<i>Short Breaks</i>	20 minutes
<i>Meal</i>	30 minutes
<i>Down Time</i> (breakdown + minor stoppages + set up + adj.)	52 minutes
<i>Ideal Run Rate</i>	10 pieces per minute
<i>Total Pieces</i>	4150 pieces
<i>Reject Pieces</i> (repairs + scraps)	105 pieces

Availability = Operating Time / Planned Production Time

Planned Production Time = [Shift Length - Breaks] = [540 - 50] = 490 minutes

Operating Time = [Planned Production Time - Down Time] = [490 - 52] = 438 minutes

The result found for the Komatsu press line availability value at the end of AM step 4:

Availability = 438 minutes / 490 minutes = 0.8938 (89,38%)

Performance = (Total Pieces / Operating Time) / Ideal Run Rate

The result found for the Komatsu press line performance value at the end of AM step 4:

Performance = (4,150 pieces / 438 minutes) / 10 pieces/minute = 0,9475 (94,75%)

Quality = Good Pieces / Total Pieces

Good Pieces = [Total Pieces - Reject Pieces] = [4,150 - 105] = 4,045 pieces

The result found for the Komatsu line quality value at the end of AM step 4:

$$\text{Quality} = 4,045 \text{ pieces} / 4,150 \text{ pieces} = 0,9747 \text{ (97,47\%)}$$

Also, the last Komatsu OEE was calculated;

$$\text{OEE} = \text{Availability} \times \text{Performance} \times \text{Quality}$$

$$\text{OEE} = 0,8938 \times 0,9475 \times 0,9747 = 0,8254 \text{ (82,54\%)}$$

Then OEE trend was monitored on AM board from step 1 to step 4. Increasing in OEE can be seen in Figure 4.19. Because OEE losses were attacked with AM application step by step in this study. Because lacks of basic conditions were focused with first three step.

Especially breakdown losses, which were caused by lack of AM application, have gone to zero value at the end of the step 2. In addition to this, lots of minor stoppages improving kaizens were prepare by operators. So, minor stoppages losses improving accelerated with step 3. And finally, equipment quality losses which were formed by repair and scrap parts in OEE were improved with step 4 applications. OEE losses improving is shown step by step in Figure 4.20.

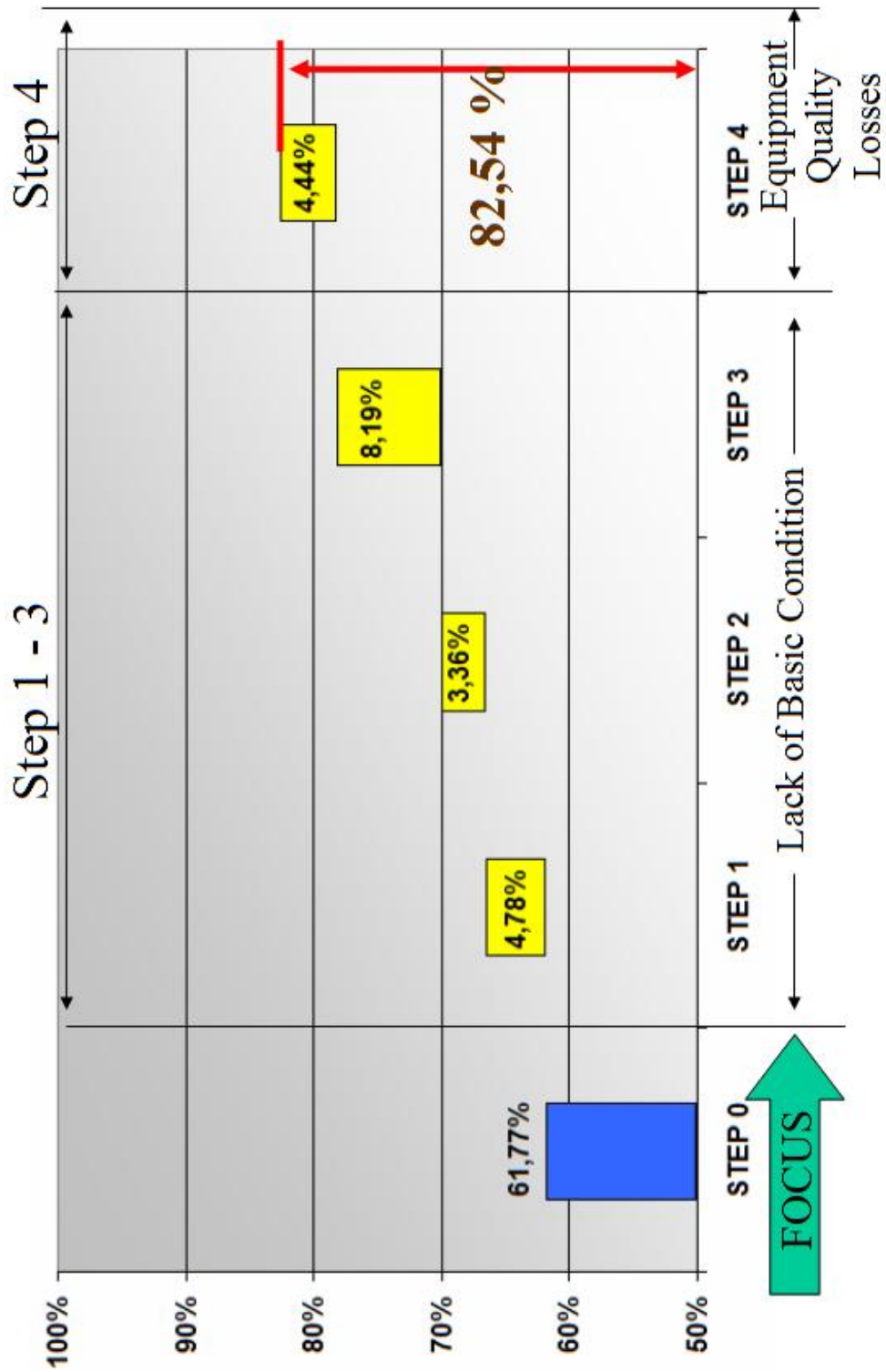


Figure 4.19. Komatsu Press Line OEE

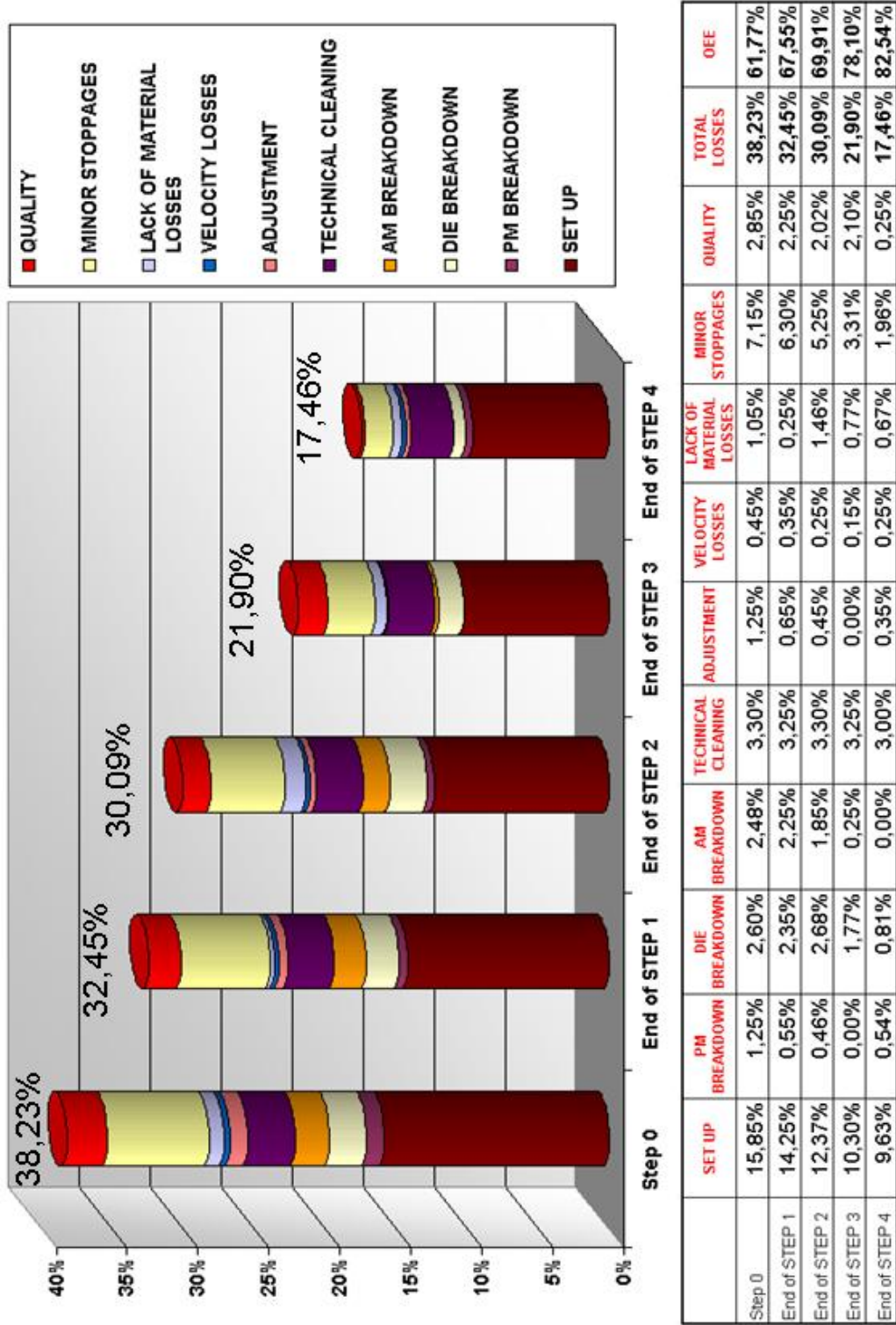


Figure 4.20. Improving of Total OEE Losses of Komatsu with Step by Step

After the AM board and area audits, Komatsu line passed step 4 successfully. Audit report step 4 is given in Figure 4.21.

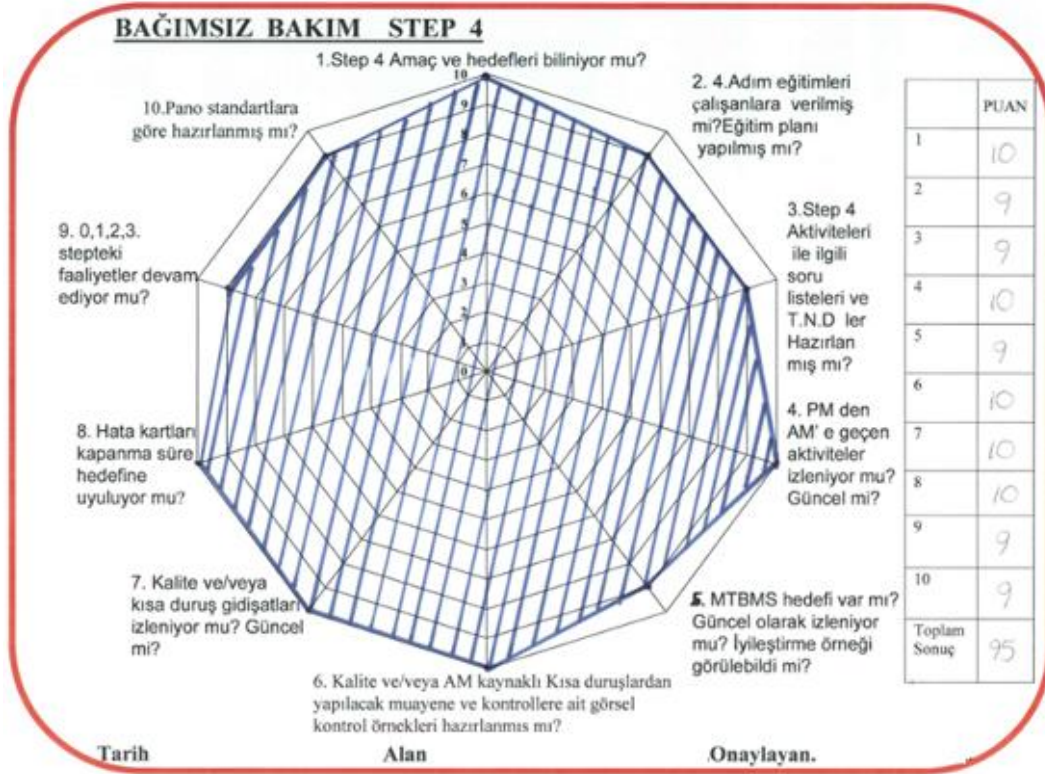


Figure 4.21. Step 4 Audit Report

In addition to these, production operator's skills have increased step by step. Before this study operators interested only with production. But after the first two steps, operators could recognized deterioration and could improve their equipment to prevent it. During cleaning and inspection they touched to their machine. Loose bolts and too much motor vibrating were discovered by operators with this touching. This kind of learning began in Step 1 and Step 2. By observing equipment closely, operators learned how to modify equipment in simple ways to prevent the same problems from ever recurring.

Equipment structure and function understanding and drawing trainings have been given to line production operators at step 3. They could draw simple structure themselves for OPL and kaizens. Also, draw the lubrication supply routes that have showed how the lubricant reaches the areas where it is needed. In addition to these, diagrams like these helped them seen more clearly what operators needed to do on

daily basis to prevent abnormalities. They also helped them carry out detailed equipment health checks.

With general inspection training at Step 4, operators learned the habit of thinking logically about how product defects occur and gain the ability to deal with the root causes of quality problems. After step 4, operators could monitor trends in equipment control as well as keeping up daily cleaning and inspection for causes that may be related to defects.

After the improving of production operator's skills, the roles of the production and maintenance departments have been determined in Figure 4.22. Production department started to focus on the prevention of deterioration and takes charge of the following:

1-Deteriorated parts could be restored by operators:

Basic equipment conditions have been established with cleaning, inspection and lubrication standards.

Proper adjustments of equipment could be made during the operation or changeover.

Breakdowns, minor stoppages and quality defects data could be recorded by operators.

Equipments could be repaired or could be improved by line operators with maintenance personnel collaborate.

2-Deteriorations have been inspected by line operators by using five senses and easy machine diagnosis:

Routine and periodic inspection points were determined at standards. Operators have applied this standards at all steps. Their inspection skills were increased step by step.

3- Finally , operators learned preventing deterioration:

Minor repairs could be made by operators. Easy part replacement works could be completed by operators. Breakdowns and quality defects promptly and accurately could be reported to the maintenance department.

Production operators have started to assist maintenance personnel in repairing equipment.

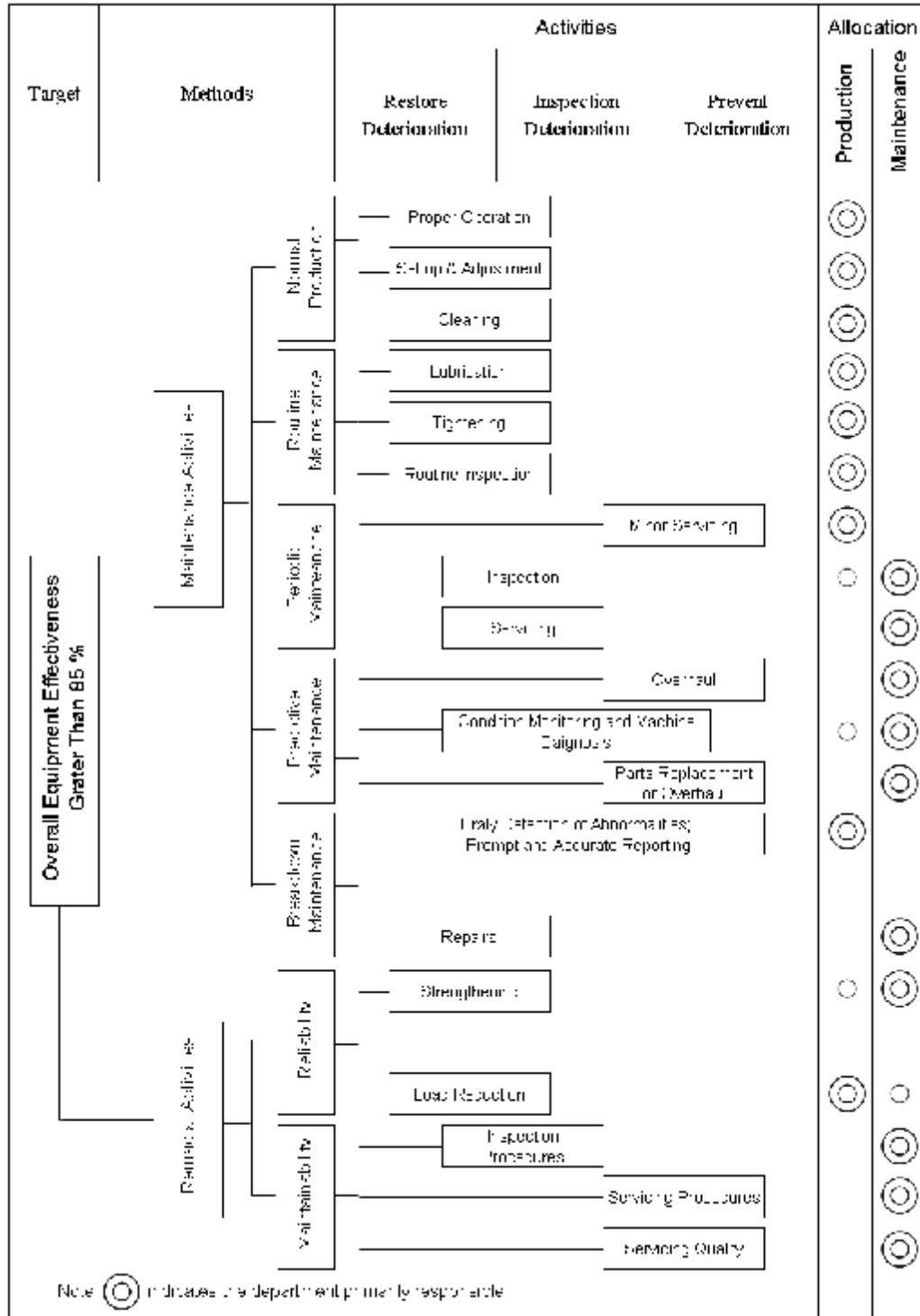


Figure 4.22. The Roles Of The Production and Maintenance Departments for Komatsu Press

5. CONCLUSION AND FUTURE WORK

5.1. Conclusions

Due to new requirements on high productivity and improving Overall Equipment Effectiveness, lots of industries have shown great interest in lean manufacturing systems. Especially, Autonomous Maintenance tool has been used on all lean production systems with different names on different equipment and operators. Improving equipment and increasing operators skills are taken as target in this system.

Improving OEE, decreasing CIL time, eliminating contamination sources and hard to access areas, reducing breakdowns and minor stoppages, improving quality and increasing operator skills are taken as performance indicators of Autonomous Maintenance. AM is applied with its seven steps to achieve these objectives.

In this work, all lean systems have been investigated. As the most appropriate system for automobile industries, WCM has been selected to apply. Autonomous Maintenance which is WCM's pillar has been applied in one press production line step by step. The following conclusions were derived after first four steps processes carried out in this work.

1- AM has been applied in a pilot line by paying special attention to Press Shop Cost Deployment analysis and Line Classification table. Komatsu line was chosen as a pilot line due to highest breakdown losses obtained in cost deployment analyses. In addition to this, from ABC line classification, Komatsu press line which was the single AA class line.

2- Before starting to AM steps, totally 37 safety risk points were determined at preparation steps. They have been eliminated by operators and line engineers with kaizens.

3- One Point Lessons were used as a major education tool in this study..From step 1 to 4, 225 one point lessons have been created and they have given to operators in this study.

4- With step 1, autonomous failure tags have been used in this study. From step 1 to the end of step 4, they have been managed 345 tags within this period. AM failure tags have been attached by line operators and they have been removed by PM and AM operators. Lots of potential problems uncovered in each category, lots of major defects discovered and eliminated with tags management.

5- 71 points of remaining contamination sources and hard-to-access areas were improved at the end of step 4. As localized containment was installed to control scatter, natural deterioration patterns replace accelerated deterioration, and the number of machine breakdowns usually dropped dramatically. When breakdowns became rarer and take up less time, quality defects from of scrap and rework typically fell as well.

6- At Step 3, according to breakdown analyses at Komatsu line, poor lubrication caused about 60 percent of all breakdowns. So, some simple lubrication duties have been transferred from PM to AM. One point has been found in robot, one point has been found in press, one point has been found in moving table, one point has been found in destacker, and one point has been found in equipment in basement. These points were selected to transfer from PM to AM checklist. Operators didn't need to more experience for this work. Because this works were too simple. According to equipment number, totally 35 lubrication duties have passed to from PM to AM group. Lubrication trainings were given to operators from PM to AM group for these duties.

7- Autonomous maintenance standards were created for all equipments in Komatsu Line. They have included cleaning, inspection and lubrication activities. 351 standards were determined for 9 robots, 6 presses, 12 moving tables 2 dестackers and equipment in basement.

8- All standard's duration has been monitored as CIL time on AM board. CIL time has been reduced considerably after elimination of contamination sources and defining hard to access areas. At the end of step 4, methodology it has decreased CIL time from 1450 minutes / month to 167 minutes with the application of ECRS. 90% improvement in cleaning time, 91,5 % improvement in inspection time and 83 % improvement in lubrication time have been obtained .

10- AM breakdowns have been monitored on AM board too. These breakdowns have been rapidly reduced from 300 minutes to 0 minutes at the end of the step 4 with the application of standards and preparing kaizens.

11- With first three steps operators have discovered some rules in their work life such as 'Cleaning is inspection', 'Inspection is detection' and 'Detection is correction'.

12- At the beginning of step 4, all Komatsu losses were analyzed with PM group. Robot arm minor stoppages eliminating was taken as a target by AM group. 130 minutes (839 €/ month =9,196 €/year) robot arm losses were found in the line. When the benefit / cost ratio were estimated, benefit was taken 9,196 €/ year. Because AM group estimated all robots arm losses would be reset. Also, estimated cost was determined 2,149 €/year. So, $9,196 \text{ €} / 2,149 \text{ €} = 4,3$ benefit /cost ratio was calculated. When calculation result was found grater then 1, step 4 was started in this line.

13- Totally 18 improving kaizens were prepared by operators. At the end of the step 4, robot arm minor stoppages were gone to zero value.

14- For calculating realized benefit/cost ratio, actual cost had to calculate. So, actual cost was calculated 2,690 € Then, realized Benefit / Cost ratio was calculated as $9,196 \text{ Euro} / 2,690 \text{ Euro} = 3, 42$. This value was satisfactory for step 4 application. Because, 2,690 € was spent, 9,196 € was gained in step 4. The net gain of Step 4 was calculated as;

$$\text{Gain of Step 4} = \text{Benefit} - \text{Cost} = 9,196 \text{ €/ year} - 2,690 \text{ €/ year} = 6,506 \text{ €/year}$$

15- With step 4, operators have discovered some rules in their work life like the following: 'Correction is perfection', 'Perfection is satisfaction' and 'Satisfaction is further action'.

16- Line's OEEs were calculated after all steps. Also, Line's OEE was calculated for one shift at the beginning of this study:

Availability = 75, 51%, Performance = 87, 83% and Quality = 93, 14% were calculated. OEE was found with using this value;

$$\text{OEE} = \text{Availability} (75,51\%) \times \text{Performance} (87,83\%) \times \text{Quality} (93,14\%) = 61,77 \%$$

OEE was increased from 61,77% to 67,55% after step 1. It increased to 69,91% after step 2. It was increased from 69,91% to 78,10% after step 3. And finally OEE was increased to 82,54 % at the end of this study. Because OEE losses were attacked with AM application step by step in this study. Especially, lacks of basic conditions were focused with first three steps. Breakdown losses, which were caused by lack of AM application, have gone to zero value at the end of the step 2. In addition to this, lots of minor stoppages improving kaizens were prepare by operators. So, minor stoppages losses improving accelerated with step 3. And finally, equipment quality losses which were formed by repair and scrap parts in OEE were improved with step 4 applications.

17- Production operator's skills have increased step by step. Before this study operators interested only production. After the improving of production operator's skills with this study production department started to focus on the prevention of deterioration and takes charge of the following:

- A. Deteriorated parts could be restored by line operators,
- B. Deteriorations have been inspected by line operators by using five senses and easy machine diagnosis,
- C. Finally, operators learned preventing deterioration.

5.1. Future Studies

For Future studies, Step 5, step 6 and step 7 will be applied for this pres shop. In addition to this autonomous maintenance system of AM application will be extended at all other lines of this press shop.

In step 5, instruction in process performance will be provided. Some quality losses that caused by process will be focused at this step. Operation and adjustment operations will be examined. Operational reliability by developing process-companent operators will be improved.The overall stability and safety of process through correct operation will be taken as a goals of step 5. Lots of equipment will be modified to make it easier to operate.

Operators will be enabled to operate process and deal with abnormalities correctly, and they will be trained to understand the relationship between press parameters and properties of the sheet metals. They will know the correct adjustment and setting techniques at the end of step 5. For these targets, general process inspection manuals and troubleshooting manuals will be prepared by line engineers and PM group.

In step 6, quality maintenance will be achieved. In addition to this, safety by establishing procedures and standards for dependable AM will be created. Some set up improving will be applied to line. Line operators will focus to work-in-process for reducing. A system of self management will be established for work flow, spares, tools, work-in-process, final products, data, and etc.

Relationships between equipment and quality will be pinpointed. A quality maintenance system will be established. Press shop layout will be reviewed and will be improved. Maintenance and control of transport equipment, spare parts, tools, work-in-process, final products, data, passageways, cleaning equipment will be standardized step by step. Visual controls will be prepared for everything in the press shop.

The share of self management by systematizing will be extended to all operators. All operators will understand the relationship between equipment, process and quality. The importance of quality maintenance will be appreciated. In addition to these, system flow-diagrams for process will be prepared. Instruction in standardization will be given to operators at this step. Also, quality maintenance manuals that systematize the relationship between equipment, process and quality will be prepared. Finally some education and guidance in analysis and improvement techniques will be given to operators with step 6 trainings.

All activities will be evolved at step 7. Improvements in line will be standardized with press shop policies and objectives. Costs will be reduced by eliminating work place waste. Equipment will be improved further by keeping accurate maintenance records (e.g., Mean Time Between Failure MTBF) and data will be analysed in them.

Line data will be analyzed in various ways to improve equipment and raise process reliability, safety, maintainability, quality, and operability. Equipment improvements will be prioritized.

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İbrahim BOZAĞAÇ was born in 12.04.1980 in Mersin. He had been lived from 1980 to 1998 in Mersin. He graduated from Cumhuriyet High School in 1997. In 2003, he graduated from University of Gaziantep, as mechanical engineer.

He started to work in 2003 in Uğurlu Makina, dealing with manufacturing of spare parts, plastic ejection dies and sand mould dies in Adana, as CNC programmer. This company was working as supplier of Cimsataş. In 2005, he started to work in Acarsan A.Ş. CNC machining & laser cutting operations was doing in this factory in Mersin, he worked at his factory as a manufacturing department production unit responsible. This company was working as supplier of Anadolu Cam Sanayii, Paşabahçe Cam Sanayii and TEMSA.

After he has finished his military service, he started to work in main Automobile Factory in 2007, Bursa, as manufacturing engineer. He is still working as Manufacturing Engineer, and in addition to this he is responsible with Autonomous Maintenance and Work Place Organization applications at Press Shop in this factory.

İbrahim BOZAĞAÇ is married, has no children. His wife Burcu is working as a government officer.