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Analysis of technical process and application of process models in tannery department of the leather industry

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ABSTRACT

The primary objective of this project is to explain the general technical process carried out in tannery department of leather industries with a detailed analysis of the requirements of the process. The paper also explains the different manufacturing steps in leather production in an industry. To make the system more effective, a few improvisations on the leather manufacturing processes that can be implemented are discussed. It also aims at defining and explaining the agile methodology, waterfall model and extracting characteristics from both the models to suit the system. The paper describes the generalized overview of standard processes carried out through leather industries and some of the processes may differ with respect to a few aspects of each organization.

Keywords: *Systems engineering, Tannery, Leather process optimization, Systems modeling.*

1. INTRODUCTION

Leather production dates back to between fifth and third millennium B.C, where Sumerians used skin as long dresses and the Assyrians used them for footwear. Leather trades have been highest in countries like Africa, India, China, etc. as the animal rearing practice have been high. Leather production has played a very important role in a country's economy and hence it is very important to analyze the process carried out in the industry to come up with a good strategy that would help in increasing the efficiency of the system.

1.1. Overview of Leather Manufacturing Processes

The steps carried out in the tannery department of a leather industry are as stated below:

1.1.1. Selection of skin: A variety of skins can be used to make leather such as lamb skin, sheep skin, goat skin, etc. Most of the leather are made from cattle, but deer skin, lamb skins are used for production of apparels as they are soft. Deer skin can also be used to make gloves. Kangaroo skin can be used to make leather that is strong but flexible, similarly Thailand string ray can be used in production of wallets. Desirable skin should be selected based on the end product required, as the strength and the quality depends on the skin chosen.

1.1.2. Soaking: This step is carried out to bring the cured hides to its original composition and dimension (to fresh hides) by adding large amounts of water and wetting agents. The skin is soaked for several hours in water to remove the debris, dead cells and excess animal fat.

1.1.3. Liming: Lime and sodium sulphide are employed to remove the hair and to split the fiber bundles. They are also sometimes treated with sharpening agents like sulphide, cyanides, amines, etc. They remove keratinous matter and also the mucins (soluble proteins) in the skin. It aids in bringing the collagen to proper form which is very helpful in tannage. Unhairing agents that are used in liming are Sodium sulphide, sodium hydrosulphide, etc. The pH is brought to an acidic level, around 4.7.

1.1.4. Deliming: This step aims in removing the lime and prevent swelling of the skin. It helps in maintaining an alkaline pH through the use of Ammonium sulphate and Ammonium chloride. The Ammonium penetrates and further protonates basic group and neutralize solution alkali's. It lasts for about two hours and is usually carried out during beam house operations.

1.1.5. Bating: This step aims in complete removal of inter fibrillary hairs from the skin through enzymes. Protease or chemicals can be used in removing the scud and unwanted proteins. It deswells swollen pellets and gives a soft hide surface. This is one method that cannot be substituted by chemicals as the enzymatic yields the best result. The pH is usually maintained at 7.5-8.5 and this method is usually applied in neck and butt area of the skin.

1.1.6. Pickling: This process involves the conversion of the skin (Matrix) for subsequent chrome tanning. It is the conversion of partly anionic matrix into a cationic matrix. It uses substantial quantities of sulfuric acid and sodium chloride. In this operation pH is adjusted to 2.5-2.8 and swelling salt is added to suppress the swelling.

1.1.7. Degreasing: This is the process of removal of fat from the skin, which otherwise would cause trouble during the finishing of leather using emulsifiers. The process can be carried out using enzymes and chemicals as well. Enzymes such as Lipases are used in carrying out enzymatic degreasing and chemicals such as Tergolix are used for chemical method. The pH should be around 6-7 and it should be carried out with care as any residual fat would reduce the quality of the leather and is bound to cause troubles at later stages of the process.

1.1.8. Tanning: There are basically two types of tanning, vegetable tanning and Chrome tanning. In the process of chrome tanning, cationic matrix is treated with Chromium sulphate to strengthen the matrix and to make it less prone to bacterial attacks. In the case of vegetable tanning, the matrix is treated with tannins which is a chemical that occurs naturally in barks and leaves of many plants. Chrome tanning is more effective but releases hexavalent chrome into the environment, which is very harmful to the environment. Vegetable tanning is not very effective but eco-friendly.

1.1.9. Dyeing: This step involves adding of dyes to make the leather more attractive and is done by choosing basic or acidic dye based on the properties of leather. The dye selected should be compatible with the leather chosen. The leather should be wet to make sure that dye is absorbed by the skin. The dye should be mixed with appropriate amount of water if in the form of powder and should be run in drums for optimum amount of time. The leather is then dried and any excess dye can be removed by cleaning the leather with a cloth.

1.1.10. Finishing: The leather thus prepared is checked for its strength and other properties. According to the desired product, the leather is crafted in many ways manually and by the use of machines to ensure proper results. The different methods of finishing are Buffing, Boarding, Plating, etc. Each method is chosen according to the requirement of the product.

1.1.11. Disposal and waste water treatment: The waste water generated through the above processes is treated and the degradable waste materials are segregated for composting. The waste water released are required to have minimum amount of chemicals and hence are treated within the plant before they are merged into drains. The various harmful chemicals produced may be hexavalent chrome, Ammonium ions, etc. There are a number of plants designed to treat the water and release them into sewage. The solid wastes, which include unused hides and damaged leather are segregated for composting and bio degradation.

Figure1: Flow of manufacturing processes

2. TECHNICAL PROCESS IN TANNERY DEPARTMENT

The below diagram explains the different technical processes in a system and each of these processes are explained in detail.

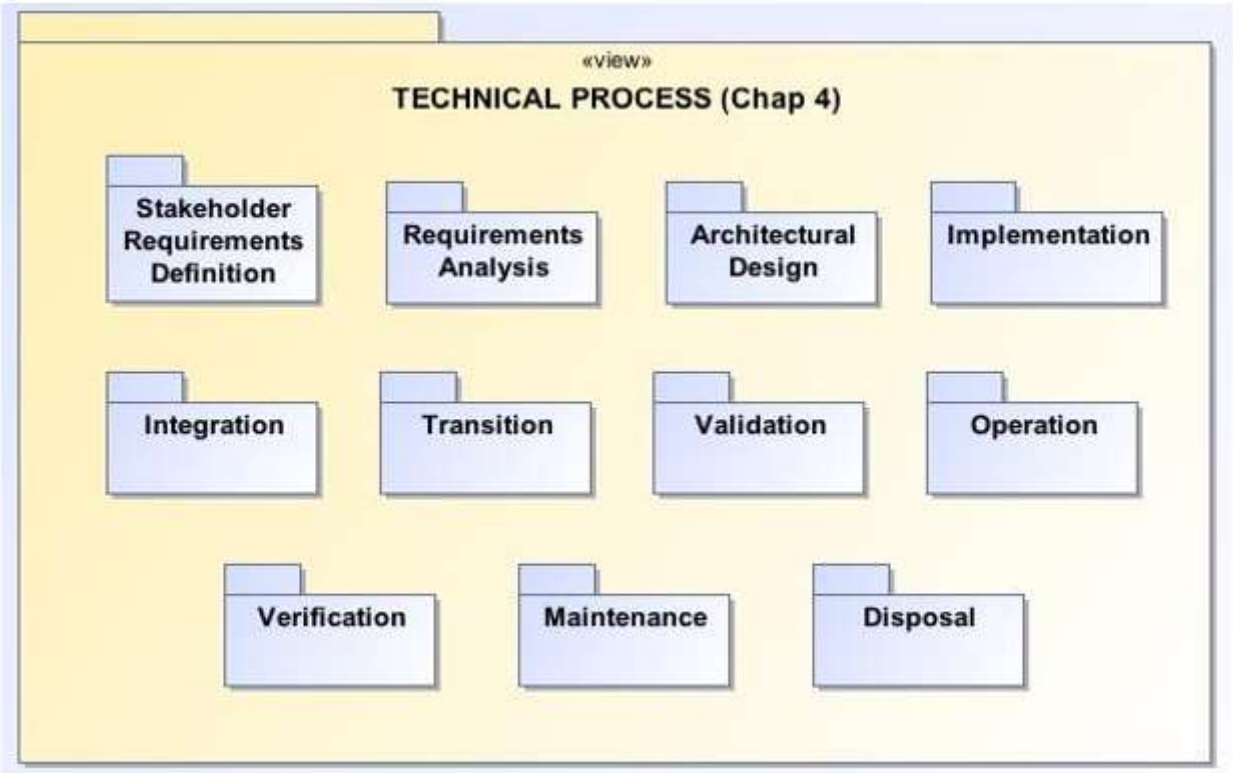


Figure 2 – Technical processes

2.1. REQUIREMENT ANALYSIS:

This step aids in analyzing the different requirements of a system that are to be fulfilled for the process to be efficient and to produce the product with desired characteristics. There are a number of requirements to be considered before starting the process and they are as described below.

2.1.1. Stakeholders' requirements: Stakeholders' in a leather industry are usually government bodies (eg: Central Leather Research Institute (India)), private groups and employees of the organization. The demands put forth by them would concentrate on

2.1.1.1. Increasing productivity economically

2.1.1.2. Enhancing brand name

2.1.1.3. Carrying out the process by satisfying the environmental norms.

2.1.1.4. Dynamic growth of the company

2.1.1.5. Meeting qualities required for the export of leather.

2.1.1.6. Meet the ethical standards for using animal skin.

2.1.2. Customer requirements: As demands of the product should be met, it is important that the customers' requirements are well analyzed. The requirements that are to be considered:

2.1.2.1. More variety of products produced.

2.1.2.2. Good quality of the leather for a cheaper market price.

2.1.2.3. More designs and colors.

Figure 3 – Samples of different types and designs of leather

2.1.3. Functional and performance requirements: Functional and performance requirements vary according to the desired product and includes

2.1.3.1. Strength of the leather

2.1.3.2. Amount of dye and other chemicals present in the leather

2.1.3.3. Wear resistance

2.1.3.4. Structure of the leather matrix

2.1.3.5. Tanning Properties of leather

2.1.3.6. Chemical resistance

2.1.3.7. Thermostatic resistance

2.1.3.8. Amount of fat content in the leather

These functional and performance requirements standards are set by each organization and are not universal.

2.1.4. Design Requirements: The designing of efficient protocols and tools to make the process efficient is important and the requirements to be considered are:

2.1.4.1. Devising ecofriendly and economical protocols for manufacturing of leather.

2.1.4.2. Process of scaling up using the devised protocols.

2.1.4.3. Building new products from the appropriate leather

2.1.4.4. Designing components of the apparels and accessories in a user friendly manner. For example- designing of soles in sports shoes should take into consideration the softness of the leather and also the resistance offered by the material.

2.1.5. Disposal planning:

2.1.5.1. Treating the waste water generated from the process and meeting the environmental norms set by the government.

2.1.5.2. Composting of used leathers.

2.1.5.3. Reusability of leather products.

The requirements hard to meet are the environmental norms and to devise ecofriendly methods in the manufacturing process. The amount of waste produced during the process is quite large and the Chrome tanning procedure adds a large amount of harmful chemical (Chrome VI) to the disposal of water which is hard to treat. Hence ecofriendly methods such as vegetable tanning, use of enzymes in carrying out degreasing, dehairing, etc. are employed. But these methods produce leathers with less strength or consume more time to produce leather, which is of the same standard as that of leather produced by chemical methods. Hence these problems need to resort while designing protocols.

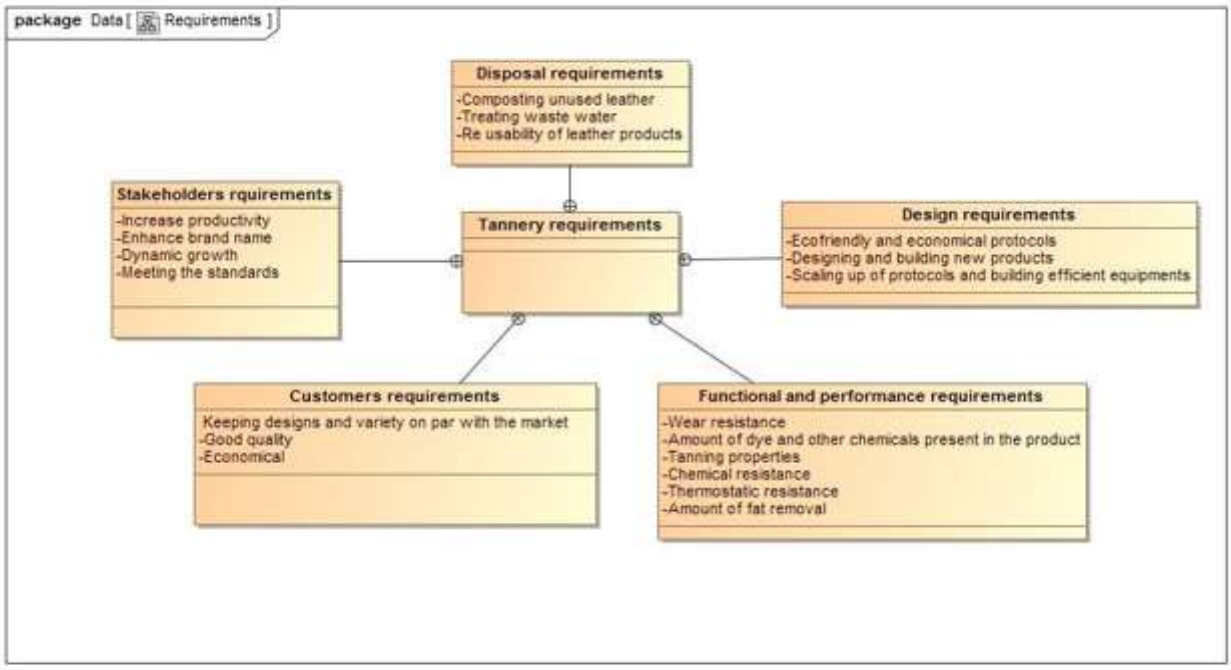


Figure 4 – Requirements of tannery department

2.2. DESIGN AND IMPLEMENTATION:

This phase includes devising protocols for each step keeping in mind the design requirements and implementing them on a small scale. It is then tested for desired results in the following phases. Designing efficient protocols can be done in 3 ways and they are elaborated as below:

2.2.1. Chemical Method

2.2.2. Enzymatic method

2.2.3. Combining both chemical and enzymatic method.

First or the third method is preferred over the second option. A few steps such as Soaking, Liming, Deliming, Pickling, and Dyeing does not employ enzymatic methods, hence chemical methods are the only option to carry out these steps. The devising of protocols takes into consideration the amount of time taken for completion of each step as the whole leather manufacturing process is a time driven process. It also defines the amount of chemicals that would be disposed of for treatment in terms of ppm (parts per million) and the various possible combination of chemical and enzymatic methods that can be carried out to bring out the best output.

2.3. INTEGRATION AND TESTING:

The parameters usually taken into account for testing in the above steps are pH, the extent of hair removal, amount of removal of fat, amount of chrome present in the leather and the strength of the matrix, wear resistance, chemical, and thermal resistance. The above parameters are usually determined within the department, but the tannery department is also integrated with various other departments for carrying out additional tests. The standards are set by the organization and are confidential.

2.3.1.The structural analysis of the matrix using Scanning Electron Microscope (SEM), to determine the quality better, which is usually carried out by the Biotechnology department of the industry.

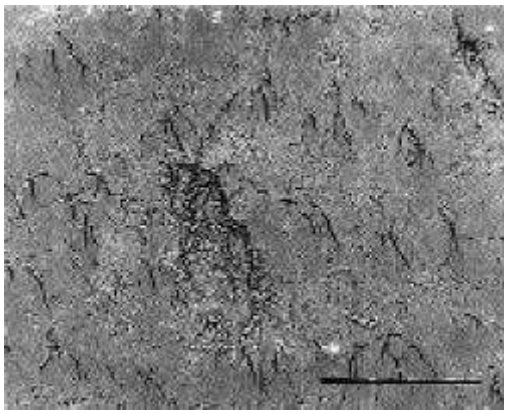


Figure- 5- An image of the crust of leather through SEM

Similarly, the amount of fat is calculated by running an equipment called soxhlet by the department and the residual fat should be less than 30% in sheep skins, 2-4% in cattle, 12-15% in goat skins.

2.3.2. The leather is tested by Government approved organization to check the standards such as the amount of dye, amount of chrome present, etc., before exporting. There are standard tests available to check the standards and testers present in the organization carry out these tests and approve the leather for export.

2.3.3. The amount of chemicals in the water or liquor disposed of is tested by the environmental engineering department. Water treatment plants are used for treating the effluent discharged from each step. The standards set by environmental norms that are to be met by the effluent discharged are

pH S.U.	6-9
BOD (mg/L)	50
COD (mg/L)	250
Total Suspended solids (mg/L)	50
Sulfide (mg/L)	1.0
Chromium (hexavalent) (mg/L)	0.1
Chromium (total) (mg/L)	0.5
Chloride (mg/L)	1000
Sulfate (mg/L)	300

Ammonia (mg/L)	10
Oil and Grease (mg/L)	10
Total nitrogen (mg/L)	10
Total Phosphorous (mg/L)	2
Phenols (mg/L)	0.5
Total coliform bacteria (MPN*/ 100 ml)	400
Temperature increase °C <	30

2.3.4. The Human and Organization resource department aids in the allocation of funds and man power for the process.

3.3.5. Product design and Development department checks for the quality and designs new products as per the requirements. The outputs are tested to check if the requirements were met.

2.4. VERIFICATION AND VALIDATION:

The verification process is carried out by the department and the product is validated by checking if the leather was appropriate and good for the desired product (Apparels and accessories). The whole process is then validated in economic terms too.

3.4.1. Scaling up of the process: If the desired results are obtained through the above procedures, it is then carried out on a large scale where in a lot of animal skins are processed at one time. Large equipment and huge drums are used to facilitate the process and the whole process is again verified and validated on a large scale.

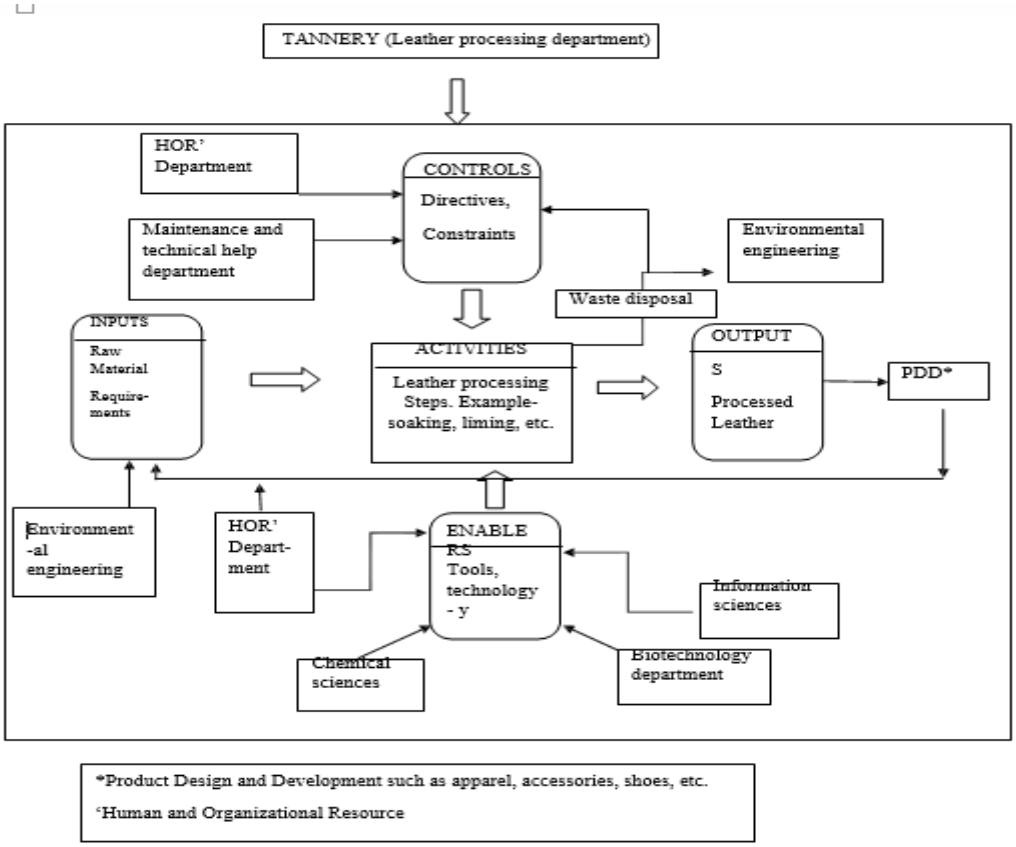
2.5. DISPOSAL AND MAINTENANCE:

After the environmental standards have been met by the treated water, it is released into sewage. The leathers that have not met the standards are piled up for composting as the skins are bio degradable. The devised protocols and processes are maintained and incase of high productivity, it proves to be a great source of income. If the devised protocols are novel, then it becomes an intangible asset for the company. After the release of the products, customers' inputs are received to maintain the standard of the product.

2.6. RETIREMENT:

Once the equipment are worn out, they are either disposed or are sold at a cheaper price to smaller companies. As the equipment used to come on a long run, it would not be a huge economical setback.

CONTEXT DIAGRAM REPRESENTING THE SYSTEM



3. OVERVIEW OF GENERIC LIFECYCLE FOR TANNERY DEPARTMENT

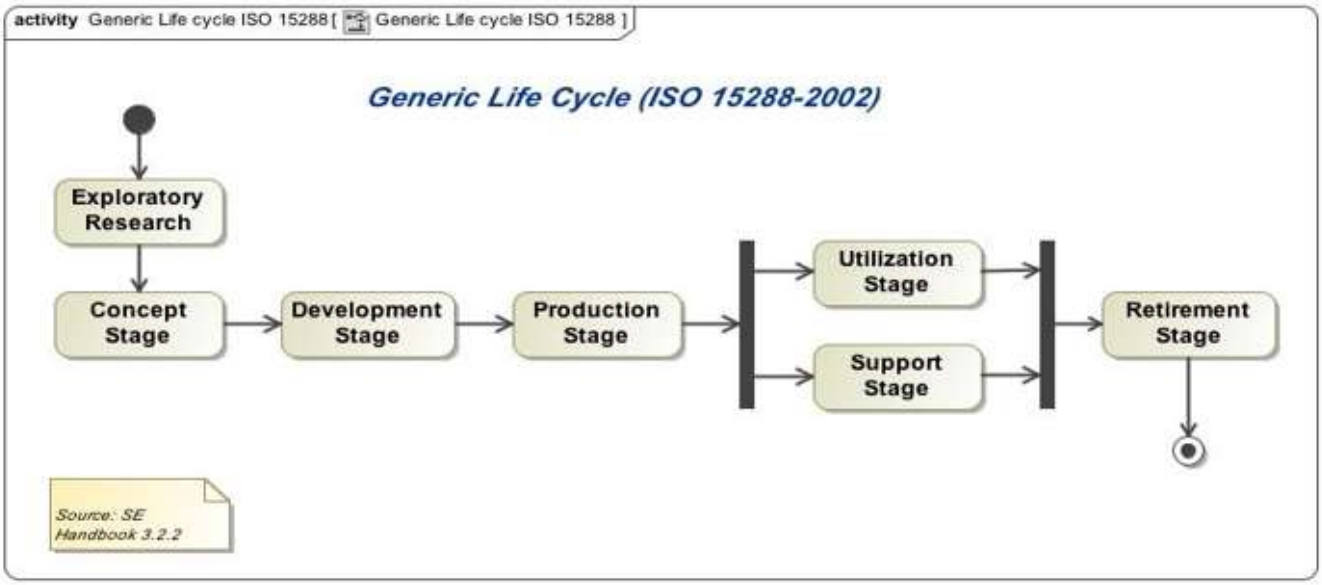


Figure 6- Generic Life Cycle

3.1. EXPLORATORY RESEARCH, CONCEPT STAGE AND DEVELOPMENTAL STAGE:

This stage includes defining the stake holders' requirements, other requirements. When the requirements are analyzed, appropriate protocols are devised to come up with viable solutions for the problems involved in the process. This phase includes Requirement analysis and Design step explained previously in the paper. Optimization of the production economically is a very important step and is carried out during this phase.

3.2. Production Stage:

This step includes the process of implementing the devised protocols and producing leathers. This phase would include implementation, integration, and testing from the technical process. The production plays a crucial role in the life cycle as both the quality and the quantity planned should be met with minimal wastage produced.

3.3. Utilization and Support stage:

This includes the utilization of the produced leather for product development by product development department. Optimizations of the designs are done by the department according to the customers' requirements and demands. It also includes disposing the waste products and providing customer support. The scaling up, disposal and maintenance steps described in the technical process come under this phase.

3.4. Retirement stage: This includes the disposal of equipment from the tannery department. The worn out equipment are disposed and equipment to be repaired or replaced are taken care of. Usually, equipment have a salvage value when sold. Retirement process explained in the technical process falls under this phase of the lifecycle.

4. IMPLEMENTATION OF SYSTEM ENGINEERING PROCESS:

(AGILE AND WATERFALL MODEL)

Process models are used in systems engineering to optimize and carry out the structured development of systems. They ensure all the requirements are met, both technical and business oriented to produce the desired quality. Waterfall and Agile methodologies are two such process models that have been followed in systems engineering. Both the process models are discussed below. Characteristics from both the process models are extracted and a model is devised that would suit the tannery system to produce enhanced results.

4.1. Waterfall model: Waterfall model was the first ever process model that was introduced. It is also known as linear-sequential life cycle model. It gives us a stage by stage product development system. It is used when the requirements of the systems are pre-defined and does not change from time to time. Each phase is completed before the next stage is reached. Few advantages of waterfall model are:

4.1.1. Easy to understand.

4.1.2. Each phase is processed separately and is easy to handle.

Few disadvantages are:

4.1.3. Once the testing phase is passed it is very difficult to go back to the previous phase

4.1.4. The high amount of risk and uncertainty.

4.1.5. Not suitable for long and ongoing projects.

The below diagram depicts the different stages and the transition of stages in a waterfall model.

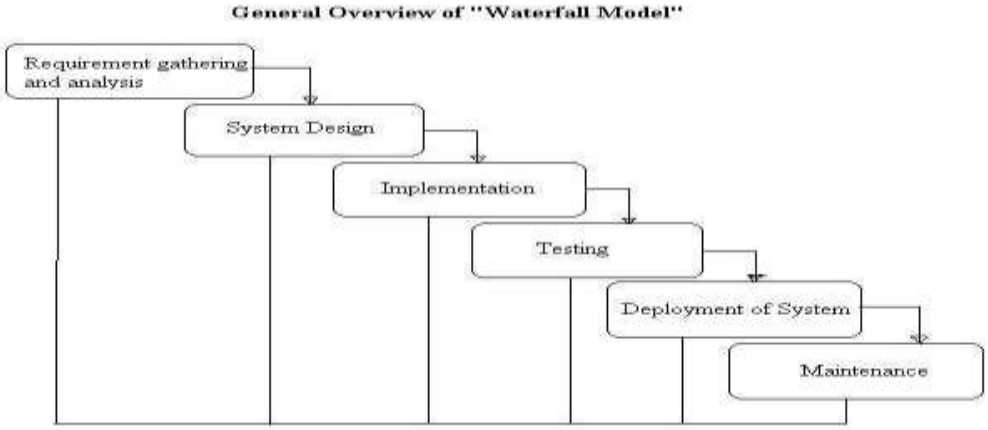


Figure 7 – Waterfall process model

- The first step analyses and gathers the requirements of the project and prioritizes the needs.
- The design phase models the protocols to achieve the goals with the required quality.
- Once all the protocols have been devised, it proceeds to the implementation phase.
- The products are tested to check if the requirements are met.
- The system is implemented with the successful protocols to produce large quantities of products. The last phase deals with maintenance of the system to produce consistent standards. Waterfall model hence is a linear and sequential approach.

4.2. Agile Methodology: the Agile methodology is characterized by adaptability. It goes by the empirical method and uses a comprehensive documentation methodology. Many iterations and feedback result in producing the desired product. Agile methodology deals with frequent adaptation and testing. It encourages teamwork, self-organization, and accountability. It follows an evolutionary- delivery model and favors object-oriented technology.

Few advantages of the process are:

4.2.1. Interactions between individuals within the organization.

4.2.2. Collaboration with customers throughout and customers play a critical role in the process.

4.2.3. The process can be subject to change throughout the plan.

4.2.4. This process facilitates continuous attention to good design and enhancement of the product.

Few disadvantages are:

4.2.5. It does not focus a lot on product development as much as it does in gathering the requirements.

4.2.6. It might prove to be inefficient in large organizations and projects.

The below diagram depicts the different stages and the transition of stages in an agile methodology.

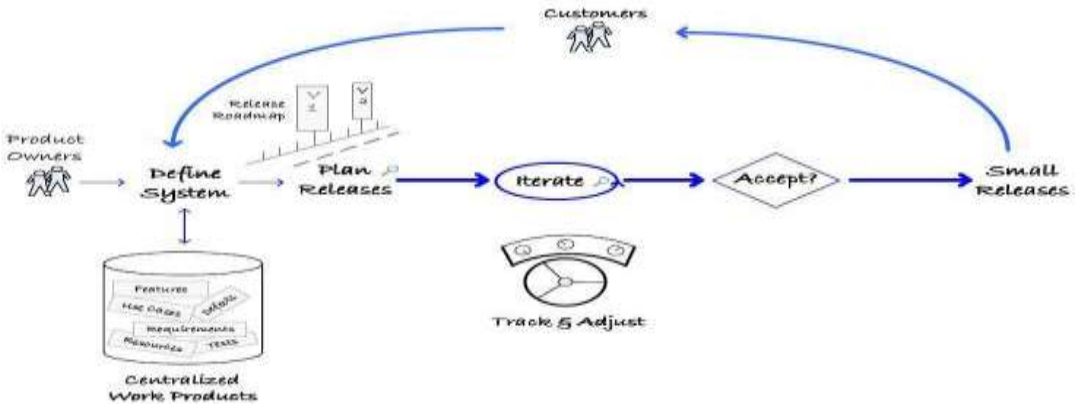


Figure 8 – Agile Methodology

- The first phase deals with defining the system. The features of the system, use cases that are used, requirements and the tests carried out are defined.
- The product roadmap is released which specifies the requirements of the product and a framework as to when these requirements would be met.
- The second phase deals with the release of plans for the project and it consists of detail timetable specifying priorities that are to be released first.
- Iterations are carried out to check the results of the plan released. There is a loop formed, which goes back to the previous phase, to amend the protocol in case the results are not desirable.
- If the project is acceptable, the plan is released on small scale to check the success of the project.
- Customers are involved throughout the plan and play a critical role in defining the system.
- Throughout the process, requirements may be adjusted and tracked to maintain the standard and quality of the output.

Hence agile methodology is a very dynamic and adaptable process.

4.3. Comparison of agile and waterfall model:

4.3.1. Waterfall cannot be subject to change once the process flows from one phase from one phase to another. Agile methodology can be subject to changes throughout the process and hence is dynamic.

4.3.2. Agile methodology ensures debugging in each phase and hence ensuring a bug-free product, which cannot be done in waterfall model without re-writing the whole procedure.

4.3.3. There is always a timely release of at least one product for the customer when there is a delay in the project which is not possible in the waterfall model.

4.3.4. Departmentalization is more effective in case of agile methodology, which is not the case in the waterfall model.

4.3.5. Agile methodology is mostly used in case of construction projects, etc., whereas agile methodology is used in case of software development.

5. TANNERY SYSTEM

The tannery system can be characterized as follows:

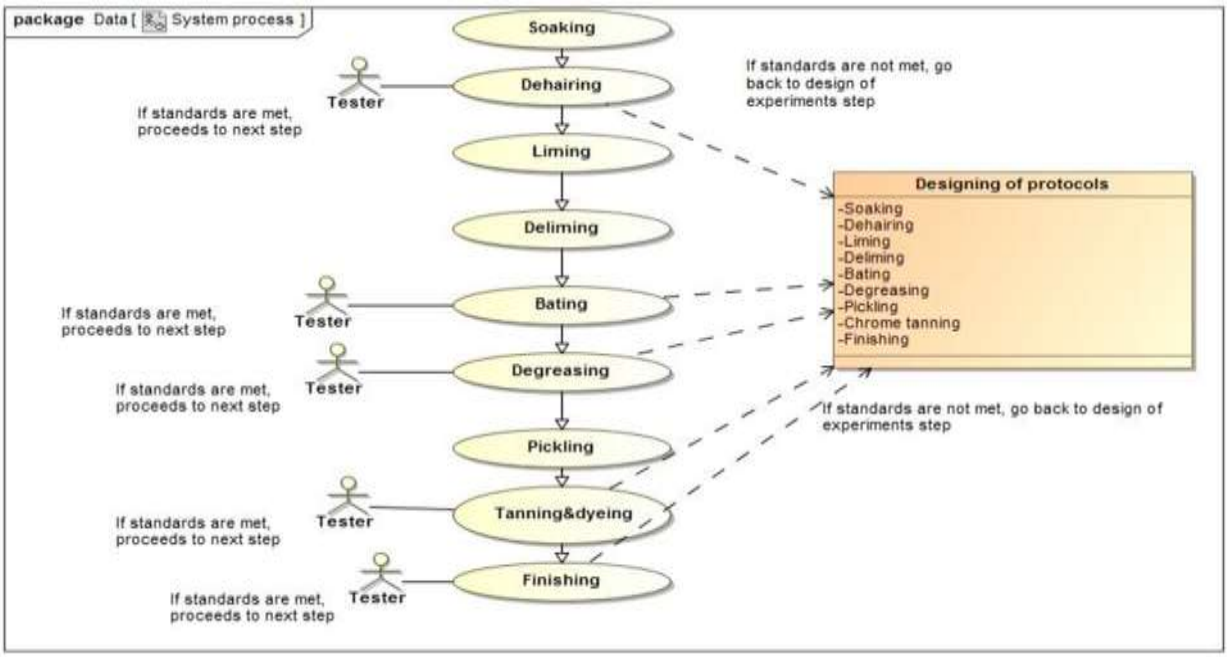
The tannery system has unique requirements and can be characterized by its process:

5.1. Has defined requirements:

The requirements for the process remains constant for at least one cycle of the process. Hence this character resembles the waterfall process model.

5.2. Iterations cannot be performed for few steps as there is the only way of carrying out the process (example -Soaking, Liming). There are not many alternatives for a few steps in the process for iterations to be performed and hence a few steps have a standard protocol to be followed. This again follows waterfall model.

5.3. A few processes can be done using many alternatives, and hence iterations and new protocols can be devised to these steps. These processes can be carried out using either enzymes, chemicals or with a combination of both which is discussed in above texts. (Example- Degreasing, Bating, etc.)



Hence the steps that have defined requirements does not undergo a loop of iteration or feedback and a direct transition to the next step takes place, which resembles waterfall model.

A few steps where new protocols are employed need to undergo iteration process to check the outcome and these are done using agile methodology. Therefore by combining both the models, a better model can be developed which suits the requirements of the system and makes it effective. This process can be depicted in a diagram as shown below. A use case diagram is used to explain the model explicitly.

The Use case diagram shown elaborates on the part of the process wherein the tester tests each phase and authorizes if the process should proceed to next step. This methodology is dynamic and also precise. At the end, the product is sent to Product Development Department where the design of products are processed according to the customers' requirements and also supports the customer by taking in the inputs and considering the market trend. The process as shown in the context diagram is linked with other departments to carry out the tests and implement them on a large scale.

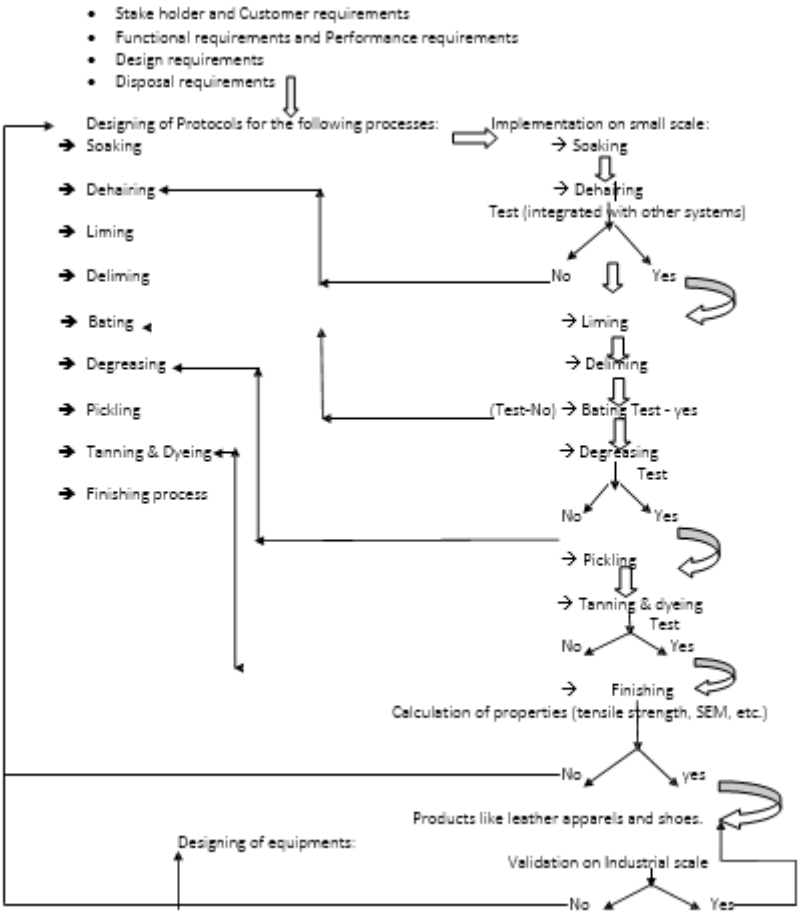


Figure 10- Representation of the process model created by extraction of characteristics from the waterfall and agile model

As shown in the diagram, the requirements of the system are described as the first step of the process. Efficient protocols and equipments are designed during each phase of the process as described earlier. Few processes such as Dehairing, Bating, Degreasing, Chrome tanning (Dyeing and Tanning) and Finishing can be done using enzymes or chemicals or using both. Hence to find the effective method many iterations can be carried out and the method that suits the best and meets the standard requirements can be chosen. As shown in the diagram, if the requirements are not met by the step, it should be reverted back to the design of protocol step to devising a new method that could satisfy the requirements of the step. The iterations should be repeated until the standards are met for each step, which results in a loop formation. Hence this method would be effective and less prone to error. Hence the whole process ends with efficient results.

6. SUMMARY

The paper provides an insight into the technical process and requirements of tannery department in the leather industry. It also describes the various constraints and the role of each department associated with the process. The improvisations that could be carried out during the design phase are discussed and also a general overview of the life cycle was provided and the technical processes associated with each phase was elaborated. The paper also discusses the characteristics of the waterfall and agile methodology and how a few specific characteristics from both the models could be extracted in order to come up with an efficient methodology. In summary, the paper aims in explaining the details of the process carried out in tannery department and focuses on creating a feasible systems engineering process, so that this model could further be developed in future and can be used to produce better results.

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