POLITECNICO DI TORINO

AUTOMOTIVE ENGINEERING

Mechanical Engineering, Aerospace, Automotive and production

MASTER DEGREE THESIS

VALUE STREAM MAPPING FOR LEANNESS OF MANUFACTURING AND NON MANUFACTURING PROCESS

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Abstract

Value Stream Mapping is the technique which identifying, demonstrate and decrease the waste in the process. VSM is introduced by TOYOTA production system. It helps to the managers, engineers, production associates, schedulers, suppliers and customers can easily identify the waste and its causes. VSM is a communication tool, strategic planning tool and change management tool.

VSM method, visually maps the flow of material and information from the time products come in the back door as raw material through the manufacturing process and to the loading dock as finished product.

Mapping out the activity in the manufacturing process with cycle time, down time, in-process inventory, material moves, and information flow paths helps to visualize the current state of the process activities and guides towards the future desired state.

In my thesis work, I have applied VSM on non-manufacturing process and manufacturing process in order to avoid the waste and increase the efficiency of the process. The final study has been the overall equipment effectiveness (efficiency) on the manufacturing process.

The first study is the non-manufacturing process, which is specifically on the leanness of educational system that is, increasing of the knowledge of the students during the lecture process. By taking the sample of the time schedule of POLITECNICO DI TORINO UNIVERSITY and applying to the two methods. The first method is the CON OF LEARNING and the second is NATIONAL TEACHING LEARNING. Generally those methods tell us, the students cannot remember or give attention the whole lecture. The lectures are divided in to two fields of courses, called business and engineering. Therefore, even if we cannot obtain 100% of effectiveness or remembering capability, we can improve the efficiency of the teaching learning process as much as possible by applying VSM.

The second is the manufacturing process, applying VSM for this process is easier than the non manufacturing process. Currently too many manufacturing company are using VSM for their process to improve the efficiency of the line. On my case also applied VSM for the manufacturing of Cylinder Head Manufacture Company. The company on the current state couldn't fulfill the customer demand because of the work station higher variability. The variability needs to be avoided in order to fulfill the customer demand. The variability's are failure, setup and rework on the three work station. Therefore, the identified variability area of the work station has been improved and avoided by taking different techniques that is VSM and finally mapping the future VSM.

Lastly I have applied the OEE methods in order to calculate the overall performance of the work station.

Content

Chapter 1, Introduction to Industry 4.0

Originally the concept of industry4.0 obtained by Germany takes the name from the European industry4.0 initiative and from the study the forth industrial revolution focuses on the adoption of come technologies called enablers. The production system and applied research are interconnection and collaboration b/n systems. The global market scenario is changing, leading to mass customization becoming of interest for the entire manufacturing system.

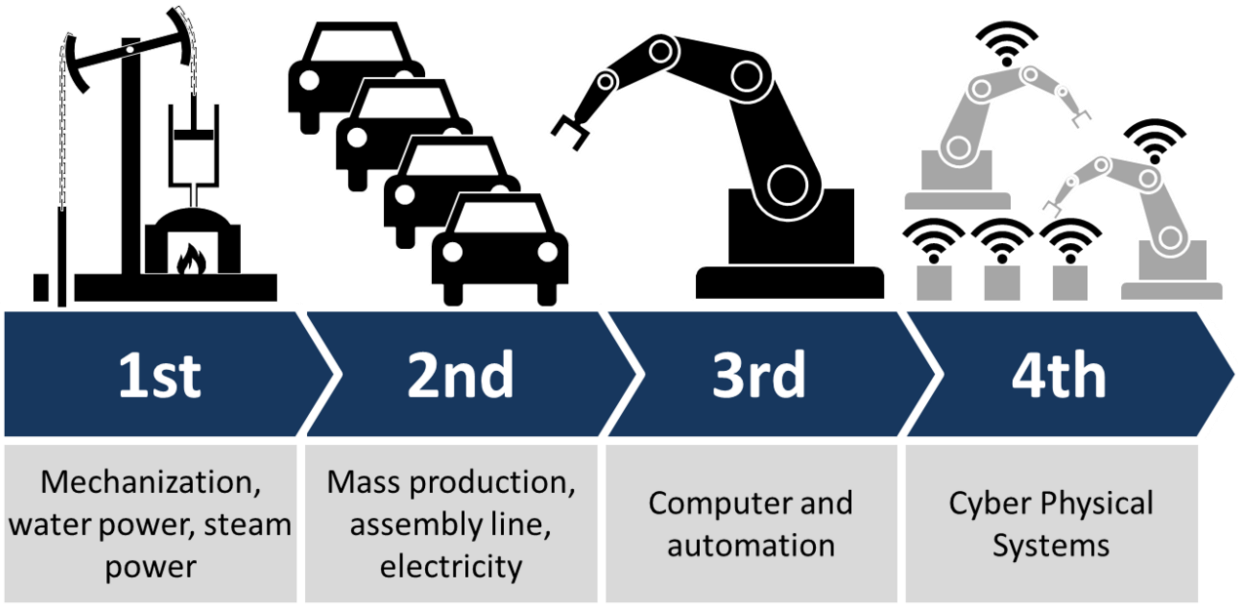

Fig. 1 industry revolution

A trend of industrial automation that integrate some new production technology to improve working conditions, increase productivity and production quality of the plant.

Industry 4.0 goes through the smart factory concept which consists

- Smart production: the technology that collaborate b/n all elements, operators, machines and tools that percents in a production.
- Smart service: information infrastructure and techniques that allow system to be integrated and also b/n the structures to integrate the companies (suppliers-customer) and with the external structure.
- Smart energy: energy consumption, create more efficient systems and reducing waste of energy according to the sustainable energy.

The key to the industry4.0 is cyber physical system (cps) or physical system that are closely connected to information system and that can interact and collaborate with other CPS system. This is the basis of decentralization and collaboration b/n systems which is closely connected with the concept of industry4.0.

The enabler's technologies are

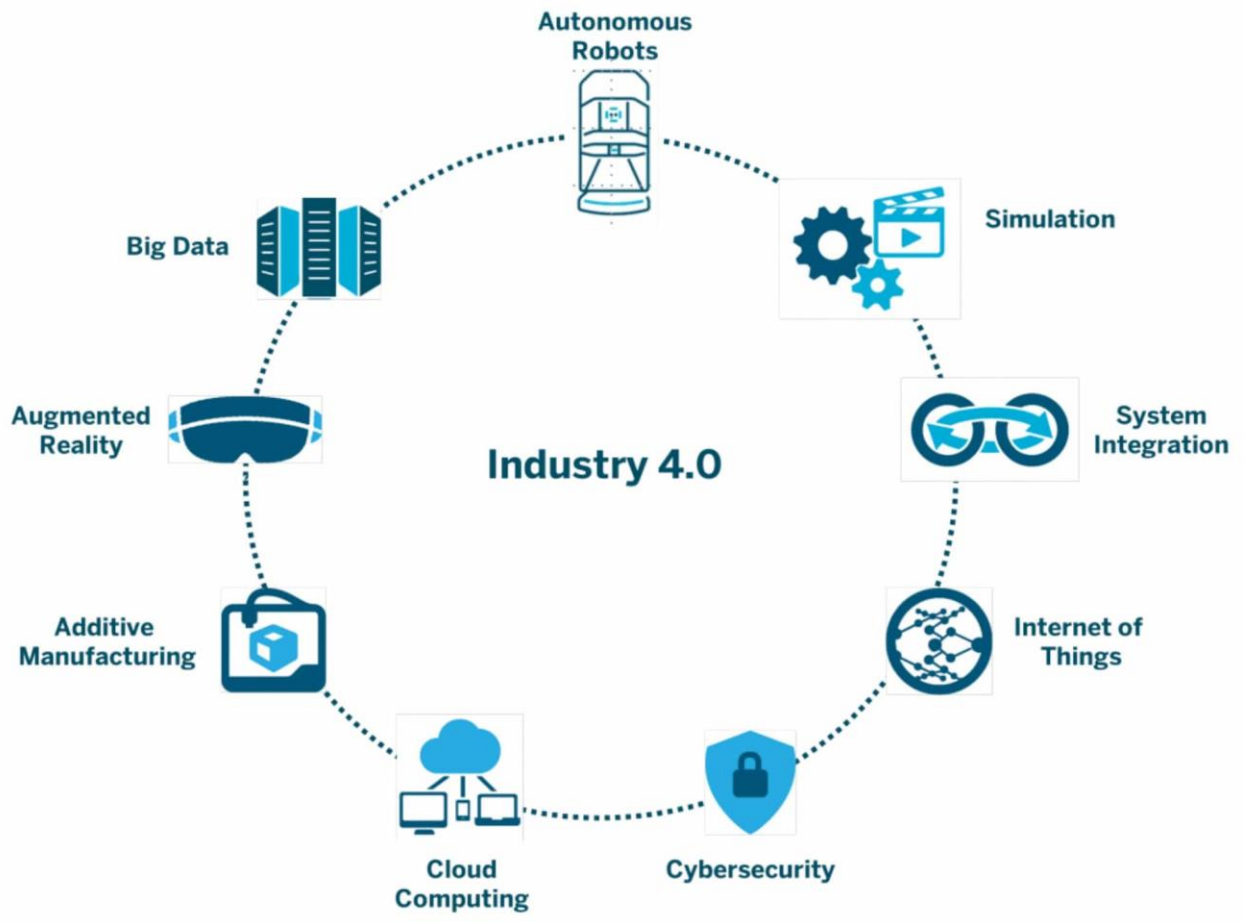

Fig.2 industry 4.0 enablers

- *Advance manufacturing solution*: interconnected and modular system that allow flexibility and performance.
- *Additive manufacturing*: increase the efficiency of the use material.
- *Augmented reality:* better guide operators in carrying out their daily activities.
- *Simulation:* b/n interconnected machines to optimize process.
- *Horizontal and vertical integration:* exchange information among all the actors in the production process.

- *Industrial internet:* communication or exchange information b/n outside the company and inside also.
- *Cloud:* information storage and manage very large amounts of data through open system.
- *Cyber-security*: the increase in internal and external interconnection opens the door to the whole issue of information security.
- *Big data analytics*: techniques for managing huge amounts of data through open system that allows forecasts or predicts.

1.1 Integration of lean manufacturing and industry 4.0

Integrating both the spheres of lean manufacturing and industry 4.0 is an important research field to be extensively explored. With the advent of computer integrated manufacturing, there was a speculation that factories of the future would operate autonomously without the requirement of human operators. Though such a statement proved to be infeasible in a practical scenario, it gave rise to the concept of lean automation, where robotic and automation technologies are employed to achieve lean manufacturing. Taichii Ohno's Toyota Production System is based on two pillars: just in time and autonomation (Ohno, 1988). Autonomation refers to automating the manual processes to include inspection, i.e. when a problem occurs, the equipment should stop automatically and not allow defects to further proceed through the line. Only when a defect is detected would a human intervention be required. Hence automation in production has played an important role right from the inception of lean manufacturing, and industry 4.0 can be considered in this field.

Chapter 2, Introduction to lean manufacturing

Lean manufacturing is one of the major businesses in the world have been trying to adopt in order to be competitive in an increasingly global market. The lean manufacturing Originated from Toyota Production System and focus on the approach of cost reduction by eliminating non-value added activities., many of the tools and techniques of lean manufacturing e.g., just-in-time (JIT), cellular manufacturing, total productive maintenance, single-minute exchange of dies, production smoothing have been widely used in discrete manufacturing. Applications have been used many sectors like automotive, electronics, and consumer products manufacturing.

2.1 value stream mapping

Value stream mapping is a visualization tool used in lean manufacturing Toyota Production System. It helps to understand the processes and thereby streamline the individual process steps using the lean manufacturing tools. The goal of using the VSM technique is to identify the individual areas of waste in the process. Any activity that doesn't add value to the product is considered as waste.
Waste can be separated into 7 commonly accepted categories such as overproduction, waiting, transportation, poor processing, excess inventory, excess motion and defective products.
VSM is the starting point in which engineers, management, production personnel, schedulers, customers and suppliers can identify current and potential areas for process waste reduction. It is a method of graphically depicting the entire process from the initial customer's request to the final delivery of product to the customer. The entire process includes areas such as order entry, customer service, scheduling, engineering, raw material ordering, component ordering and most importantly, the individual process steps in manufacturing. Within the mapping, both the physical process flow and informational process flows are determined and graphically displayed.

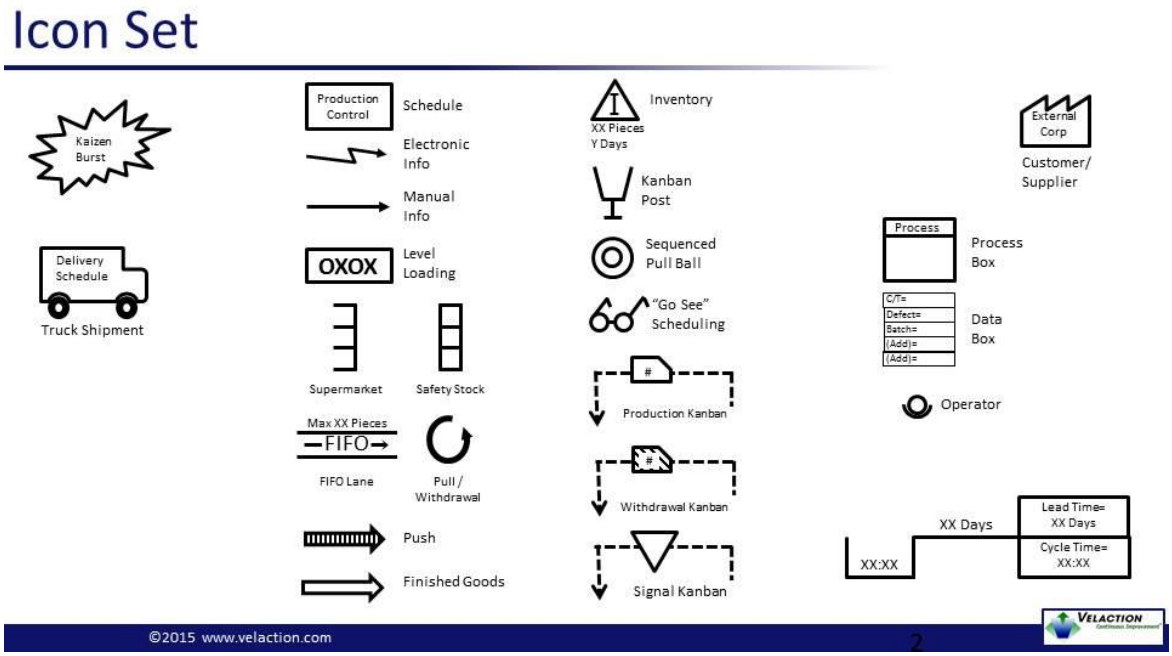

Fig. 3 Value Stream mapping icons

The measurement of lean manufacturing is mentioned in ten factors

1. Supplier's feedback: critics and performances of products and services received from customers to be periodically communicate back to suppliers for effective transfer of information.
2. Just in time delivery by suppliers: the required quantity of products to be delivered by suppliers at the specified time when customer require it.
3. Supplier development: suppliers to be developed along with the manufacturer to avoid inconsistency or mismatch in competence level.
4. Customer involvement: give high priority for the customers by involving in order to fulfill their needs and expectations.
5. Pull production: an initiation of need from the successor through kanban should enable the flow of production from the predecessor signified as JIT production.
6. Continuous flow: a streamlined flow of products without large halts should be established across the factory.
7. Setup time reduction: the time required to adapt resources for variations in products should be maintained as least as possible.
8. Preventive maintenance: failure of machines and equipment should be avoided by effective periodical maintenance procedures.

9. Statistical process control: quality of products is of prime importance, no defect should get percolated from a process to a subsequent one
10. Employee involvement: with adequate motivation and entitlement, an employee has to be empowered for an overall contribution towards the firm.

2.1.1 information flow and material flow

In this approach need to study value stream mapping which is one part of lean manufacturing.
Value stream mapping (VSM) is methods for analyzing the current operating state and design a future state for the serious of events that take a product or service from its beginning through to the customer known as material and information flow mapping.
VSM analysis both material and information flow.
Material flow: the material flow is essentially mapping that materials as opposed to information embark on right from the time that any material is received within the manufacturing site, right through to the point that customers actually receive the finished product. The material flow has to be recorded at various stages throughout its journey. The creation of the VSM is a process that is involved in terms of identifying waste and looking at where flow is subject to bottlenecks etc.
Information flow: There are sources of information, all of which need to be included within the VSM. Customers will provide information they will also have a need to have information from the company itself. It is in essence a 2 ways project. Companies who supply the raw materials will also supply and need information. In addition those involved in transporting finished products will be involved in both receiving and distributing information.
The information that people have whether in the office or on the shop floor is a functional aspect of the information flow. Without those involved in production having adequate information there is a risk that the production process will be wasteful and efficient.
Material and information flow are two sides of the same coin, both of them should be mapped. In a production flow what come first are a material movement and the other flow which is information flow. VSM describes a simulation model that was developed to contrast before and after scenarios in detail in order to illustrate to manager potential benefits such as reduced production lead time and low work in process inventory. It is the graphic display method used in industry and aims to identify waste in production process. And key point in the lean manufacturing process.

2.1.2 process data and timeline calculation

All set of process activities that contribute to the creation of a product starting directly from the supplier passing through the entire assembly line up to the delivery of the finished product.
VSM can be a communication tool, a business planning tool, and a tool to manage the changed process.
Aims of VSM:

- Not focus on the a single process but on the flow
- Find the cause of waste within the flow
- Give the tools to all staff in order to read the flow
- Improvement the lean manufacturing system
- Shows the links between the material flow and the flow of information

Generally, the continues analysis of the process allows starting from the VSM improvement project to perfect over time the VSM itself and to eliminate everything that does not represent added value to the finished product.
The efficient of VSM is represented by all the indicators typical of lean manufacturing:

- Takt time
- Continuous streaming
- Level the volume peak
- Level the mix avoiding peaks of the same items
- Develop the ability to produce the whole mix in the time unit

The analysis of the value chain is not the improvement of the single process but the global and continuous optimization.
The tool that can be to manage the process is current state mapping and future state mapping. So how do we create VSM.

1. Choose the product or product family
    - Select one needs to be improvement
    - Select valuable to the company
    - Select High likelihood of success
    - Can form the basis of improvement for other product family
2. Define the process to be mapped and bound the process
    - Supplier to customer

3. Create a process box for each process steps
    - Receiving, Milling, grinding, painting, assembling, shipping…
4. Information flow
    - This is the most important technology which the VSM particularly differ from the other techniques is adding the flow of information.
5. Collect process data

We need to record the process data for the process. Typical data that should be collected like:

- Inventory
- cycle time which the time taken to make one product
- Change over time which is from last good piece to the next
- Up time which is machine utilization
- Number of operators,
- Net available working time,
- scrap rate and
- Pack size or pallet size.

6. Create a time line
    - How long inventory remains in the system
    - How long the product is processed for
    - Use inventory and daily demand to calculate how many days of inventory you have
    - Processing time taken to process one item not a batch
7. Analyze the data
    - Total lead time
    - Total process time

From those steps, our vsm tells us (current vsm), that the data box shows us which process have long change over or poor quality performance and other issues.

Next step for our VSM is future VSM

- Create ideal state VSM
- This should be a challenging improvement on where we are today
- Future state maps can then be created to move us toward the ideal using kaizen improvement bursts.
- Move from current to ideal state VSM

2.1.3 Create the current VSM

This is done by gathering information from the shop floor, so it provides the information we need to develop the future state. The information flows, the definition of the time line under process, under the inventory to define the production lead time. That means the time taken by the piece to cross the factory. It gives us or helps to establish the connection between customer, suppliers, production process, production planning and supervision of the entire company system.

To create the map, I have taken an example for the better Steps of current VSM

Step 1, Calculate takt time:

Step 2, Get a pencil and eraser: the best value stream maps have eraser marks all over them. Don't use a pen when drawing these.

Step 3, Have a piece of paper: it is generally preferred 11"x17" paper size. It's big but not too big to carry around. While the map can be draw by using software but it is recommended always draw the map on paper first. Then we are ready to chare the masterpiece with the senior manager, we might choose to use the software.

Step 4, Walk the process front to back: quickly walk the process with our team in order to understand the general flow. It's important to also define the start and stop point of the process. Don't attempt to take on too much.

Step 5, Draw the customer box and detail: in the top right hand side of the paper we draw the little saw topped box representing our customer. We also note their monthly and daily demand along with the takt time as calculated in step 1.

Step 6, Go to the end: start the process from the end of the process and begin drawing the map back to front. It is recommended that draw the map with the team. The other thing is to ask person on the team to map it out, so we can compare and consolidate when we get back to the room.

There are many ways to do this. Experiment and do what works best for our situation.

Step 7; Focus on the material flow first: this includes the process boxes and data boxes. Regarding the data boxes, if we don't have all the data perfectly collected on the day of the mapping exercise just do the best we can. We can always assign homework to go and validate the figures later.

In fact, even if we think we have solid data, the six sigma side of me urges us to validate our measurement system to make sure we can trust the data. If we want to get really tricky state both a measure of central tendency and dispersion.

After studying the manufacturing process collect cycle time information at each step.

Step 8, Add inventory or wait time: once we have all the process and data boxes, it's time to add in inventory and waiting time. These are the little triangle with an "I" in the middle.

For inventory, we simply count the number of pieces in between the processes and note them under the triangle. We also can convert these pieces into days supply. To do this, we divide the number of pieces by the average daily demand which we used to calculate talk time.

Lastly, don't attempt to map every part number. Choose one or two key components to start with. We can always add more to the map later.

Step 9, Draw the information flow: this step is what really separates a VSM from traditional process maps. In addition to learning about how material flows we also want to understand how information flows. We learned that production schedules each process step in isolation. In other word, each work station gets its unique production schedule. We draw this using straight manual information lines.

We also add in the information flow from our customers as well as to our suppliers. The information can be 30 days electronic forecasts as well as electronic daily orders. Conversely, sends suppliers an electronic weekly forecast.

Step 10, Add the timeline: we can add the time line to the bottom of the VSM. This saw tooth looking line helps us separate the value added cycle time taken from data boxes and from the non-value added time daily or hours supply information.

The last step in the process is to sum up all the "value added" cycle time and note them the end of the timeline. We also the "inventory" times and notes that on the timeline.

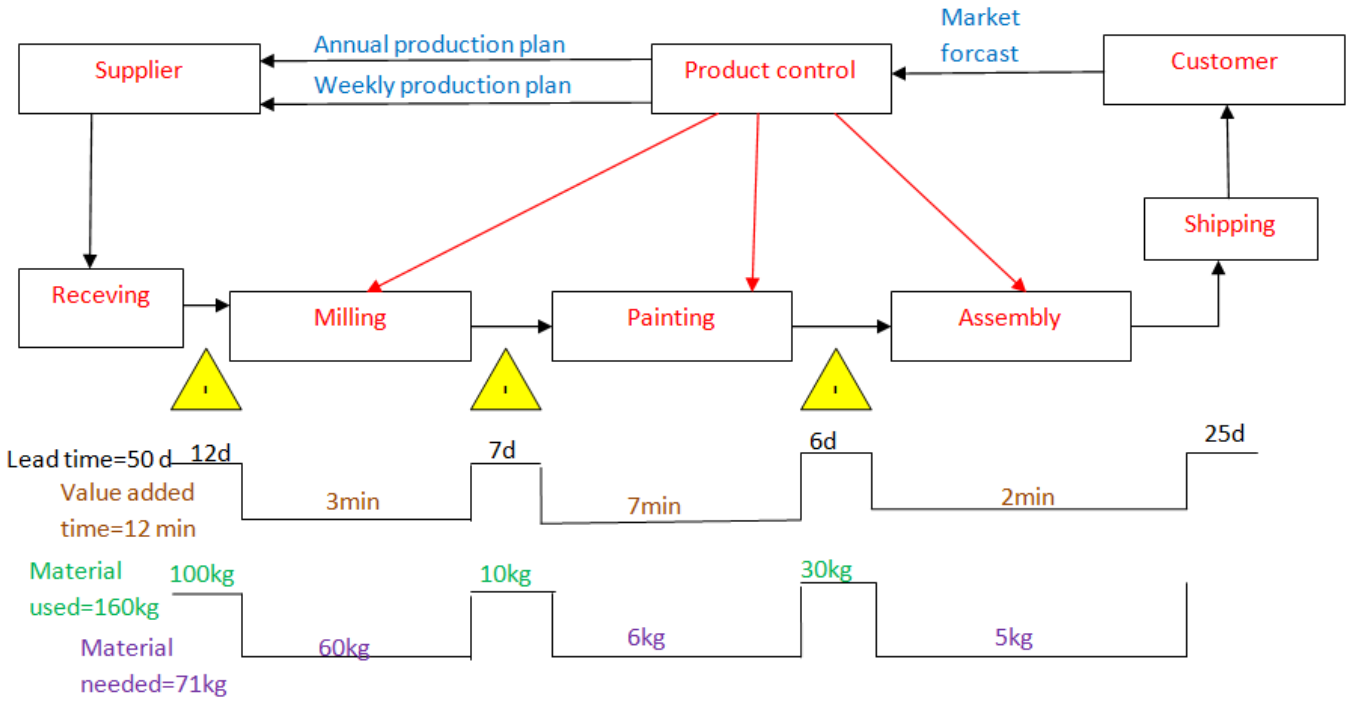

Fig.4 Example of CVSM

2.1.4 Create the future VSM

It starts from the current map or the existing process from which we try to identify any imperfection in the flow of value going to modify indication parameters in order to define the optimum and reliability process.

A future state map helps with the larger process of developing our lean manufacturing strategy. It requires significant knowledge of core disciplines and other specific topics.

Guidelines for developing future state VSM

1. Is the process capable of meeting customer needs? Produce to takt time
2. Should we produce to supermarket or direct to shipping? Decide build strategy
3. Where is continuous flow possible (pull)? Create continuous flow
4. Where do we need to buffer flow? Use FIFO to buffer flow and keep sequence
5. How do we control production? Use supermarkets to control production
6. Where is the pacemaker process? Send customer schedule to one point in the process
7. How do we level the production mix? Level the production mix at the pacemaker
8. What increment of monitor or control the process? Release small, consistent increment of work at pace maker

2.1.5 Improvement techniques

- Supermarket system: is one of the three pull strategy (continuous flow, sequential pull and replenishment pull) that can be implemented between to process steps when designing a future VSM. The supermarket will only be considered when one piece flow and FIFO are no longer an option. A supermarket is a method of managing inventory in which a variation of parts can be kept without knowing in what order the parts will be taken from the inventory. This mean the internal customer will take a random part from the supermarket. A pull connection with supermarket is therefore also known as a replenishment pull system. To inform the internal supplier about the parts that need to be replenishment, kanban can be used.
- Kanban: is a Japanese term that can be translated in to 'visual signal' and is used to visualize production and transport signals in a process. Complex computerized systems are no longer necessary when standard parts can automatically be replenished using this simple card system. Kanban is used when a pull-connection between two process steps is chosen to be a supermarket. The upstream processes which replenish the supermarket have to know what product need to be produced. The kanban signal provides this information. As a pull connection, both one piece flow as well as FIFO is more desirable than the supermarket because they do not need a separate signal to know what to replenish.

  A kanban (Rother, 2010) which means the supermarket is transformed in to a FIFO lane or a one piece flow line.

  The canban system can be explained using 6 rules

  1. The downstream process only takes products out of the supermarket which are used immediately. In two card system, material can only be collected with a kanban card
  2. The upstream process produces the exact amount of products listed on the kanban card. Nothing is produced without a card.
  3. The kanban signal always stays with the product. As soon as there is material without a kanban, or a kanban without material, a problem has occurred.
  4. Defects won't be transported downstream, which means all workstations have their own quality check.
  5. Kanban is can be used when volumes vary about 10% max.
  6. The number of kanban cards represents the amount of inventory, hence waste (muda) in a process. The number of cards should therefore continuously be reduced.

- Pull system: is a process in which a work station starts to work on his work order only when there is a free slot on the output side. This means the trigger for producing anything on the workstation comes from the customer side, which can be internal as well as external. The customer pulls order through the process instead of a traditional push connection in which products are produced no matter what happen on the output side of the workstation. Because inventories between workstation are managed in a pull system, which directly influences and maximizes the lead time, pull always has a preference over push.

  The three different forms of pull connections can be identified;

  1. The continuous flow: connection has the highest level of pull, since all three factors are included. Products are worked on one by one and with a maximum inventory of one between the workstations, a workstation can only work on the product that is waiting in front of it at that time the fixed sequence, and can only produce when the inventory behind it is less than one no inventory. Multiple workstations with continuous flow between them are also known as work cell or u-cell.
  2. The sequential pull: connection is the second best possible pull connection, in which the fixed quality is determined, the sequence of product is defined, but a buffer with a defined maximum is allowed between workstations to buffer for variance. This usually implemented using FIFO.
  3. The replenishment pull: the supermarket is the third and last option, in which a maximum number of products is waiting to be worked on, but it is unknown which type of product will be pulled out next. This type of inventory is also known as a supermarket and can be controlled using kanban.

- Kaisen : is a Japanese word for “improvement”. In business, kaizen refers to activities that continuously improve all functions and involve all employees from the CEO to the assembly line workers. It also applies to processes, such as purchasing and logistics that cross organizational boundaries into the supply chain. It has been applied in healthcare, government, banking and other industries.

  By improving standardizes programmes and processes, kaizen aims to eliminate waste. The use of the kaizen model for continuous improvement demands that both flow and process kaizens are used, although process kaizens are used more often to focus workers on continuous small improvements. In this model, operators mostly look for small ideas which, if possible, can be

implemented on the same day. This is in contrast to traditional models of work improvement, which generally have a long lag between concept development and project implementation.

Based on the above criterion, we are going to draw the future VSM.

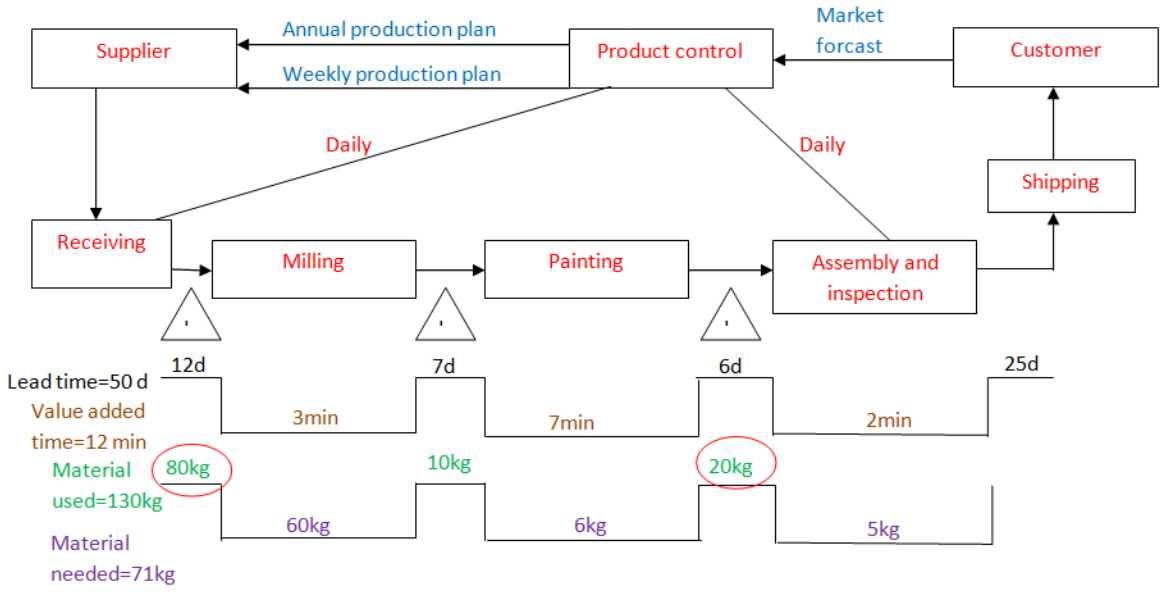

Fig. 5 Example of FVSM

According to the analysis of VSM, the material that has been used in the process which means the waste material decreases by 30kg. So the future VSM is the improved one than the current VSM next the future VSM will becomes the current VSM.

Once the mapping is complete, the time line will be drown which tells us how much value time is contained in the lead time. One of the objectives of the future state will be to reduce non-value time to the advantage of value based one improvement of response time.

2.1.6 Chapter summery

The table gives the intern recommendations suggested in the current state map, various tools were also applied as future state map such as kanban, kaizen, pull system, and and so on were implemented for daily consumables required for the WS process and suppliers. Deciding the new location for off cut storage resulted in extra space inside shop for material movement by handling equipments such as forklift and mobile trucks. Symbols include kaisen burst symbol with shaggy burst sign, circular arrow indicates pull system and the triple rectangular block is the sign for supermarket here considered as new

off storage area and cut part storage area. Also numerous benefits were achieved from value stream mapping improvement such as space saving better housekeeping, better storage area, clear process flow and the involvement of labor at all levels of improvement. The cycle time and value added time changes achieved in the future state maps are compared in table.

Type of waste	CVSM	Cause	Effect	FVSM (recommendations and Kaizen changes)
Unnecessary human motion	Movement of worker between processes	Layout, location and procedural issues	Leads to labor fatigue and less efficiency	Proper tracks defined ,developed Kaizen layouts and standard procedures (SOP) developed
Conveyance of material	Using material handling equipments	Layout, location and logistics	Lesser value added time	Vertical racks, proper allotment of cranes and pallets developed, fabricator involved in planning of material pick up from shop
Over-production	Excess quantity of same cut parts forecasted for rework	Wrong prediction of demand and scheduling ,planning inefficiency	Storage problems	Just In Time methodology used from contractors order point of view
Inventory	Shop floor work in process inventory with extra stock	Flexibility in job priorities, fabrication planning, design changes	Excess storage, less floor space, inefficient shop	Just In Time methodology used from contractors order point of view and Kanbans for daily consumable items
Over processing	Information flow	Too much data entry ,record keeping, approval procedures,	Time consuming delivery even the parts are physically cut	Only SAP entries and material issue and return formats developed
Rework	Only found in tagging and number punching, QC stamp	False punching, QC stamp transfers	Storage , retrieval and identification problems	Training given to operator for job coding and material identification and stamp transfer
Space	Issue to be taken at priority	Excess ordering, advance planning, improper shelving, Flexible material flow	Material storage and retrieval problems, problem in material handling	Vacant area available outside shop allotted as off cut storage area (OC01) which gave open space for material handling inside shop. Also vertical racks and trailers provided for off cut storage.

Waiting	Between processes and handling equipment and material retrieval	Waiting for QC approval, third party inspector, drawing corrections, nesting time delay.	Reduction of shop efficiency and delay in cutting and delivery	Alternate nesting options , calculation and study of QC plan, Improvement of master plan ,scheduling and BOM entries

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Table 1. Type of waste

VSM is just a tool

1. Draw the current status
2. Identify waste/problem in the process flow
3. Draw future state
4. Define the action to move from current to future plan
5. Implement action
6. Monitor the results possibly and then start again

The end is a flow better with less waste (material, process time), more efficient and effective.

Chapter 3 Leanness for non-manufacturing process

In order to solve any problem, the engineer needs to have an understanding of the larger system and the effects that each step in the system has on it. The idea of problem solving is not limited to manufacturing system or engineers. It is the basis for solving any engineering problems from research to analysis to design to production to distribution. To solve engineering problems, engineers are uses analysis tools rather than guessing.

VSM is one of the analysis tools that are very reliable when there are multiple contributions to the problem to be solved. This technique is not limited to the engineering field. VSM is also used for analysis of any process including the flow of information and office paperwork, Industries, medical fields, food service, municipal service and educational institutes use this tool to improve their process.

VSM is a method to think through a current situation, create an ideal situation and determine the best way to get to that bridge the gap. VSM is not limited to only manufacturing environment; it is usable for many scenarios including the process of engineering design, sales, marketing and any process can be improved by the technique of VSM.

3.1 Analysis of lean knowledge

On this analysis mainly focused on value added that is increasing knowledge and the non value added that does not increase the knowledge specifically during the lecture time in the university. Knowledge can be evaluated by exam or presentation and it is known that how much the students can remember the lecture during the lecture time. Taking in to account in the university students are attending the class lecture for 3-4 hours.

Despite there being anywhere from 20-150 students in the class room, there is little actual interaction. This model of process illustrates the daily activities of the students and how they increase the knowledge when they attending 3-4 hours lecture. The number of students is larger because of economical way to educate larger number students. We know the number of students increase and the longer hour will decrease the value of knowledge in different factors or limitations. But in my case I have avoided those limitations.

3.2 characteristics of knowledge

In order to study the characteristics, I used two studies as a reference for the leanness of the non manufacturing process called learning process by applying the VSM technique in order to calculate for my case studies.

The first was Edgar dale's principle and in 1946, he introduce the experience "*CONE OF LEARNING"* and the concept in a textbook audiovisual method, and he revised two times in 1954 and 1969, and he referred to inform viewers of how much people remember based on how they encounter information. However, dale included no number and didn't base his cone on scientific research and he also warned peoples not to take seriously. But in my case study I took as one of the reference to know the characteristics of the knowledge.

The second studies tells us that in 1996 in a journal called the *NATIONAL TEACHING AND LEARNING* FORUM two professors from research on human attention and retention speaks against the value of longer lectures. So the study determined that students needed 3-5 minute of settling down, which would be followed by 10-18 minute of optimal focus. No matter the teacher how he good or not or how compelling the subject matter. These studies focused on college students and of course it was done before the age of texting and tweeting. Presumably, the attention spans of younger people today have become even shorter or certainly more challenged by distraction.

3.2.1 CONE OF LEARNING METHOD

Dele's cone of experience is a visual mode that composed of 11 stages starting from bottom of concrete experience to become more and more abstract as it reaches the peak of the cone and the order based on the number of sense but not difficulties and the experience can be mixed and interrelated for the meaningful learning. The balance must be achieved between concrete and abstract experience in order to catch and address all the need of the learning in all the domains of development and in order to help each learner in their holistic development.

By going one by one starting from the concrete to abstract experience, we will see more the difficult components of the cone of learning that will help us to grasp the real meaning of educational technology.

1. Foundation of learning that means doing presentation, real things, simulation and real expression; in this level the learner learned by doing himself and learning happens through the actual hand on experience. This level proves one of the principles in the selection and use of

teaching strategy, the more sense that involved in the learning strategy, the more and the better the learning will be.

2. In the bottom second level, participation and giving talk more practical and it makes learning experience more accessible to the learner. In these experiences it provides more concrete, even if not as concrete as direct experience.
3. It is visualized explanation of important facts, ideas or process through the use of pictures, drawings, films or other types of media in order to facilitate clear and effective learning. In this level, things are shown based on how they are done.
4. The last three sub levels also combined because they are used hand in hand and those are a visual symbolic and verbal symbolic. It is the most complex and abstract among all the components of the cone. In the visual symbolic level charts, maps, graphs and diagrams are used and for verbal symbolic in the level of words, ideas principles, formulas and so on.

After doing the different cone of experience, it is possible to improve the learning capability. We can use variety of materials and medium in order to maximize the learning experience. It is not enough use one media if we take advantage of the other. There is nothing wrong to combine different media as long as it is useful for the benefit of the learning. Also, it is more helpful for the learning using the concrete experience (active) for the support of abstract experience (passive).

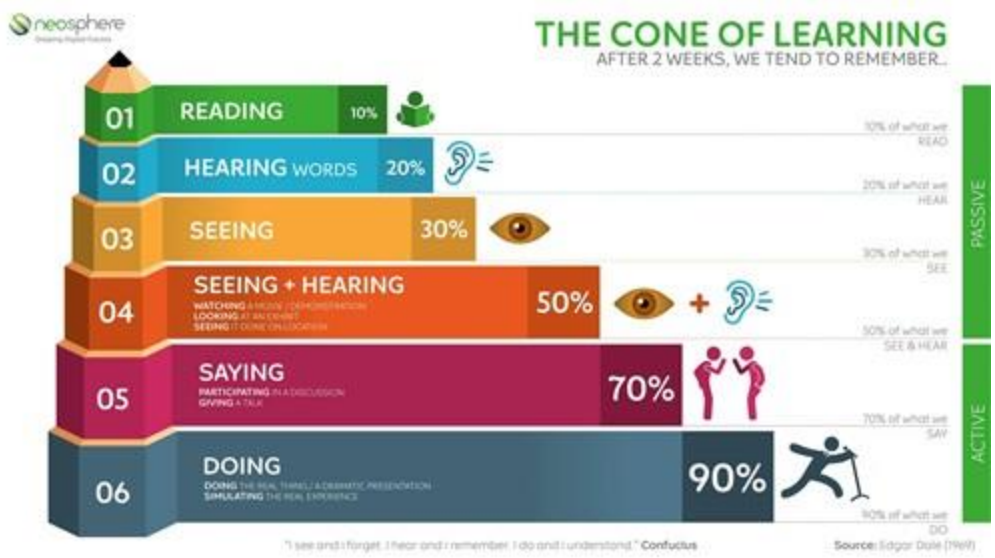


Fig. 6 Cone of learning

3.2.2 NATIONAL TEACHING AND LEARNING

The study from 1985 which tested students on their recall of fact contained in a 20 minute presentation. While might expect that recall of the final section of the presentation would be greatest the part heard most recently. In fact the result was strikingly opposite. Students remembered for more of what they did heard at the very beginning of the lecture. By the 15 minute mark, they did mostly zone out. Yet this studies been refuted went largely unapplied in the real world.

In this case study in order to tackle those challenges apply VSM technique that could increasing the value of knowledge by finding where the defective area of failures, waiting and setup, even though, it could difficult to implement this study, thanks to the internet technology which we have the ways to use the internet lectures and there will be a possibilities to divided up in to shorter sub 15minute session and be delivered outside the class room, but this could work for many business schools, with engineering or science class time can be used for students to collaboratively tackle more challenging question or projects. In this VSM study I propose internet for the knowledge increment. The information flow is more of effective, if we need some references, could access easily from the internet. There will be more time for transportation waiting (queue), traffic jam and watching TV on the current VSM. This leads to increase the non value stream of the process.

According to the principle of VSM, it needs to improve the material flow process which is the knowledge and information flow which is specifically the information exchanging through the companies, department, teachers and students. So in order to improve the material flow process ”knowledge”, we will do some experimental process or will take action by using different alternatives based on the national teaching and learning and make some improvement.

3.3 value of knowledge

Lecturing is the common method of teaching lean manufacturing topic including VSM in an educational environment and normal method of assessing the student is by a formal exam. This method is relatively easy to administer; however, the students will lack a true grasp of the advantage of lean manufacturing and how to use lean manufacturing in an industrial setting if they are not directly involved in the process.

By using Edgar dale’s “cone of learning” example, we can see the student attending only the lectures on a subject only retain approximately 20% hearing of the material and is considered “passive” learning. In

order to improve the engineering student's attention, the course must organize as an "active" learning experience or mix different Medias.

3.4 create current VSM of knowledge

This mapping stream extracted from the general daily activity of the figure (fig.2) and the aim of this study as I said before how knowledge improves specifically by looking only the process that which an input lecture time, study at the library. Generally speaking, there are many kinds of knowledge improvement techniques, for example radio, television, internet and others but in my case I have focused on the university study.

In the figure below process does not tell us detail activities but generally those are the probable activities that could get the knowledge especially during the lecture and reading in the library. Later will see detail factors that could decrease the attention and how It improves according to the cone of learning and national learning and teaching and we will see what kinds of techniques could improve in order to tackle the decreasing factors. As we know the aim of VSM is to satisfy the customer or fulfill the customer's needs, the companies' profitability, in our case the customer is the employer or company and the supplier is the teachers or professors in the university. At the beginning the VSM has been implemented on the manufacturing process but currently there are different sectors are going to be using this technique that is non manufacturing process because of the need to lean in every sector. In my case I'm using for educational system that is specifically for improvement of student's knowledge. So I'm trying to categorize the process which means making the relation knowledge needed by "customer" and lectures, books and internets are the source for the knowledge improvement called "supplier"

3.4.1 Outline of the process

The process map diagram that is listed below the daily schedule starting from the morning activity; wakeup, washing, eating breakfast and then going to university taking 60 minute including transportation and waiting bus, attending 4 hours lecture in the morning including 15 minute break (setup) in between the lecture time. The studies focused on the lecture time and how students give attention and retention during the allowing time. Then have lunch, taking nap, coffee. After lunch, the 3 hours lecture started in the afternoon including 15 minute break (setup); sport, shower, dinner and take some refreshing and then back to study, finally go to sleep. The sleep time will be 7 hours. These are the daily activity or schedule commonly students has using but different students may have different experience. In my case I have chosen this kind of schedule.

3.4.2 Draw the flow of knowledge and information

Daily activities

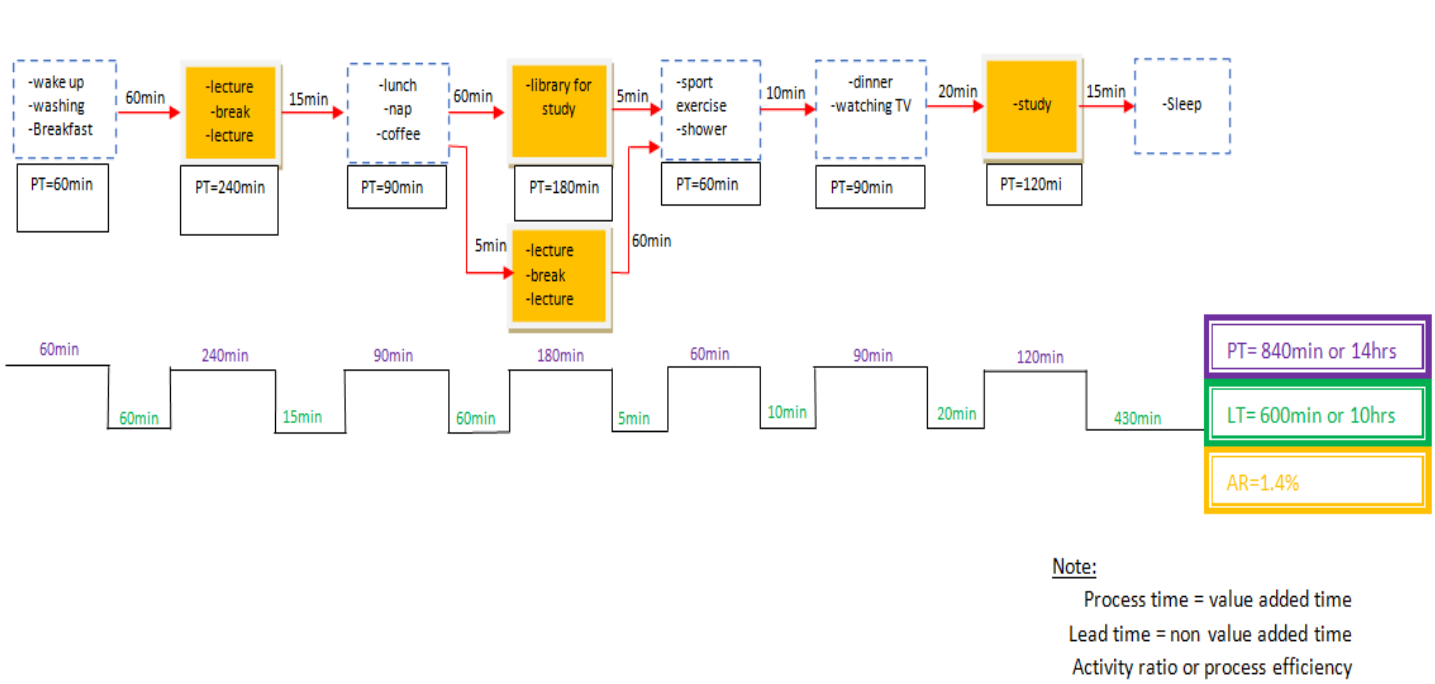


Fig. 7 Daily activity of the students

As we see on the figure below the value added time or PT= 540 minute our objective is on this because this is the process that could get knowledge, but this is general case, when we come to the real world, this could different.

Therefore, we will see in detail process on the other stream mapping and based on the real map, we could take some improvement in order to write the future or the improved stream mapping.

➢ **Current Value Stream Mapping**

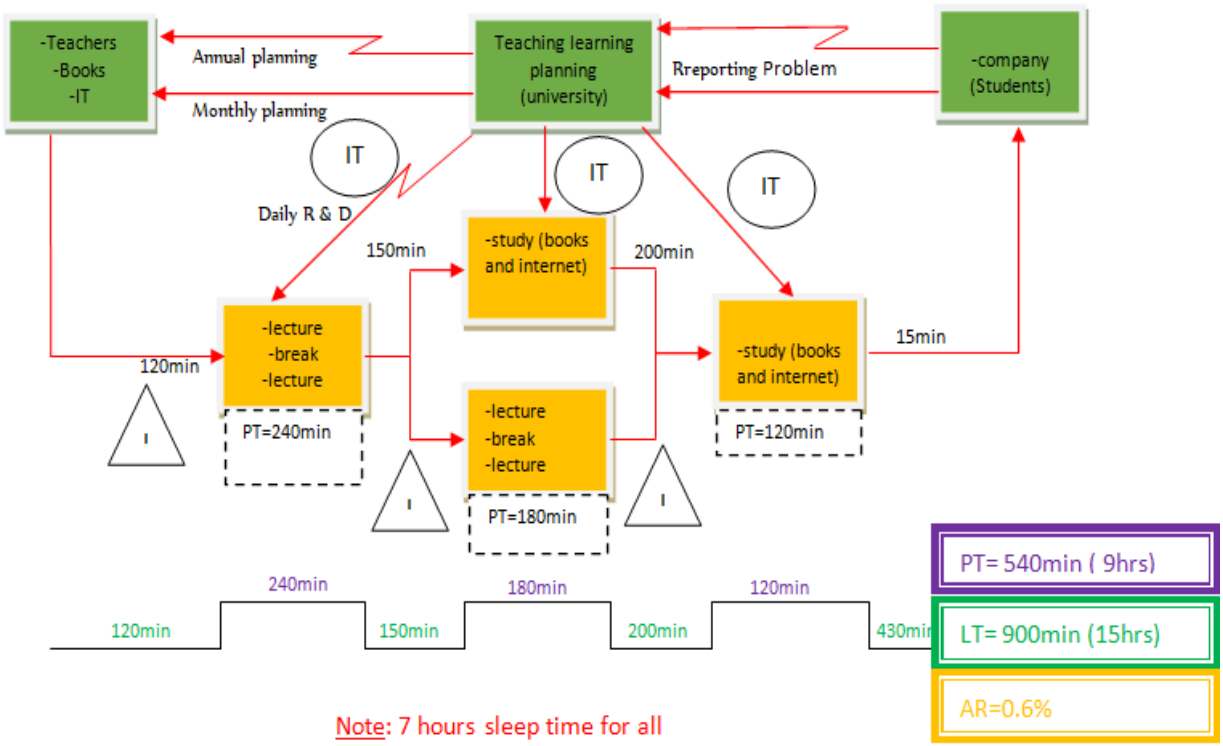
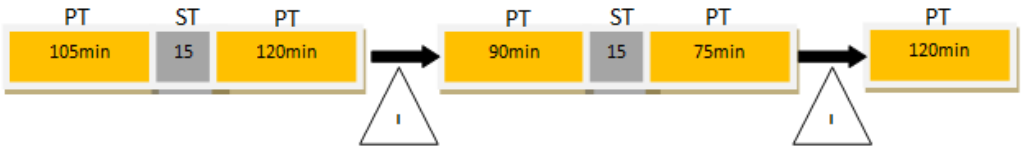


Fig. 8 Current Value Stream Mapping of knowledge Flow

3.4.3 Analyzing the process

From the above the current VSM process, I need to extract the possible factors that could increase the knowledge in the process and listed below the lecture time and library study time in order to improve the attention.



The triangle box is the inventory that is, if the lecture from the cone of learning only hearing, the students could remember or attention 20% of the lecture so 80% of the lecture could be non value added. So the 80% of lecture will be stored in the inventory. That non value lecture time should

compensate during the study time or other techniques. We will see different techniques how to manage those non value added lecture time.

3.5 create future VSM of knowledge

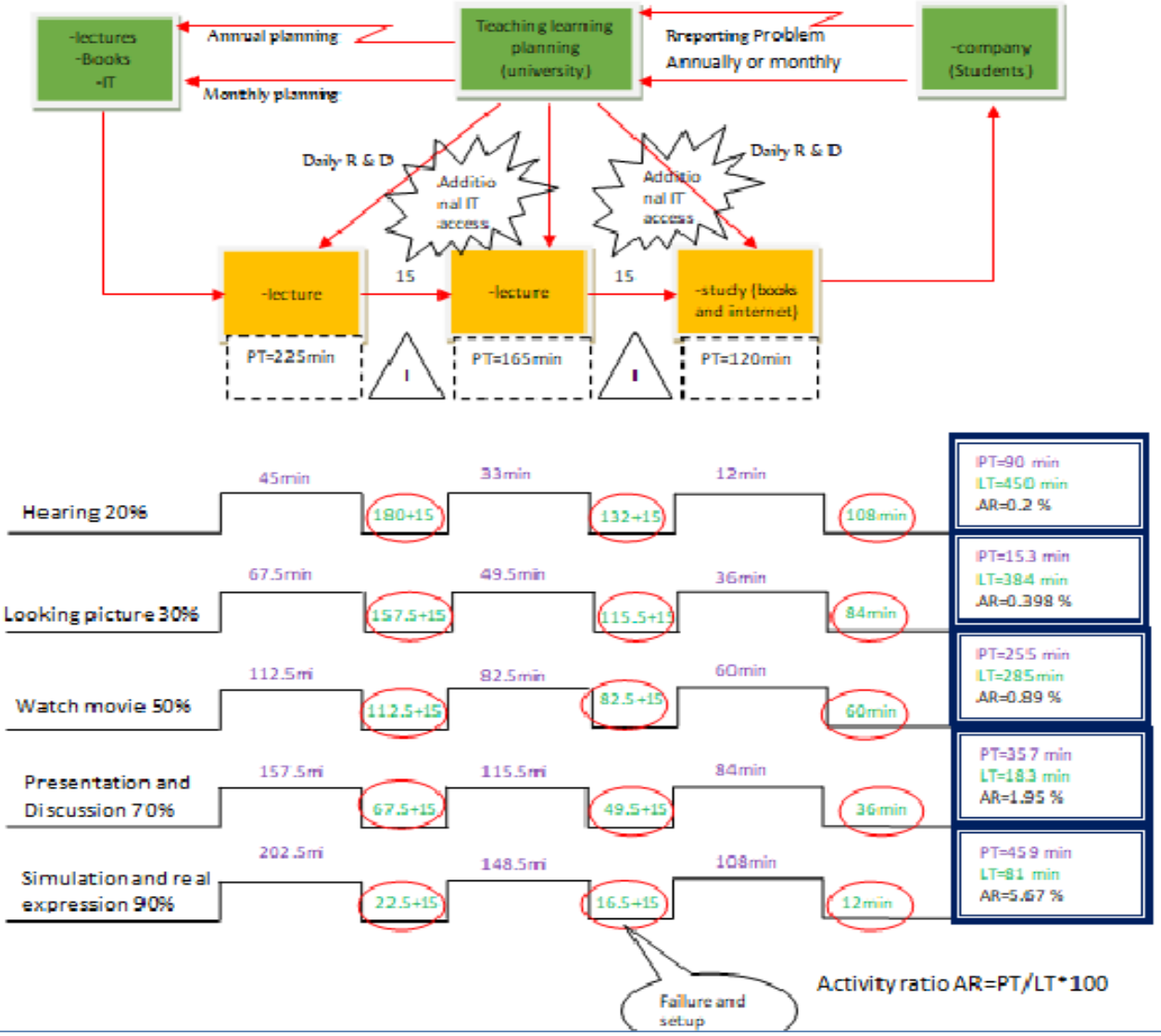


Fig. 9 Future Value Stream Mapping of Knowledge Flow

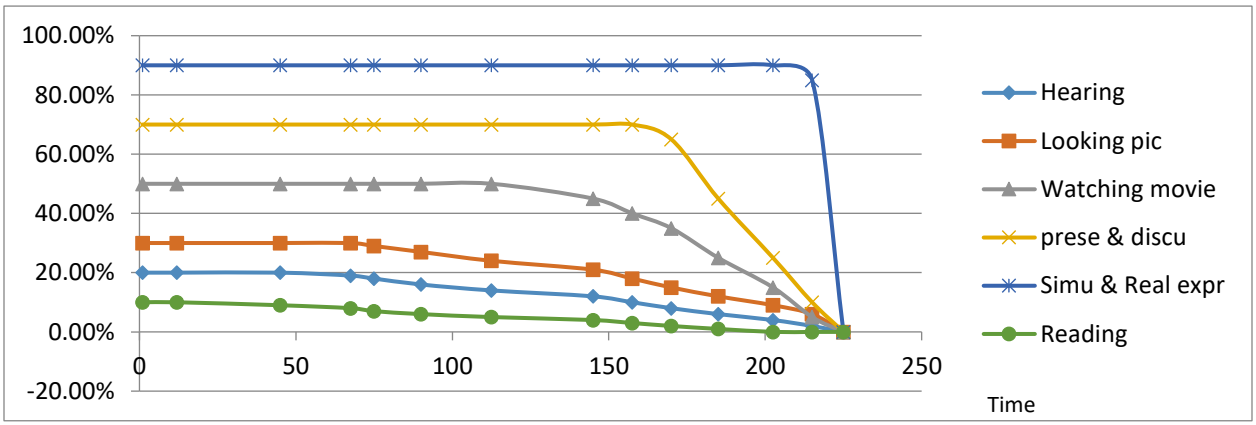
3.5.1 Time line and performance

success						
Lecture	10%	20%	30%	50%	70%	90%
Morning (min)		45	67.5	112.5	157.5	202.5
Afternoon (min)		33	49.5	82.5	115.5	148.5
Library (min)	12		36	60	84	108

Failures and setup						
Day	10%	20%	30%	50%	70%	90%
Morning (min)		180	157.5	112.5	67.5	22.5
Afternoon (min)		132	115.5	82.5	49.5	16.5
Library (min)	108		84	60	36	12

Table 2 performance knowledge according to the COL

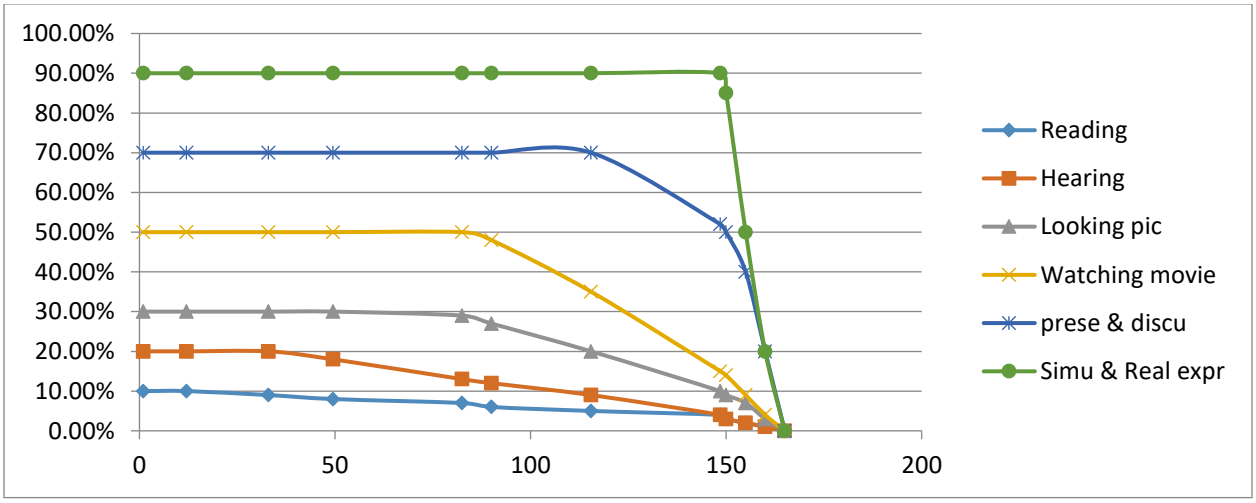
Morning lecture attention performance



	11.25	22.5	45	67.5	75	90	112.5	145	157.5	170	185	202.5	215	225
Reading	10.00%	10.00%	9.00%	8.00%	7.00%	6.00%	5.00%	4.00%	3.00%	2.00%	1.00%	0.00%	0.00%	0.00%
Hearing	20.00%	20.00%	20.00%	19.00%	18.00%	16.00%	14.00%	12.00%	10.00%	8.00%	6.00%	4.00%	2.00%	0.00%
Looking pic	30.00%	30.00%	30.00%	30.00%	29.00%	27.00%	24.00%	21.00%	18.00%	15.00%	12.00%	9.00%	6.00%	0.00%
Watching movie	50.00%	50.00%	50.00%	50.00%	50.00%	50.00%	50.00%	45.00%	40.00%	35.00%	25.00%	15.00%	5.00%	0.00%
prese & discu	70.00%	70.00%	70.00%	70.00%	70.00%	70.00%	70.00%	70.00%	70.00%	65.00%	45.00%	25.00%	10.00%	0.00%
Simu & Real expr	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	85.00%	0.00%

Fig. 10 decreasing performance of COL morning session

Afternoon lecture attention performance



	8.25	16.5	33	49.5	82.5	90	115.5	148.5	150	155	160	165
Reading	10.00%	10.00%	9.00%	8.00%	7.00%	6.00%	5.00%	4.00%	3.00%	2.00%	1.00%	0.00%
Hearing	20.00%	20.00%	20.00%	18.00%	13.00%	12.00%	9.00%	4.00%	3.00%	2.00%	1.00%	0.00%
Looking pic	30.00%	30.00%	30.00%	30.00%	29.00%	27.00%	20.00%	10.00%	9.00%	7.00%	3.00%	0.00%
Watching movie	50.00%	50.00%	50.00%	50.00%	50.00%	48.00%	35.00%	15.00%	14.00%	9.00%	4.00%	0.00%
prese & discu	70.00%	70.00%	70.00%	70.00%	70.00%	70.00%	70.00%	52.00%	50.00%	40.00%	20.00%	0.00%
Simu & Real expr	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	85.00%	50.00%	20.00%	0.00%

Fig.11 decreasing performance of COL afternoon session

Assume lectures only hearing by 20% for 225 min in the morning lecture, and some studies says that student's attention higher or maximum and can easily remember 20% of the lecture, therefore, the graph indicated below starting from time zero till time 180 minute the attention will lose and after 180 minute to 225 minute that means 20% of the lecture is the effective process. So during the 225 minute only 45 minute lecture can remember and have got knowledge. Therefore, the loss is very high and needs intensive improvement.

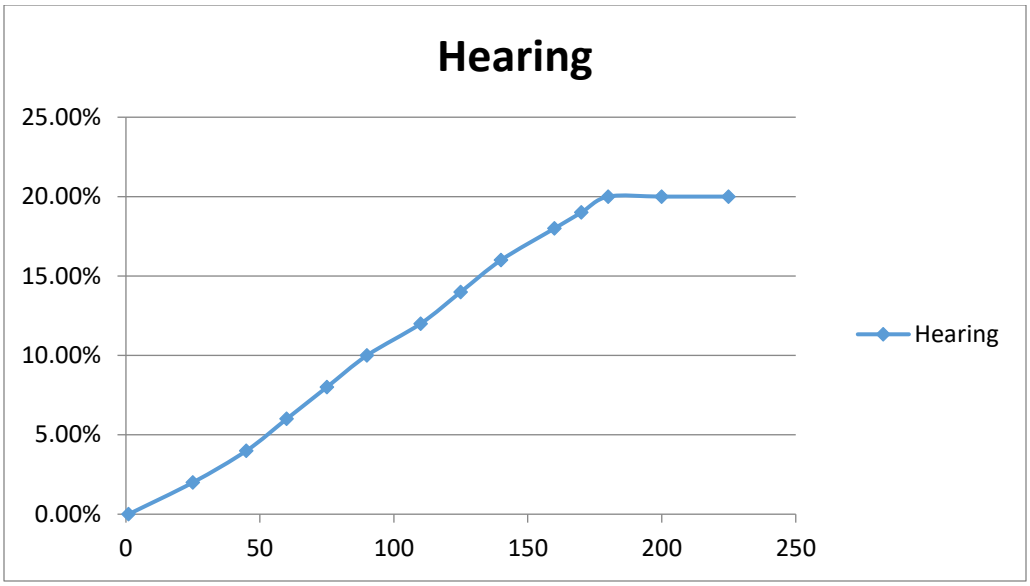


Fig. 12 performance of hearing increment

3.5.2 Determine the appropriate metric for improvement

3.5.2.1 The cone of learning method

On the hearing experience we will have 45 minute an effective attention out of 225 minute lecture, if the lecture held only hearing that means there will no mixing other experience, we will have only 20% of effective lecture, 80% will be loss.

By taking other possibilities that is mixing different media of experience, we can improve the learning experience.

Example: during lecture

Case 1

From 225 min hearing 50%*225min = 112.5 min * 20% = 22.5 min

From 225 min looking picture 30%*225min = 67.5 min * 30% = 20.25 min

From 225 min discussion and doing exercise 20%*225min = 45 min * 70% = 31.5 min

74.25 min is effective

Case 2

From 225 min hearing 60%*225min = 135 min * 20% = 27 min

From 225 min looking picture 20%*225min = 45 min * 30% = 13.5 min

From 225 min discussion and doing exercise 20%*225min = 45 min * 70% = 31.5 min

72 min is effective

Therefore, we can see the difference from the above two cases, the first option is better than the second. So By doing different mixing options, we can select the better teaching style.
According to the above calculation the maximum value added is 74.25 min which is effectively give attention and will have knowledge out of 225 min during the morning lecture. But if we take only hearing that means without mixing the media, only 45 min can be given attention out of 225 min that means 20%. We can have improvement especially if the lecture held 225 min only hearing, the student can give attention 45 min and lose or fail 180 min. even if the improvement is 74.25min which means 33% increases, yet it needs improvement.
In order to improve the failure time, we will wait and take action on the third process that is study time. The non used time is 117 minute and in the study process we will have 120 and divide it by 7 hours lecture morning 4 hours and afternoon 3 hours. So we will have 68.57 minute study time for the morning. During the study time also couldn't fulfill the value added on the given time. So it needs additional study time. We could manage it by using cone of learning experience.
Example: during library

- Reading 20%*68.57 min= 13.7 min * 20% = 3 min
- Simulation and real expression 30%*68.57min=20.57min * 90% = 18.5 min
- Talking with friends 50%*120min= 34.285 min * 70% = 24 min

= 3 min + 18.5 min + 24 min = **45.5 minute**

Therefore, 45.5 min + 74.25 min = 120 minute out of 225 minute lecture
53.23% is the improvement or the success and 46.77% is the loss. In order to improve this loss we can manage the daily activity schedule by increasing the study time and minimizing the transportation and waiting, nap time, lunch time and watching TV or other tasks and additionally we can add the weekend time too.

3.5.2.2 NATIONAL TEACHING AND LEARNING METHOD

Another study is the NATIONAL TEACHING AND LEARNING. According to the study in 1996 in a journal called the NATIONAL TEACHING AND LEARNING FORUM two professors from research on human attention and retention speaks against the value of longer lectures. So the study determined that students needed 3-5 minute of settling down that is setup, which would be followed by 10-18 minute of optimal focus 2 minute decaying that is failure before ending the 20 minute lecture. No matter the teacher how he good or not or how compelling the subject matter. Usually this kind of settling working

for the business students and, if we apply the cone of learning in the business students, that does not work properly in addition that will not be effective. For that reason the NTL has chosen the lecture style will be 20 min followed by 5 min setup time and mapping the future value stream even if not really applicable in the existing world.

Let us compare the COL and the NTL. According to the cone of learning experience the effective attention for the 225 min lecture in held in the morning:

	Experience	Ratio	Effective time	Failure time	Failure ratio
1	hearing	20%	45 min	180min	80%
2	Watching movie/demonstration	50%	112.5min	112.5	50%

Table 3 Performance

By mixing the two passive experiences we can improve the learning process

3.5.3 Analyzing the process

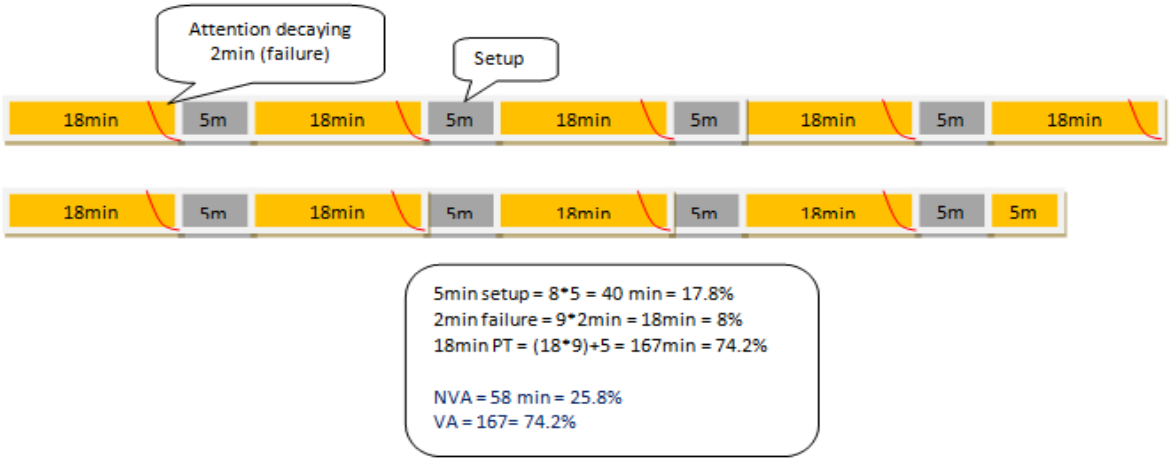
Case 1

Let's see the lecture time without dividing it 20 by 5 minute principle

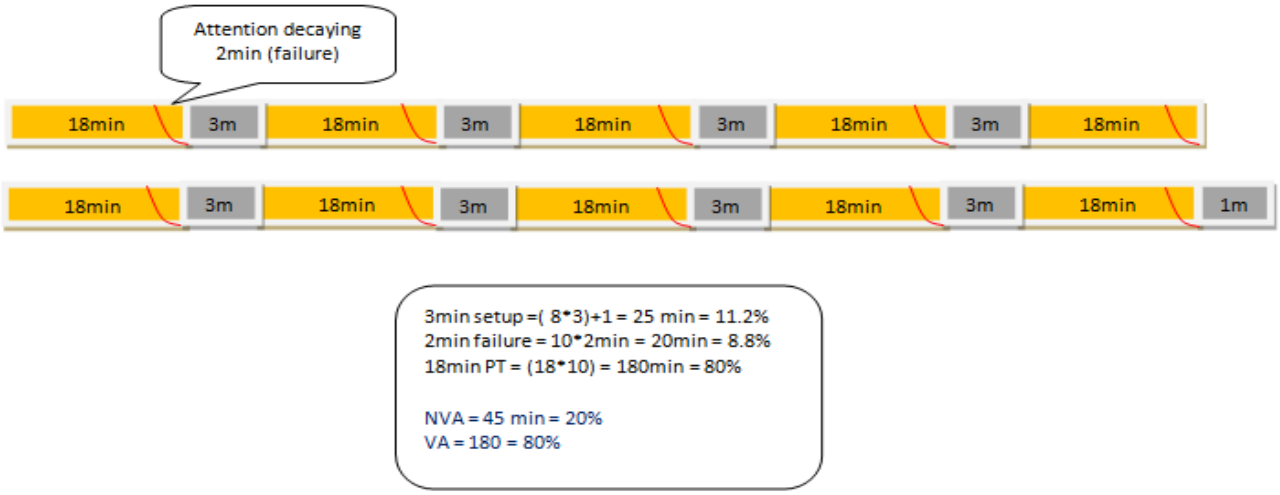
225min*20% hearing= 45 min

Let us see this on the NTL method and we could easily understand which method is more effective for the business filed course.

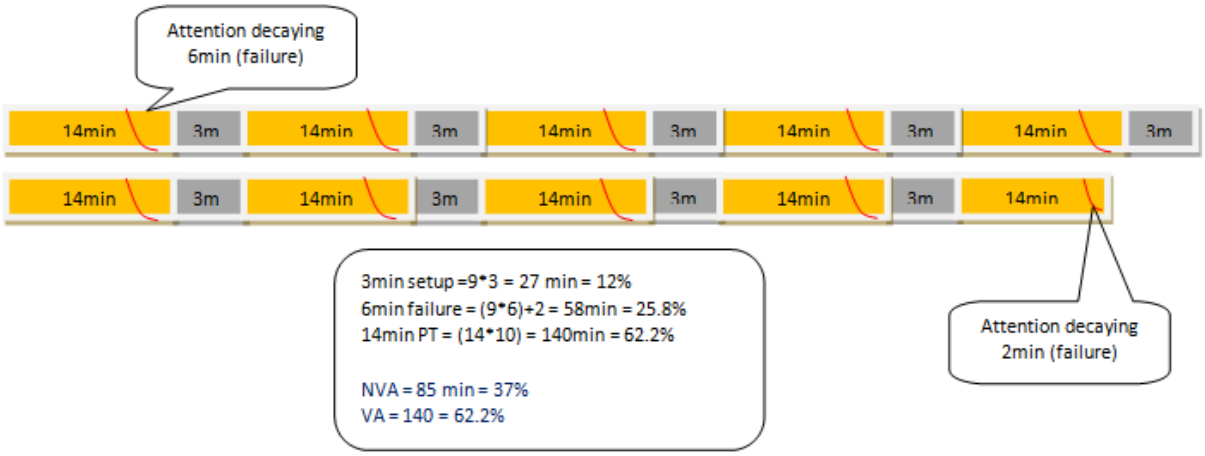
Case 2



Case 3



Case 4



	Case 1 (NTL)	Case 2 (NTL)	Case 3(NTL)	Case 4 (NTL)
VAT	45min	167min	180min	140min
NVAT	185min	58min	45min	85min
Eff.	20%	74.2%	80%	62.2%

Table 4. Performance comparison

As we see the whole cases (1-4) that uses different alternative ways based on the studies on NTL for the improvement method, there are different results case 2 is 74.2% case 4 is 62.2%. The value added in case 3 has been greater than the rest of the cases, 80% of the value is added on the learning process but when we see the value of the cone of learning that is case 1, we have only 20% value added.

Therefore practically as we see the national teaching learning for business students is more useful even if it does not applicable in the existing world.

3.5.4 Initiate the improvement

Other possible techniques to improve attention:

- Teachers need techniques to harness students' attentions and energy as soon as they arrive in the classroom

  Students enter the classroom with divided attention. Beyond daily distractions such as smart phones or other technological toys, students have lives outside the four walls they occupy for a short time. It is often difficult for them to cast friends, sports or even other classes from their minds as they walk through the classroom door.
- Beginning class with effective transitions that means much like the hook of a well written essay, teachers need strategies to capture the attention of their students in the first ten minutes of class. By
  - Asking questions related to today's topic
  - Short writing exercises help students focus
- Using student centered pedagogy to battle short attention spans

  Students in the 21st century do not have the same attention span as students did 18 to 20 years ago. Education research has found that students focus on a single activity from 18 to 20 minute. Research shows that while students commonly lose focus for under a minute before they refocus, their ability to maintain attention diminishes throughout the class period. Additionally, students focus more effectively when teachers integrate in student centered pedagogies. Considering that students are more actively engaged at the beginning of the class aside from the first few minute when they are settling in it may be more effective to begin classes with the lectures and shift to an activity about 18 to 20 minute in to the class period. From there, teachers can return to recap the activity, which will promote student interest and engagement as it is a reflection of the activity that they just completed. Regardless of the structure, research shows that integrating in activities ensures and switching up content delivery models help to maintain student interest.
- Improve recall by asking students to make connections and apply knowledge at the end of class, it is important that teachers wrap up the material covered in order to ensure students remember what was covered and connect it to what has been done and what will be done.

Additionally, students need an opportunity to apply their knowledge, the last 10 minute of a lesson are a good time to do so. Some tips to end class.

- Reference questions or activities completed in the first five minutes of class. Ask students to discuss what they wrote or to reflect on how their understanding has changes.
- Ask students to apply the information taught to an activity before they leave class. This helps to cement the information before they go home.
- Discuss how what the class did today will relate to their assignment or how it bridges into the next class.

Wrapping up the class and helping students to bookend the lesson ensures students understand the purpose and use of the information they have received. It helps them connect their learning to what comes next as well.

- Structured class periods improve student learning: timing is everything, and teachers who carefully structure the class period ensure students are able to activate prior learning, effectively receive information and remember the information they learned.

3.5.5 Chapter summery

In my case study for the knowledge improvement in the class room have choose different techniques. There are many types of techniques that have been done by different researchers' or institutes and still are going to do. For my case study I used the two types as I have tried to show in detail in this chapter. For the cone of learning mostly recommended for the engineering students. Because, engineering fields are usually based on practical, simulation and presentation. Therefore by mixing the different experience from the cone of learning, the teachers or the institutes could manage the lecture time. Different courses have different behaviors and different teachers' also have different ways of experience, in order to tackle this challenge, the institutes or the teachers can manage their lecture time based on the cone of learning.

Another technique that I used is the national teaching and learning, this techniques mostly used for the business field. The business filed usually hearing not simulating or presentation. If we use the cone of learning technique for the business field, the students could give attention 20% only. But if we use the national teaching and learning method, the student attention will be from 62% to 80%. In this method also we can have different improvement cases that I have showed before.

Applying this improvement techniques in the knowledge improvement flow, and the future VSM will improved. The non manufacturing VSM improvement techniques may not similar to the manufacturing VSM. In the manufacturing VSM the material process improved by different techniques kanban, kaizen, pull or supermarket system, shop floor…etc

The information flow and time ladder are similar. VSM usually focused on the material flow or knowledge flow, if this flow improved the information and the time ladder will directly or indirectly improved.

Chapter 4, Leanness for manufacturing process

4.1 overview of process flow

The company planned to produce 100,000 parts of cylinder head per year in the three shifts, 8 hours working per shift with nonstop; the working days will be 6 days in a week in order to fulfill the customer need. But currently the company could not produce 100,000 parts per year due to the work station higher variability. The first work station is cutting task; the second work station contains drilling and milling tasks and the third work station finishing. Time for service, repair and maintenance could be scheduled at the end of the week because of the busy schedule of the working hour in a week.
In the first work station there are different activities but eliminating the other activities to simplify the mapping process and I consider only the cutting activity and the object according to the given data the work has done, in the second activity there will be milling and drilling this activity increase the setup time because of a single machine and multiple work task. In this work station also there are different activities but for our simplicity, eliminate the detail activities and consider milling and drilling, in the third activity we can have the finishing activities.

In the current VSM we can see in all work station has very high variability and we could say worst case. Therefore, the Variability comes from:

- Repair time for machine failure
- Process time
- Setup time
- Re-work
- Etc

Let us see in detail the tasks held by each WS and generally what kind of problem that could affect our WS performance in the existing process.

4.2 Analysis of process flow

Work station 1

Failure: machines or tools need maintenance in order to keep them in good working order. While, there are certainly any number of problems that can lead to issues and errors within the machine. Some

problems are more common places than others. Other problem comes from the life time of the machine that means the depreciation of the machine also take in to consideration. But on my case taking the failure comes from lack of maintenance, improper service time others. The common causes of machine's failures are:

- Poor or improper maintenance

  Machines need to be carefully cleaned and lubricated on a regular basis. A lack of cleaning could lead to a buildup of dirt and debris. This might seem to be purely a hygiene issue, but it can have real implications in the machines output.

  Therefore as we see the company working hours is 24 and working for 6 days per week. During the cutting process, a buildup of dirt could be preventing the machine from working correctly and providing the most accurate instruction. If this issue continues to go unchecked till the end of the week, it will create challenges as the machine struggles to locate and hold materials still. This leads to greater issues with accuracy and precision and ultimately leads to more errors. Another cause might be improper lubrication that could lead the machine parts (cutting tool) sticking or not moving as smoothly as they should. This leads to overheating, stacking, breakage the tools and the machine by blockage the air passage
- Improper setting or tools

  The tools are becoming blunt, a cutting coolant or lubricant is falling to work correctly or a tool is moving at the wrong speed. These are the cause for the problems. If the tool moving slowly, the material will be under the cutting edge for longer than it should be. If the tools moving faster than the cutting tool parameter, the tool becomes heater and heater. So this results in the burning and scarring. Similarly, if the coolant is not working correctly, things could be getting hot and lead to breakage.
- Poor or improper programming

  The other issue that could lead to serious problems in the machining is incorrect programming. Since the programming directly contains the creation of the product. Therefore, if the programming is incorrect, the product will have problems. This caused by new or inexperienced employees. The employees may not have a complete accurate understanding of machines process or may enter the incorrect code to the machine and other factors…

Additional contribution factors for machine failures

- Wear and tear

- Cracking
- Leakage seal or fittings
- Corrosion of the equipment components
- Breakdown of certain electronic components

All the above causes are the problem reasons for the machine and tool failures in the first WS. This leads to increase the variability of the process by increasing the cycle time, queue cycle time and decrease the performance of the work station. Therefore, this has to manage by sustainable maintenance, continuous machine service, assign skilled man power and cleaning but if the machine fails continuously, changing the new machine or other alternative actions has to take in order to improve the work station performance. Otherwise, it will increases the cost, the process time and decreases the profitability of the company.

Work station 2

Setup time: the term of anglo-saxon origin, has different meanings, even if it is always referred to a preparation operation for the subscript start-up of a system.

- In the informatics setup is installation
- In production systems such as machines, lines, work stations, it is defined as tooling
- More generally for any system, it is defines as setup, as the set of operations necessary to prepare the start-up of the system in question.

The goal of setup time reduction is to reduce down time and variability. Reducing setup time will boost the company's capacity, increase manufacturing flexibility and increase overall output. If the machine is not running, we cannot make money.

The causes for the setup time increments are:

- Searching for misplaced or lost tools, waiting for tooling, obtaining process instruction etc..
- Removal of previous tooling and mounting or placement of the next job's tooling
- Loosing and tightening fasteners for tooling, loading materials in to position
- Calibrating tooling, establishing initial control setting
- Re-calibrations, missing or broken tooling or fixtures, incorrect materials being used
- Additional measurements of parts until setting are correct

By avoiding those causes or by reducing the setup time, we could have

- An increased capacity and shorter lead time of the line
- Better quality or more consistent process

- Low manufacturing costs and improved cash flow
- Less inventory
- Better utilization
- Low process variability

Suggestion for reducing the setup time

- Improve production line or job sequence by grouping technology using work cell
- Design product standard
- Mechanization or atomization

Therefore, in my case study in a second work station the setup time is the cause for the limitation of the performance of the manufacturing process. In this WS holds different tasks, milling, drilling with a single machine. Changing the tools obviously implemented. In order to avoid tool change within a single machine, make the system atomized to be improving the performance of the WS. This gives us an improved WS cycle time, lower lead time and lower variability.

Work station 3

Rework: according to the business dictionary, rework is defined as; correcting of defective, failed, or non-confirming items, during or after inspection. Rework includes all follow-on efforts such as disassembly, repair, replacement, reassembly etc…

There are several reasons why a product could be found to defective or requiring rework:

- Machine malfunction or human error
- Design change not communicating in timely manner
- Design change not implemented properly
- Product damaged in transit
- Product damage in use

Therefore, Rework is one of the source of variability in manufacturing systems is quality problem. This happens when a WS performs a task and then checks to see whether the task was done correctly. It wasn't the task is repeated. If we take the additional processing time spent that means getting the job right, it is easy to see that this situation is equivalent to the non-preemptive increases. Variability is increased by inspections caused by poor quality and possible rework. This can be compared with the non preemptive outage which means that we do rework between the jobs. It affects the production same way than setups meaning that seals capacity and adds variability of the effective process time.

Hence more rework implies more variability. More variability causes more congestion. These variability impacts, coupled with the loss of capacity, more rework a disruptive problem indeed.

How to avoid or reduce the rework?

Some studies seven ways and others five but for my case I have taken five ways to reduce the rework from the work station process;

1. Update and maintain an organized filing system: the company must transform the paper files to digitalize, software and filling systems to manage our CAD drawing, BOMs, standard operating procedures. Using digitalized files makes it much easier to track revisions, ensuring your employees are referencing the most update and accurate information.
2. Communication: communicate design changes to our contact manufacturer immediately. Changes can cause significant disruption to production if it's not handled properly. It's best to avoid making major design changes in the middle of a production run. Instead, wait until the next order for full implementation to ensure the change is adequately planned and executed. This will also make the product revision levels easier to track for you, the supplier and our customer.
3. Be proactive: quality control issues by taking a proactive rather than a reactive position. Make regular factory inspections to identify problems and to look for ways to improve processes. We can find the root cause of the issue and resolve it as early and as simply as possible by:
    - Acquiring new equipment and fixtures
    - Improved employee training
    - Software upgrades or additions
    - Greater attention during design phase
    - More emphasis on pre-production process
    - Additional packaging or handling procedures
4. Implement and emphasize quality control procedures: using a well developed and tightly monitored quality control procedure is essential to minimizing costs associated with rework. Adopting a total quality management in a closed loop plan, do, check and act, continuous improvement system is a great start. Six sigma quality and lean manufacturing practices will help you eliminate waste and improve quality.
5. Create scrap materials plan: it's always preferable to repair or alter a product, but sometimes scrapping is unavoidable. In the event you need to scrap, try to reduce the amount of waste as much as possible.

Rework may be a fact of manufacturing life, but it shouldn't consume our time and energy. Based on the above five steps can simplify our life by having good quality processes in place, that could result in even better products for our customers.

In the third WS the tasks could be:

- Sanding: is a power tool used to smooth surface by abrasion with sandpaper. Sanders have a means to attach the sand paper and a mechanism to move it rapidly contained within housing with means to hand hold it or fix it to a workbench. There are different types of sanders for different purpose. For example flap sander or sanding flap wheel is a sanding attachment shaped like a rolodex and used on a hand held drill or mounted on a bench grinder for finishing curve surface.
- Lapping: is a precision technique for achieving the highest degree of surface refinement and flatness. It involves a skilled crafts person who uses a soft iron tool together with mild abrasive slurry to slowly work the surface with random, light and linear motion by hand. This fills microscopic surface voids and flattens high spots.
- Polishing: is the process of creating a smooth and shiny surface by rubbing it or using a chemical action, leaving a surface with a significant specula reflection. In some material such as metals, glasses, black or transparent stone. Polishing is also able to reduce diffuse reflection to minimal values. When an unpolished surface is magnified thousands of times, it usually looks like mountains and valleys. By repeated abrasion, those mountains are worn until they are flat or just small hills. The process of polishing with abrasives starts with coarse ones and graduates to fine ones.

There are many types of finishing process but on my case I have taken only those listed on the above for the third WS. The work may repeat because after the quality control has checked and if they found mountains or other defective parts, they will return the defects parts and then rework will perform.

Generally speaking:

As we see on our manufacturing process the natural variability is higher. According to variability expressed in terms of the coefficient of variance in stochastic variables any system is classified that from 0-0.75 lower, from 0.75-1.33 medium, greater or equal to 1.33 is higher variability. The natural variability comes from or caused by.

- Worker ability: good practical skills, the ability to work quickly and methodically, the ability to concentrate while doing repetitive tasks, the ability to follow instruction and so on.
- Material variation: if the row materials change, the change can create variations in the overall process. There might be a difference in quality form the same supplier, which may fall within the specified limits but is still enough to cause variation in the process, or material from a different supplier may not be identical to the one from the first supplier.

Quality control: includes

- Defining the quality standards for each product
- Selecting the quality control method
- Defining the number of products or batch that will be tested
- Creating and training employees for quality control
- Creating a communication system for reporting defects or potential issues.

After checking and creating document approach quality control, need to create procedures for handling defects. The defect parts could be re-worked again and this leads to the work station time (effective process time) will increase at the same time the variability will increase.

Therefore, in my case study on the third WS held by the finishing process with one machines and held many finishing tasks due to that the errors on the finished product will increased. So it needs more important by looking and studying the root causes of the problem that leads to higher variability in the work station, and take decision in order to improve the process. The cause could be lack of skilled employee, material variability, or process variability etc.

On the current manufacturing process the whole WS have higher variability. The variability comes from the failure, setup and rework. This will affect the company's performance time, cost and quality. This will leads to lose the customer need. So in order to improve this problem, and make the company profitable plus fulfill the demand, I'm applying the lean manufacturing principle which is the value stream mapping. The lean principle of VSM technique is very simple to implement on the existing process in order to improve the working efficiency of the process and increase the performance as well.

In order to decrease or eliminate this variability, the work station needs to avoid the failure of the machine. The company has to repair durably or has to change the machine to increase the performance of the line.
In the second WS there is setup time. This also increases the variability of the line process. In order to avoid the setup time needs the machine automat.

4.3 create current VSM

Value Stream Mapping: as I said in the first chapter it's a lean management method for analyzing the current state and designing future state for the serious of events that take a product or service from its beginning through to the customer. A value stream focuses on areas of a firm that add value to a product or service, whereas a value chain refers to all of the activities within a company. The purpose of VSM is to identify and remove or reduce waste in VS and increasing the efficiency. Waste removal is intended to increase productivity by creating leaner operations which in turn make waste and quality problems easier to identify.

4.3.1 Outline of the process

In the first step we create the backbone of the VSM. We need to identify the operations and draw them in a straight line that means the process. Then add the external sources that are the customer to the right side and the suppliers to the left side as we see in figure below.

4.3.2 Map the information, material flow and performance

- **Current value stream mapping**

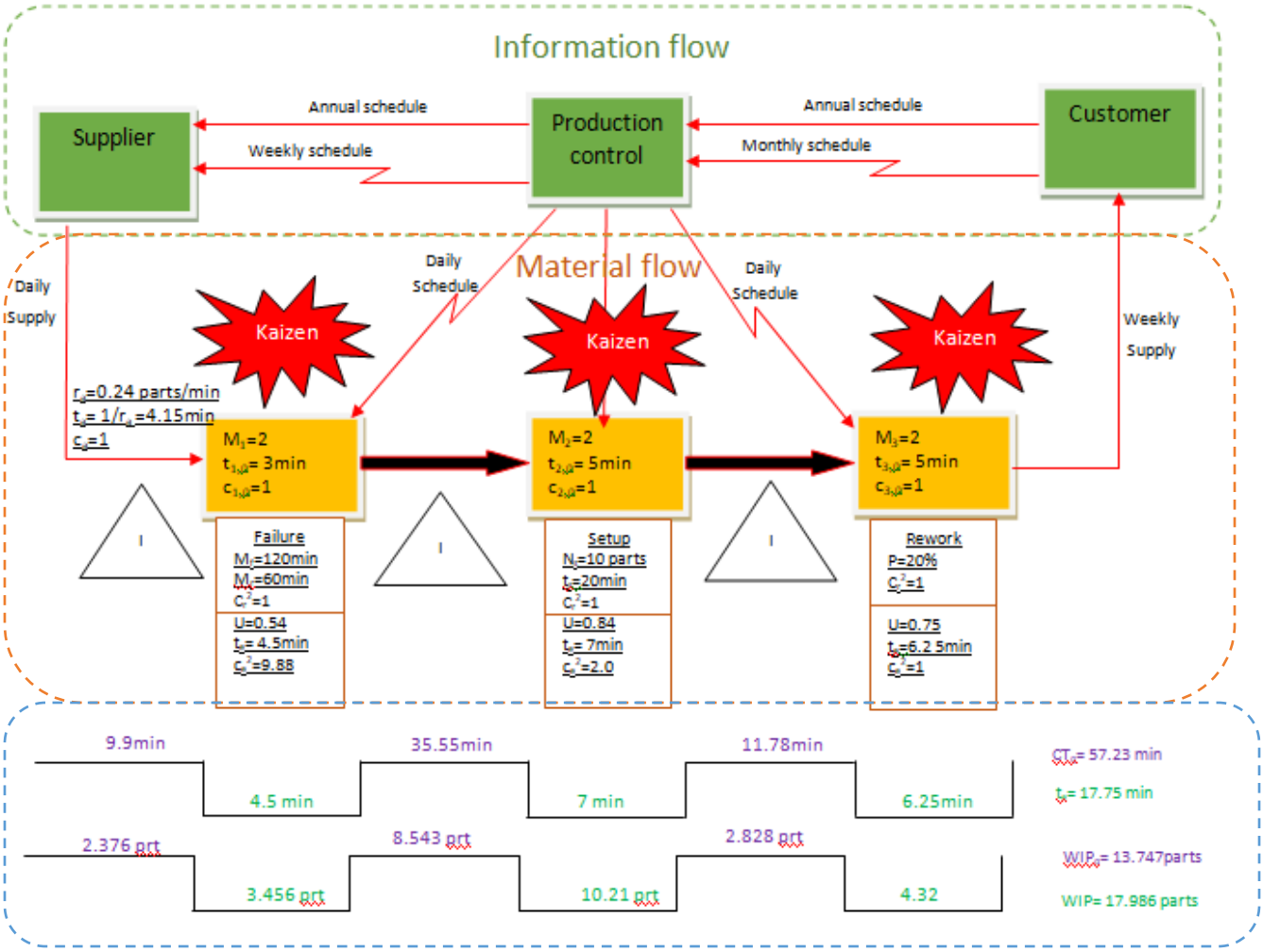


Fig. 13 CVSM Manufacturing Process

4.3.3 Add process data and calculation

In this step, we need to calculate the takt time, the process time and waiting time or inventory lead time and add these to out VSM. This will help us to calculate the total lead time, process time and process efficiency.

The takt time is the production pace that we need to be able to maintain in order to meet customer demand. In order to know the performance of our WS the calculation will be as follow:

If U < 1 the system is working

U ≥ 1 the system doesn't work

	Final Departure SCV		$= yc_d^2+(1-y)$	2.124	1.861	1.376
WS performance	Utilization	u	u	0.540	0.840	0.750
	Final Departure Rate (parts/time)	r_d	r_d	0.240	0.240	0.240
	Queue Time (time)	CTq	CTq	9.900	35.557	11.782
	Cycle Time (time)	CT	$= CT_q+t_e$	14.400	42.557	18.032
	WIP (parts)	WIP	$= r_aCT$	3.456	10.214	4.328
	WIP in Queue (parts)	WIP_q	$= r_aCT_q$	2.376	8.534	2.828
Line Performance	Cumulative Cycle Time (time)		Si(CTq(i)+te(i))	14.400	56.957	74.989
	Cumulative WIP (parts)		Si(ra(i)CT(i))	3.456	13.670	17.997

CCT = Tt_e + TCT_q= 17.75min + 57.23 min = 74.989 min

CWIP = $TWIP_q$ + TWIP= 13.747 + 17.989 = 31.736 parts

Current

Average time 17.75/3= 5.92 min

Per day => 1440min/5.92min = 243.24prts/day

Per year => 243.24*6*4*12 = **70,054. 05 prts**

The difference per day => 347-243.24 = 103.76 prts

The WS performance in the current VSM cannot produce the 100,000 parts per day due to the variability of the process. This leads to increase the lead time or cycle time which is the part spending in the line. In order to fulfill the customer request, the company has to improve the working station performance.

4.3.4 Analyze the capacity and customer demand

The above current work station system doesn't fulfill the customer demand because of the first, second and the third WS process a greater variability. The capacity at this current manufacturing process couldn't meet our plan. Therefore, the process couldn't fulfill the customer demand. The system does work because the utilization on the three WS has less than 1. Even if the utilization is less 1 and the system working, that doesn't mean fulfill the demand. Therefore, due to the variability failure, setup and rework, the process time has increased the variability also increased. In order to fulfill the customer needs, the manufacturing process should be improved by removing the failures, rework and setup time.

4.4 create future VSM

When we have done our analysis of the current state map, we will have a number of improvement ideas that we would like to implement. Before we do this, it is useful to illustrate what the process would look like after we make these changes. Sometimes this can help to avoid mistakes and also generate even better ideas for improvement.

When creating the future state map, there are some useful principles and methods that can be applied. These are discussed in the following section.

In the principle of VSM the improvement will be continues every time the company's process mapping needs to be leanness. The first CVSM could not fulfill the customer need at the given arrival rate. So it needs improvement in the whole WS. If the manufacturing line performance doesn't fulfill the customer demand while the line able to produce the product, we need to use different techniques in order to improve the WS performance whether by eliminating the WS variability or by increasing the parallel machine. But increasing the parallel machine could be difficult in terms of cost. So basically the principle of VSM is without increasing the machine or other costs, increase the performance of the existing line by eliminating waste of time because time is a very critical issues for the company. Time directly related with cost.

4.4.1 Determine the appropriate metric for improvement

Demand **= 100,000** per year

TT = available time/ demand = 60*24*6*4*12/100,000 = 414,720/100,000 = 4.15 prt/min

T a = 4.15min = 1 part = Td

R a = 1/TT = 0.24 parts for a min = Rd

1440 min/4.15 = 347 parts per day

In this way the company can fulfill the demand. But if the company not yet fulfills the demand, the same action has to take till the demand fulfils by applying the VSM. One of the advantages of VSM is this, till the maximum WS performance, the improvement will continue

4.4.2 Create the map of the future

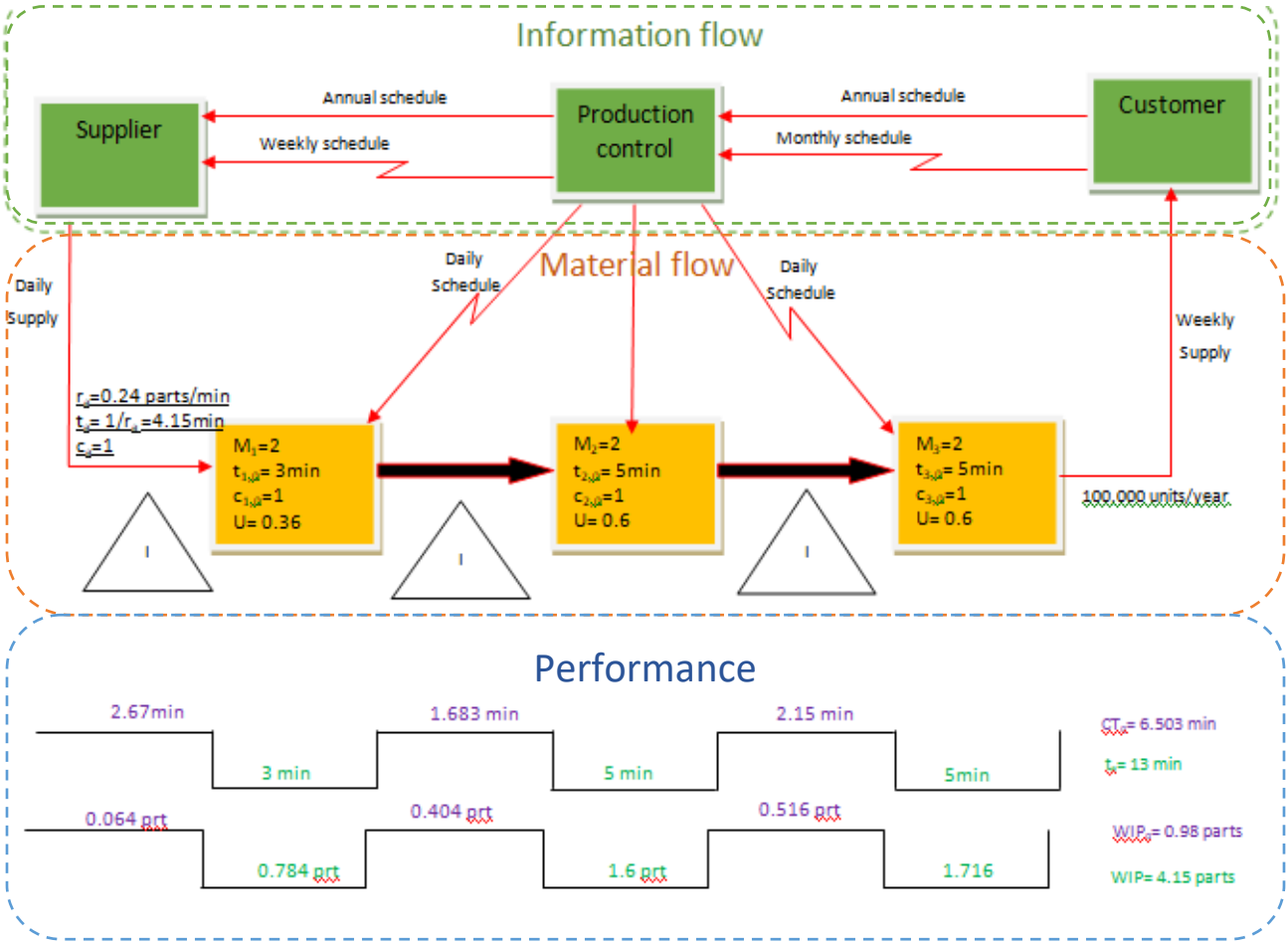


Fig. 14 FVSM of manufacturing Process

	Final Departure SCV		$= yc_d^2+(1-y)$	0.130	0.443	0.643
WS performance	Utilization	u	u	0.360	0.600	0.600
	Final Departure Rate (parts/time)	r_d	r_d	0.240	0.240	0.240
	Queue Time (time)	CTq	CTq	0.267	1.683	2.150
	Cycle Time (time)	CT	$= CT_q+t_e$	3.267	6.683	7.150
	WIP (parts)	WIP	$= r_aCT$	0.784	1.604	1.716
	WIP in Queue (parts)	WIP_q	$= r_aCT_q$	0.064	0.404	0.516
Line Performance	Cumulative Cycle Time (time)		Si(CTq(i)+te(i))	3.267	9.950	17.100
	Cumulative WIP (parts)		Si(ra(i)CT(i))	0.784	2.388	4.104

4.4.3 Initiate the improvement

By removing or eliminating the variability failure, setup and rework, we can improve our system and increase the performance of the line.

To compare the CVSM and FVSM WS, I have attached the data of the WS performance of the line.

The maximum performance of the WS in the future VSM

Average process time 13/3=4.33 min

1440 min/4.33min = 332.33 prts

Per year 332.33*6*4*12 = **95,711.04 prts**

The difference 347-332.33 = 14.67 prts/day

4.4.4 Chapter summery

In the manufacturing process case study I have chosen the most efficient and effective ways of improvement. As we see on the future map not yet fulfill the demand, therefore, to fulfill the demand we can do another future map and the existing map will be the current map. According to that I suggest for the company to use additional time or overtime in order to meet the goal.

Generally speaking by using VSM technique we can understand the company's productivity and anyone can see where the problem area.

In this specific study we have seen how VSM is valuable for the company because it can tell us the overview of the process. The whole process can be seen on a single paper and tells us how look like the process. As we see the annual production capacity is increased. In the current or previously the company couldn't fulfill the customer demand even if the manufacturing process be able to produce 100% but couldn't produce or couldn't use the ability due to the WS variability. As we see the variability are failures, setup and re-work. We have seen how those variability decreases our production performance. Therefore by using VSM the production performance is increased and the company now can produce and fulfill the annual demand.

Chapter 5, overall equipment effectiveness (efficiency)

It's named by seiichi nakajima in 1960s to evaluate the effectiveness of the manufacturing utilization.
It's based on the Harington Emerson ways of thinking regarding labor efficiency.
OEE breaks the performance of the manufacturing unit in to three separate but measurable components.

- Availability
- Performance
- Quality

Each component points to an aspect of the process that can be targeted for improvement. OEE may be applied to any individual work center or rolled up to department or plant levels. This tool also allows for drilling down for very specific analysis, such as a particular part number, shift or any several other parameters. It's unlikely that any manufacturing process can run at 100% OEE. Most manufacturers' benchmark their industry to set a challenging target 85% is not uncommon.
Calculation of OEE

5.1introduction to OEE

The simple way to calculate OEE is as the ratio of fully production time to planned production time. Fully production time is just another way of saying manufacturing only good parts as fast as possible (ideal cycle time) with no stop.
OEE = ideal cycle time/ planned production time
But the preferred calculation of OEE is based on the three parameters or factors that are stated on previously. Multiplying the three factors
OEE = availability * performance * quality

Availability (setup)

The availability portion of the OEE metric represents the percentage of scheduled time that the operation is available to operate. The availability metric is a pure measurement of uptime that is designed to exclude the effects of quality, performance and scheduled downtime events. The loss due to waste availability is called availability losses.

Example: ***operating time = scheduled time – break downtime – unplanned downtime***

Availability takes in to account all events that stop planned production long enough where it makes sense to track a reason for being down.

Run time is a planned production time less stop time, where the stop time could be unplanned or planned stop.

So availability can be calculated as

Availability = run time / planned production time

Run time = planned production time – stop time

Performance (failurs)

The performance portion of the OEE metric represents the speed at which the work center runs as a percentage of its designed speed. The performance metric is a pure measurement of speed that is designed to exclude the effects of quality and availability. The losses due to wasted performance are also often called speed loss.

Example: operating time = scheduled time – unscheduled time

So performance can be calculated as

Performance = actual unit / scheduled unit

Performance takes in to account anything that causes the manufacturing process to run at less than the maximum possible speed or product of unit when it is running including both slow cycles and small stops.

Performance should never be greater than 100% but if it is, that usually indicates that ideal cycle time is set incorrectly (it is too high).

We can apply this performance evaluation for failures. Machines running but not at maximum performance, sometimes the machine fails due to different reasons. The reason which is that already stated previously on WS performance evaluation.

Quality (rework)

The quality portion of the OEE metric represents the good unit produced as a percentage of the total unit started. The quality metrics is a pure measurement of process yield that is designed to exclude the effects of availability and performance. The loss due to defects and rework are called quality losses.

Quality = unit produced – defective unit / unit produced

Quality takes in to account manufactured parts that do not meet quality standards, including parts that need rework, remember OEE. Quality is similar to first pass yield, in that it defines good parts that successfully pass through the manufacturing process the first without needing any rework.

OEE takes in to account all losses, resulting in measure of truly productive manufacturing time.

5.2 Why prefer OEE

OEE scores provide a very valuable insight an accurate picture of how effectively our manufacturing process is running and it makes it's easy to track improvements in that process over time.

What our OEE score doesn't provide is any insights as to the underlying causes of lost productivity. This is the role of availability, performance and quality.

- Planned production time: is described in the OEE factors pages, the OEE calculation begins with planned production time, so first exclude any shift time where there is no intention of running production typically breaks.

  Shift length – breaks

- Run time: the amount of time that production is actually running not stopped. The stop time should include both unplanned stop and planned stop. Both provide opportunities for improvement planed production time-stop time.

5.3 how calculate OEE

To be able to better determine what is contributing to the greatest loss and so what areas should be targeted to improve the performance, these categories': availability, performance and quality have been subdivided further in to what is known as the six big losses to OEE.

The reason for identifying the losses in these categories is so that specific counter measures can be applied to reduce the loss and improve the overall OEE.

Therefore in the end, OEE is useful as a heuristic but can break down in several circumstances. It may be for more costly to run a facility at certain time. Performance and quality may not be independent of each other or of availability and loading. Experience may develop over time. Since the performance of shop floor managers is at least sometimes compared to the OEE, these numbers are often not reliable and there are numerous ways to fudge these numbers.

Consider a system where the cost of error is exceptionally high. Therefore higher quality may be for more important in a proper evaluation of effectiveness than performance and availability.

Applying the OEE on the VSM, we can evaluate the effectiveness of the line. Compare the current VSM and future VSM. The future VSM can fulfill the demand but the current couldn't. Therefore, take the

future VSM as the scheduled or maximum optimum amount of production and the current is the actual or unplanned schedule.

5.4 Determine the work station by OEE

Work station 1 (failures)

We can apply the OEE to evaluate how manufacturing operation in utilized. So in the first WS the machine is affected by failures in the current VSM, due to that the performance of the WS or the machine will be decreases but the availability and the quality is good.

Availability

The scheduled time 1440 minute per day with without downtime, unplanned downtime and etc..

Therefore, **A = 100%**

Performance

- Natural process time = 3 min

  r_a = 1/3 =0.33 unit/min

- Actual or effective process time = 4.5

  r_a =1/4.5 = 0.222 unit/min

- Scheduled time 1440 min/day
- Scheduled unit 1440 min/day * 0.33 unit/min = 480 unit/day

But due to failures the production amount of unit will be decreases.

- Actual time 1440 min/day *0.222
- Actual unit 320 unit/day

Therefore the performance is

P = actual unit / scheduled unit = 339/480 = 0.67

Therefore, **P =67%**

Quality

There is no rework in this work station so the quality

Q = unit produced – defect unit / unit produced = 1

Therefore, **Q = 100%**

OEE, $_{WS,1}$ = A * P * Q = 1 * 0.706 * 1 = 0.706

Work station 2 (setup)

In these work station the machine has higher setup time in the current VSM, so it will decrease the availability of the machine. But the performance and the quality of the machine in this WS is good.

Availability

- Natural process time = 5 min

  r_a = 1/5 =0.2 unit/min

- Actual or effective process time = 7 min

  r_a =1/7 = 0.143 unit/min

Unplanned unit = 0.143 * 1440 = 205.7 unit

Planned unit = 0.2 * 1440 = 288 unit

Run time = 205.7 unit * 1440 min / 288 unit = 1,028.5 min

The loss time due to setup is 1440 – 1028.5 = 411.5 min

A = run time / planned production time

A = 1028.5 min / 1440 min = 0.71

Therefore, **A = 71%**

Performance

The machine performance in WS 2 is good that means no failures

Therefore, **P = 100%**

Quality

In WS3 no rework the machine can perform the quality of the product.

Therefore, **Q = 100 %**

OEE, $_{WS,2}$ = A * P * Q = 0.635 * 1 * 1 = 0.635

Work station 3 (Rework)

- Natural process time = 5 min

  r_a = 1/5 =0.2 unit/min

- Actual or effective process time = 6.25 min

  r_a =1/6.25 = 0.16 unit/min

Availability and performance of the third WS is good but there is rework, so according to the OEE, it needs to calculate the quality of the process.

Quality

Q = unit produced – defect unit /unit produced

Max capacity produced per day = 1440 min/day / 5 min/unit = 288 unit /day

Actual capacity produced per day = 1440 min/day / 6.25 min/unit = 230.4 unit /day

Defect unit: 288 – 230.4 = 57.6 unit / day

Q = (230.4-57.6) / 230.4 = 0.75

OEE, $_{ws,3}$ *= A * P * Q = 1 * 1 * 0.75 =* ***0.75***

TOTAL OEE IN THE LINE = $OEE_{WS,1} + OEE_{WS,2} + OEE_{WS,3} = 0.67 + 0.71 + 0.75 = 2.13/3 =$ 71 %

5.5 chapters summery

On the OEE we can visualize which area needs to be target in order to give attention. This technique is easier to analyze and we can see the specific work station that have less performance, quality and availability. Therefore as we see from the calculation based on the previous data, it's been calculated for each WS.

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