International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Application of Lean Manufacturing in Aquaponics to Reduce Overall Cost and Improve Productivity

[1]Bhavyanshu Kadu, [1]Rahul Maurya, [1]Vishrut Kekatpure, [1]Abhishek Kulkarni ,[2]Prof. Paramjit Thakur

[1]Student, Saraswati College of Engineering, India.
[2]Professor, Saraswati College of Engineering, India.

ABSTRACT :

Aquaponics is amalgamation of techniques from traditional farming as well as hydroponics .It is a soilless crop production technique. Aquaponics uses both the hydroponics and aquaculture industries methods and equipment's. The main objective of this purpose of this research is to document the production methods and also check the profit gained from the use of commercial aquaponics in the USA and internationally. In today's day and age ,commercial usage of aquaponics production exists primarily to control environments using methods from traditional farming as well as hydroponics. The principles and practices of LM were not only implemented in the manufacturing organizations, but also in service organizations. Even though there are a number of articles dealing with the theory and practice of LM have been published, not many organizations have been successful in using the LMS.

1.INTRODUCTION

This chapter will introduces the background of lean manufacturing, Aquaponics and vertical farming. The primal concepts of lean manufacturing and its application in farming are also summarized at the end of this chapter.

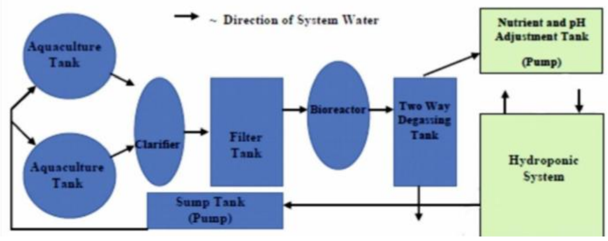
1.1 BACKGROUND

The increase in industrial revolution made the way to speed up the production with the new agricultural methods. Traditional farming methods were accompanied with theutilization of fossil fuels, and alluvial lands were discovered and used to set up spaces for growing crops at higherefficiency. The challenges of agriculture due to lack of land gave rise to a new soilless agriculture. That new method is called Aquaponics.The principles and practices of Lean Manufacturing (LM) were not only implemented in the production in organizations, but also in service organizations. Although numerous articles dealing with the theoretical and practice of LM have been published, ironically, not many organizations have been successful in implementing the LMS and demonstrate a improvement in performance like Toyota Motor Corporation (TMC).Hence, understanding the difficulties in high overall cost in aquaponics system ,the lean manufacturing is applied in this work to simplify the overall process, minimize the cost of production and increase the productivity.

1.2 SOILLESS FARMING (Aquaponics)

Soilless agriculture is a method in which the crops are grown in mineral solutions packed with nutrients. The amount of mineral solutions depends on the crop under cultivation. Basically, mineral solutions contain essential cations and anions, namely magnesium, calcium, potassium, sulphates and nitrates. Leading types of soilless solutions are medium culture and solution culture. These are further subdivided into categories, such as continuous flow solution, static solution and **Aquaponics** for solution cultures, and gravel and sand culture for medium cultures. Aquaponicsagriculture does not require the use of toxic chemicals. Unlike soil-based agriculture, where farmers have to use fertilizers to increase crop yield and spray pesticides to keep weeds and pests away, crops are somewhat protected from pests and weeds.

1.2.1 COMPONENTS OF AQUAPONICS



Components of aquaponics

The three types of hydroponic systems used in Aquaponics are: 1) deep water culture (DWC) or floating raft technique, 2) media filled grow beds, or 3) nutrient film technique (NFT).

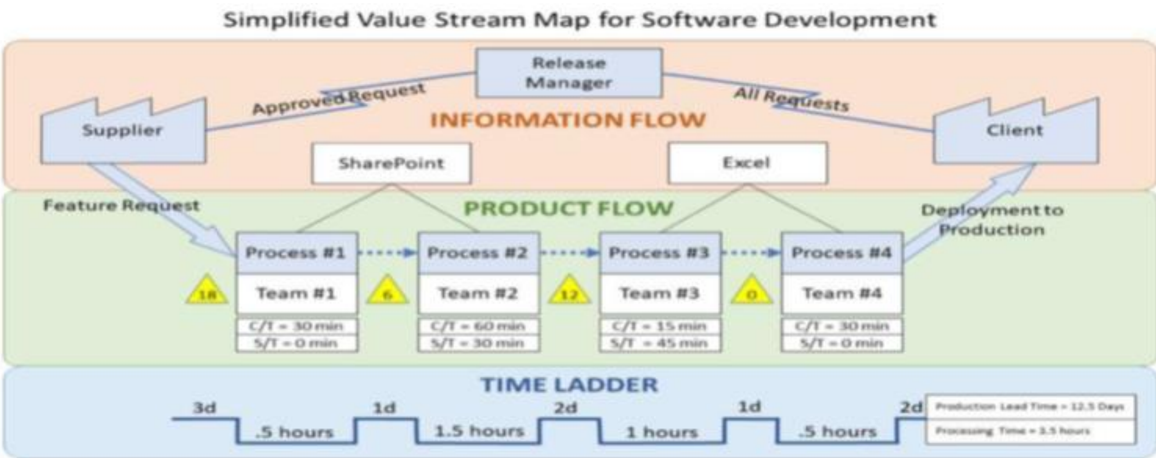
LEAN MANUFACTURING

Lean Manufacturing Systems (LMS) requires a thorough understanding about the 'constituents of LMS', 'performance measures of LMS', 'implementation procedure of LMS' and 'assessment of LMS'.The globalization phenomenon has resulted in opening up of new markets, which in turn gave rise to ever-demanding customers and ever-spiralling competition from domestic and international players. Hence, the organizations are attempting to implement the LM principles and concepts to remain competitive.

Lean manufacturing principles guide the way of improving quality and productivity through elimination of wastes. Lean manufacturing principles stipulate the adoption of certain conventional techniques, tools, approaches and models in a systematic manner.

- **VALUE STEAM MAPPING**

Value-stream mapping is a lean-management technique toanalyse the current state and to design the future state for the series of events that takes products/services from its primary stage through to the customer with reduced lean wastes as compared to current map. 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.



Value stream map

- **5S CONCEPT**

5S is a philosophy and a way of organizing and managing the workspace and workflow with the intent to improve efficiency by eliminating waste, improving flow and reducing process unreasonableness. The decision-making process usually comes from a dialogue about standardization, which builds understanding among employees of how they should do the work.

5S components

- **KAIZEN IN LEAN MANUFACTURING PARADIGM**

Kaizen is the word for "improvement". Kaizen is a set of activities help to that constantly improve the functions and involve employees ranging from the CEO all the way to the assembly line workers. It can also be implemented other fields such as purchasing and logistics, that cross organizational boundaries into the supply chain. It has also been utilized in areas of health care, psychotherapy, life coaching, government, and banking.

2. LITERATURE REVIEW

2.1 LITERATURE ON AQUAPONICS

Danaher et al. [1] experimented the usage of a swirl separator in replacing clarifier in order to concentrate solids in the clarifier. Their study resulted to find no difference in fish and plant yields or system water quality (pH, DO, etc.) from using the swirl separator in comparison to a clarifier.Future improvements to filters will be an important consideration, given that increased filtration has been found to increase plant yields and fish health Sikawa and Yakupitiyage [2]. As Aquaponics grew in popularity the commercial sectorentities quickly adapted the DAS over CAS. Practitioners should be warned that it is unclear if DAS are as sustainable and economical as CAS is based on the higher requirement for space, infrastructure and additional fertilizer. With Aquaponics primary selling point of being a sustainable system, developing commercial systems which are truly sustainable is of utmost value. To add to the complexity of aquaponics systems, either CAS or DAS may use varying hydroponic systems, further affecting the productivity and efficiency of the system. nutrient film technique (NFT) (Goddek et al. [3] ; Maucieri et al. [4]. A review on hydroponic systems in aquaponics found that 43% of the m used a media-based system, 33% used DWC, 15% used NFT, and 9% used other less common hydroponic systems (Maucieri et al., 2018. (Schmautz et al.) [5], ebb and flow (Knaus and Palm) [6], and vertical towers/walls (Khandaker and Kotzen) [7]. A study by Lennard and Leonard (2006) investigating the effectiveness of a NFT system compared to a media culture and DWC system got to know that the NFT system had the lowest yields of lettuce. This may be due to a lower percent of roots in contact with the aquaponics water, as opposed to DWC in which all of the roots are completely submerged in the water. [8]. Maucieri et al. (2018), who reviewed 122 articles found that NFT was one of the least successful hydroponic part of aquaponics systems.

2.2 LITERATURE ON LEAN MANUFACTURING

Golhard and Stamm[9] and Keller and Kazazi[10] have provided a general review on the literature related to 'JIT manufacturing systems'. Apart from this, many review papers related to individual components of JIT production system were also published. Waters-Fuller [11], Gunasekaran[12] reviewed the literature related to JIT purchasing. Honold[20] contributed in reviewing the literature related to the employee empowerment. Sendil Kumar and Panneerselvam[13] presented a literature review on Kanban system in which they surveyed about 100 papers. It was published by Filho and Fernandes [14] in the Gestao&Producao [15] journal, published by Departamento de Engenharia de Producao of Universidade Federal de Sao Carlos. This paper is published in Portuguese language. On the other hand, Landsbergis et al. [16] reviewed the literature related to surveys and case studies from various industrial sectors such as auto industry, health care industry and telecommunications, which dealt with the impact of new work systems on job characteristics, injuries, and illness to understand about the potentially major health effects of current employment and industrial trends. But, this paper provided only a review on the impact of work organization due to LM, which is just one of the issues associated with LM transformations.

3. PROBLEM DEFINITION AND OBJECTIVES

3.1 PROBLEM DEFINATION

The demand of organic exotic vegetables is increasing exponentially in last few years, and its high cost, availability of space and high usage of fertilizers on plants in metropolitan region is becoming a barrier, we were compelled to think for the future of such areas. Indian middle and upper middle class population is growing very rapidly and there is also increase in number of young working couples, resulted in increase in demand for exotic vegetables like lettuce, broccoli etc. Changing taste and preference towards consumption of basic foods items, which is driven by longer working hours, increase in the number of income families, more exposure to advertising, for comfort and convenience etc. Especially people living in cities are become more health and hygiene conscious. Exotic vegetables are globally important and a source of cash income for small holders; public and private sector partners supplies adequate seeds of accepted lines to small holder farmers at a reasonable price. Hence we find AQUAPONICS as competent solution of all the above mentioned challenges.

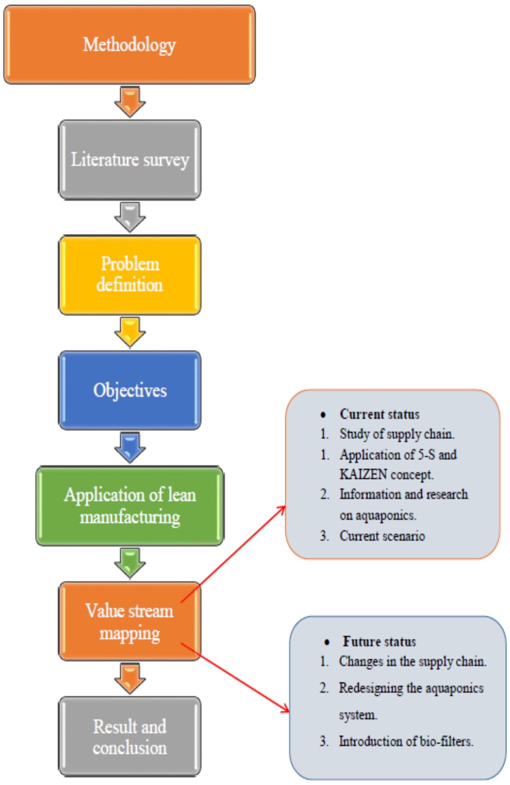
3.2 OBJECTIVES

A) To study the complete supply chain and logistics of exotic vegetable in Mumbai as it is one of the most densely populated metropolitan cities in India and it is observed that most of small scale farms of these exotic vegetables are found nearby Mumbai and it is also a hub to many vendors of exotic vegetables.

B) To apply the concept of lean manufacturing which would be mainly focused to value stream mapping(VSM) in reduction of production cost in exotic vegetable business.

C) To design the complete layout of a new Aquaponics system and henceforth reduce and minimize the cost of production of exotic vegetable.

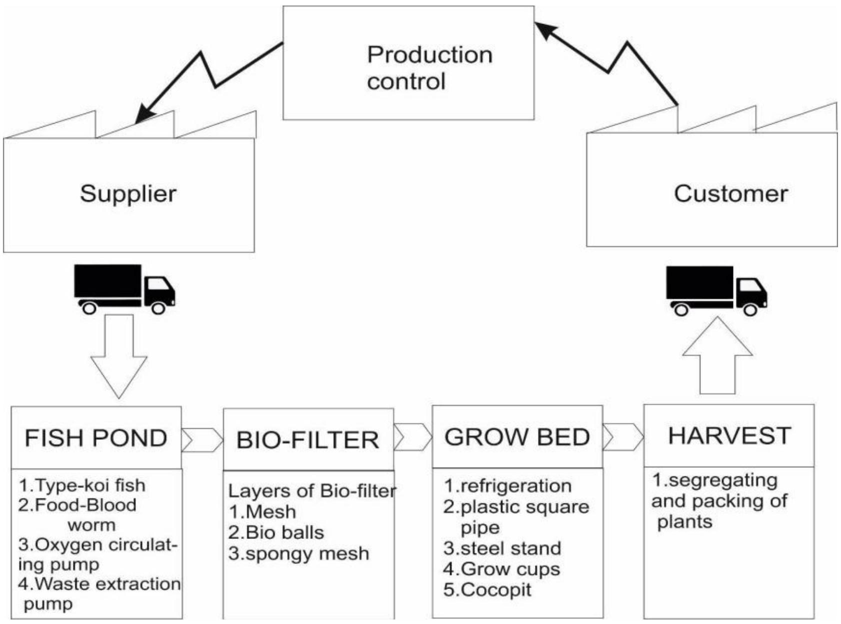
4. PROPOSED METHODOLOGY



5. APPLICATION OF LEAN MANUFACTURING

The field of lean manufacturing has offered valuable tools and techniques to eliminate the wastes. Some of these techniques are unique to the field of lean manufacturing. For example, Kanban card and value stream mapping are unique tools and technique respectively of lean manufacturing field. One of the ideals of lean manufacturing paradigm is visual communication. In the case of manufacturing companies, the actual working environment is represented by production shop floor. In order to carry out this task, techniques like flow charts, string diagram and process charts are generally used.

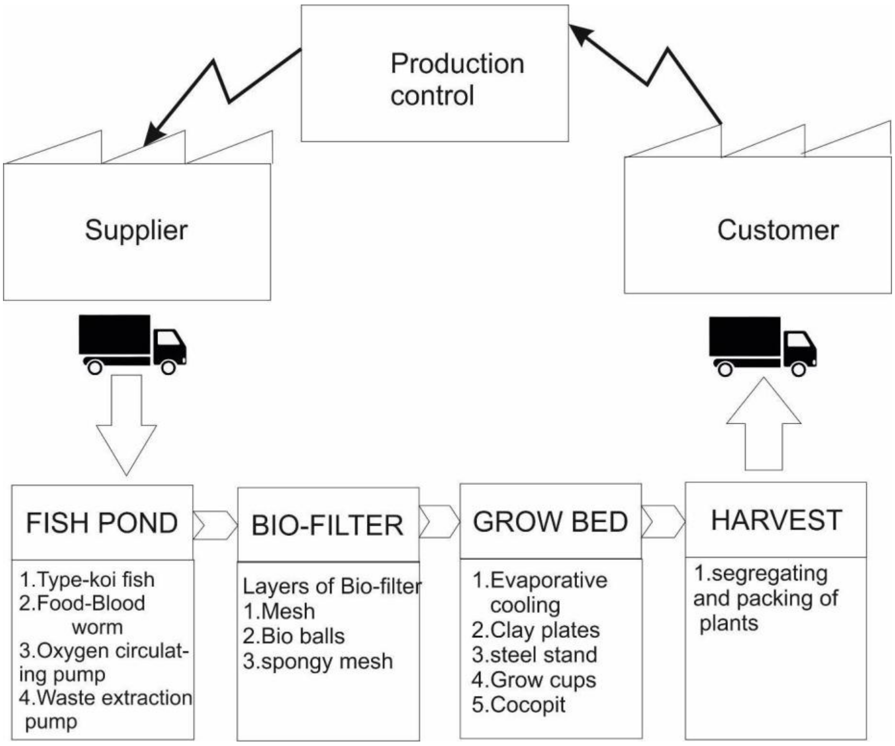
5.1 CURRENT STATE MAP



Current state map

The current system used for aquaponics is shown in above fig., It uses traditional refrigeration system to maintain the room temperature as per need of vegetable. Which uses high amount of electricity which give rise to high operating cost of system. Initial cost is utilized for seeds, fish food, bio balls and for coco pit etc. After harvesting the product is transported to vendors or directly to customers.

5.2 FUTURE STATE MAP



The current state map picturizes the existing practices which on analysis would reveal the waste elimination opportunities. After gathering this knowledge, the future state map is developed. In initial stage, the future state map can be developed like the way it was done in case of developing current state map. The change is done with refrigeration system. Evaporative cooling technique is used for cooling the environment of the plants are per their requirement.

6. COST REDUCTION IN AQUAPONICS

6.1 THE HEATING LOAD

The heating load is the amount of heat energy that would need to be added to a space to maintain the temperature in an acceptable range. The cooling load is the amount of heat energy that would need to be removed from a space (cooling) to maintain the temperature in an acceptable range.

1) Solar Heat Gain: There are three different ways in which heat from the sun can be utilized in interior spaces ,they are conduction, convection and radiation. Conduction occurs across walls and roofs, since they are exposed to a temperature. Convection refers to heat transfer due to the bulk movement of hot outdoor air/ indoor air transferring between surfaces at different temperatures.

2) **Heat from Human Beings**: Occupants are also the major source of heat in building interiors. Consider that a human consumes hundreds of calories each day in the form of food, and part of this energy is released as heat during metabolic processes.

3) **Outdoor Air Heat**: The warmer air outside of conditioned spaces is called outdoor air or atmospheric air. Due to its higher temperature, outdoor air tends to increase the average room temperature when it enters indoor spaces.

Considering all the above factors for the heating load, a detailed study was performed and the following results were calculated:

Outside design conditions: 93°F 60% relative humidity

Inside design conditions: 68°F 55% relative humidity

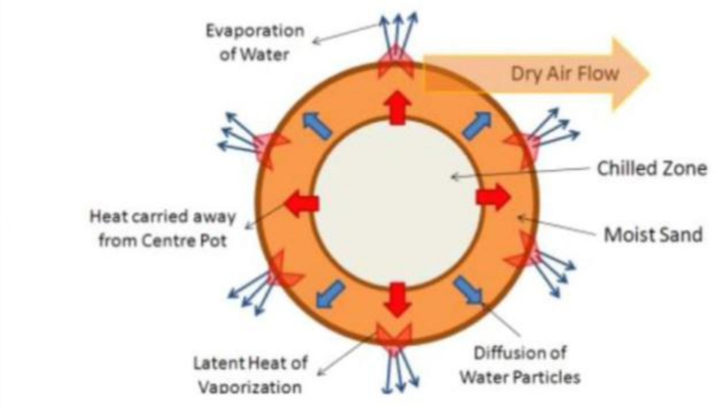
SENSIBLE HEAT	LATENT HEAT
Wall Exposed to north Area= 375 sq. ft U-factor = 0.35 EQTD = 15°F sensible heat = A*U*EQTD = 1968.75 Btu/hr Exposed to south Area= 375 sq. ft U-factor = 0.35 EQTD = 29°F Sensible heat = A*U*EQTD = 3806.25 Btu/hr Exposed to east Area = 375 sq. ft U-factor = 0.35 EQTD = 29°F Sensible Heat = A*U*EQTD = 3806.25 Btu/hr Exposed to west Area = 375 sq. ft U-factor = 0.35 EQTD = 23°F Sensible Heat = A*U*EQTD = 3018.75 Btu/hr Roof Area = 1000 sq. ft U-factor = 0.17 EQTD = 43°F Sensible Heat = A*U*EQTD = 7310 Btu/hr Floor Area = 1000 sq. ft U-factor = 0.38 EQTD = 25°F Sensible Heat = A*U*EQTD = 9600 Btu/hr Lighting load Area of light = 1000 sq. ft Light density = 1.81 Ballast factor = 1 Sensible heat = 1000*1.81*1*3.4=6154 Btu/hr People Number of people = 25 Sensible heat = 25*285 = 7125 Btu/hr Equivalent load = 588*3*3.4=5997.631 Btu/hr Ventilation CFM/person(A) = 10 Number of people(B) = 25 CFM/sq. ft(C) = 0.18 Total area(D) = 1000 sq. ft Ventilation = A*B+C*D = 430 CFM Air change per hour(ACPH)=VOLUME/60=250 CFM Bypass Bypass factor = 0.12 Temperature difference = 30°F Sensible heat=430*0.12*30*1.08=1671.84 Btu/hr Non bypass Sensible heat = 430**(1-0.12)*30*1.08 = 12260.16 Btu/hr Total sensible heat gain = 62718.631 Btu/hr Considering 5% safety factor and 7.5% for fans Total sensible heat gain = 70558.45 Btu/hr	People Number of people = 25 Heat gain per pound = 165 Btu/hr Latent heat gain = 25*165 = 4125 Btu/hr Ventilation (A) Bypass Fresh air = 430 CFM Bypass factor = 0.12 Heat gain/pound = 48 Latent heat gain = 430*0.12*48=2476.2 Btu/hr (B) Non Bypass Fresh air = 430 CFM Bypass factor = 0.12 Heat gain per pound = 48 Latent heat gain=430*(1- 0.12)*48=10163.2 Btu/hr Plants Number of plants = 2500 Heat gain per plant = 7 Watts Conversion factor = 3.4 Latent heat gain = 2500*7*3.4 = 59500 Btu/hr Total latent heat gain = 84264 Btu/hr Considering 5% safety factor Total latent heat gain = 88477.2 Btu/hr

6.2 DEVELOPMENT OF THE POT IN POT REFRIGERATOR (PIP SYSTEM)

The thesis is based on the most efficient, widely utilized and almost free substantial technique of evaporative cooling. Evaporative coolers in a method which help to give out cold air by forcing hot dry air on a damp pad.

OPERATION TECHNIQUE

When evaporation occurs from a surface, there is an energy associated with the phase change known as the latent heat of vaporization. In a given system, as air flows over the wet surface, water on the surface of pot evaporates also by absorbing heat from inside of pot. This cooing effect is known as evaporative cooling and is most effective in dry climates due to the lack of moisture content (relative humidity) in the air.



Pot in pot system

AFFECTIONS PARAMETERS:

Relative Humidity: When the relative humidity is low, the amount of water vapour in air willbe less as well. Under this condition air is capable to take additional amount of moisture, hence the rate of evaporation and cooling rate are more

Air Movement: The movement down. On other hand if humid air is removed away and replaced with fresh air, the evaporation rate will increase

Air Temperature: Areas with the higher temperatures will have higher rate of evaporation and will result in higher cooling will. With lower air temperature less evaporation and lesser cooling will take place.

Surface Area: The greater the surface area to volume ratio available for evaporation the more amount of water can evaporate, the greater the rate of evaporation. Following are the fabricated pots.

6.3 COST REDUCTION

Considering the requirements of air conditioning and after briefly describing the setup as mentioned in above scenario the whole purpose of VSM was focused on cutting down the facility usage of electricity by trying to eliminate the Air conditioning system. Checking the adaptability of plants with the new system an overall estimate of cost reduction is done for area of 1000sqft.

PROTOTYPE FOR PIP SYSTEM

COMPARISION OF SYSTEMS:

Current indoor aquaponics system		**Pot in pot system**	
1.Cost of motors	10,000/-	1.Cost of motors	10,000/-
2.Cost of air conditioning	4,00,000/-	2.Cost of manufacturing of pots	3,00,000/-
3.Cost of lighting	4,00,000/-	3.Cost of lighting	2,00,000/-
4.Miscellaous cost (fish, water, seeds, man power, transportation)	1,00,000/-	4.Miscellaous cost (fish, water, seeds, man power, transportation)	1,00,000/-
5.Cost of maintaining desired temperature (heat loadcalculations)	4,00,000/- (per year)	5.Cost of maintaining desired temperature	5,000/- (per year)
TOTAL CAPITAL COST	9,10,000/-	TOTAL CAPITAL COST	6,10,000/-
MAINTAINANCE COST	6,15,000/- (per year)	MAINTAINANCE COST	2,15,000/- (per year)

All are expected costing for 1000sqft area and growing 2500 plants

7. RESULT AND CONCLUSION

Considering the above mentioned criteria, developments in the production chain are necessary as world steps into lean era. Steps considered in lean manufacturing help in removing wastes of overproduction, transport, waiting time, inventory and other related defects. Decision of using VSM is made to enhance the production quality and save lead time. Also further decrease in cost can be achieved by considering machinery usage in industry and other related mechanisms. Aquaponics being one of the option to develop and cultivate exotic and reliable crops when combined with VSM can be a competent solution in areas where population density is high and availability of soil or farms is almost zero viz. area like Mumbai and many other metropolitan cities. We were able to achieve a good growth in plants and optimize our solution. The utility of Value stream mapping provided a way to replace the traditional air conditioning methods to evaporative cooling along with cost cutting.

REFERENCES

1. Danaher, J.J., Shultz, R.C., Rakocy, J.E., Bailey, D.S., 2013. Alternative Solids Removal for Warm Water Recirculating Raft Aquaponics Systems. J. World Aquac. Soc. 44, 374–383.

2. Sikawa, D.C., Yakupitiyage, A., 2010. The hydroponic production of lettuce (Lactuca sativa L) by using hybrid catfish (Clarias macrocephalus × C. gariepinus) pond water: Potentials and constraints. Agric. Water Manag. 97, 1317–1325.

3. Goddek, S., Delaide, B., Mankasingh, U., Ragnarsdottir, K.V., Jijakli, H., Thorarinsdottir, R., 2015. Challenges of sustainable and commercial Aquaponics. Sustain. 7, 4199–4224.

4. Maucieri, C., Nicoletto, C., Junge, R., Schmautz, Z., Sambo, P., Borin, M., 2018. Hydroponic systems and water management in Aquaponics: A review. Ital. J. Agron. 13, 1–11.

5. Schmautz, Z., Loeu, F., Liebisch, F., Graber, A., Mathis, A., Bulc, T.G., Junge, R., 2016. Tomato productivity and quality in Aquaponics: Comparison of three hydroponic methods.

6. Knaus, U., Palm, H.W., 2017. Effects of the fish species choice on vegetables in Aquaponics under spring-summer conditions in northern Germany (Mecklenburg Western Pomerania).

7. Khandaker, M., Kotzen, B., 2018. The potential for combining living wall and vertical farming systems with Aquaponics with special emphasis on substrates. Aquac. Res. 49, 1454–1468.

8. Cooper, A., 1979. The ABC of NFT, 1st ed. Grower Books, London.

9. Lennard, W.A., Leonard, B. V., 2006. A comparison of three different hydroponic sub- systems (gravel bed, floating and nutrient film technique) in an Aquaponics test system. Aquac. Int.

10. Molovan, I., Băla, M., 2015. Analysis of aquaponics organic hydroponics from the perspective of setting costs and of maintenance on substratum and floating shelves systems. J. Hortic. For. Biotechnol. 19, 73–76.

11. Mcmurtry, M.R., Sanders, D.C., Cure, J.D., Hudson, R.G., Haning, B.C., Amand, P.C.S., 1997. Efficiency of water use of an integrated fish/vegetable co-culture system.
J. World Aquac.

12. Pattillo, D.A., 2017. An Overview of Aquaponics Systems: Hydroponic Components. NRAC Tech. Bull. Ser. 19, 1–10.ss

13. Asciuto, A., Schimmenti, E., Cottone, C., Borsellino, V., 2019. A financial feasibility study of an aquaponics system in a Mediterranean urban context. Urban For. Urban Green. 38, 397–402

14. Delaide, B., Monsees, H., Gross, A., Goddek, S., 2019. Aerobic and anaerobic treatments for aquaponics sludge reduction and mineralisation. In: Goddek, S., Joyce, A., Kotzen, B., Burnell, G.M. (Eds.), Aquaponics Food Production Systems: Combined Aquaculture and Hydroponic Production Technologies for the Future. Springer International Publishing, Cham, pp. 247–266

15. Yep, B., Zheng, Y., 2019. Aquaponics trends and challenges - A review. J. Clean. Prod. (November)

16. Golhar D.Y. and Stamm C.L. (1991) 'the just-in-time philosophy: a literature review', International Journal of Production Research, Vol. 29 No. 4, pp.657-676.

17. Keller, A.Z. and Kazazi, A. (1993) 'Just-in-time manufacturing systems: a literature review', Industrial Management & Data Systems, Vol. 93 No. 7, pp.2

18. Waters-Fuller, N. (1995) 'Just-in-time purchasing and supply: a review of the literature', International Journal of Operations & Production Management, Vol. 15 No. 9, pp.220-236.

19. Gunasekaran, A. (1999) 'Just-in-time purchasing: an investigation for research and applications', International Journal of Production Economics, Vol. 59 Nos. 1-3, pp.77- 84.

20. Honold L. (1997) 'A review of the literature on employee empowerment', Empowerment in Organizations, Vol. 5 No. 4, pp.202-212.

21. Sendil Kumar, c. And panneerselvam, r. (2007) 'literature review of jit-kanban system', the international journal of advanced manufacturing technology, vol. 32 nos. 3-4, pp.393-408.

22. Filho, m.g. and fernandes, f.c.f. (2004) manufactures a review that rates and analyzes work by pointing out future research perspectives.

23. Gestao&producao, vol. 11 no. 1, pp.1-19.

24. Landsbergis, P.A., Schnall, P. and Cahill, J. (1999) 'The impact of lean production and related new systems of work organisation on worker health', Journal of Occupational Health Psychology, Vol. 4 No. 2, pp.108-130.

25. Seth, D. and Gupta, V. (2005) 'Application of value stream mapping for lean operations and cycle time reduction: an Indian case study', Production Planning and Control, Vol. 16 No. 1, pp.44-59.

26. Dhandapani, v., potter, a. And naim, m. (2004) 'applying lean thinking: a case study of an Indian steel plant', international journal of logistics: research and applications, vol. 7 no. 3, pp.239-250.

27. Berkley, b.j. (1992) 'a review of the Kanban production control research literature', production and operations management, vol. 1 no. 4, pp.393-412.

28. Resta, B., Dotti, S., Gaiardelli, P., Boffelli, A., 2016. Lean Manufacturing and Sustainability: An Integrated View, in: Nääs I. et al. (Eds.), Adv. Prod. Manag. Syst. Initiat. a Sustain. World. APMS 2016. Springer, Iguassu, pp. 659– 666. doi:10.1007/978-3-319-51133-7_78

29. Gupta, S.M., 2016. Lean manufacturing, green manufacturing and sustainability. J. Japan Ind. Manag. Assoc. 67, 102– 105

30. Martínez León, H.C., Calvo-Amodio, J., 2017. Towards lean for sustainability: Understanding the interrelationships between lean and sustainability from a systems thinking perspective. J. Clean. Prod. 142, 4384–4402. doi:10.1016/j.jclepro.2016.11.132

31. Sajan, M.P., Shalij, P.R., Ramesh, A., Biju Augustine, P., 2017. Lean manufacturing practices in Indian manufacturing SMEs and their effect on sustainability performance. J. Manuf. Technol. Manag. 28, 772–793. doi:10.1108/JMTM-12-2016-0188

32. Resta, B., Dotti, S., Gaiardelli, P., Boffelli, A., 2017. How Lean Manufacturing Affects the Creation of Sustainable Value: An Integrated Model. Int. J. Autom. Technol. 11, 542–551. doi:10.20965/ijat.2017.p0542

33. Kowang, T.O., Yong, T.S., Rasli, A., Long, C.S., 2016. Lean Six Sigma Sustainability Frameworks: A Case Study on an Automotive Company. Asian J. Sci. Res. 9, 279– 283. doi:10.3923/ajsr.2016.279.283