Lean-BPM Integrated Model to Improve Productivity in SMEs in the Aquaculture Sector: A Research in Peru

Piero Rios-Del Castillo, Renzo Guia-Espinoza, Juan Quiroz-Flores*, Martin Collao-Díaz, and Alberto Flores-Pérez

***Abstract*—The development of aquaculture in Peru has been developing progressively in the last five years, to opt for an innovative and sustainable economic activity. Despite this growth, it has been affected by climatic factors that harm aquaculture crops. Added to this is the lack of product training, insufficient production capacity, and high raw material costs. Faced with these problems, it has been chosen to provide a production management model through Lean Business Process Management (Lean-BPM) that facilitates the control of processes, inventories, production plans, and cleaning; so that finally the productivity of small producers increases. The results show the efficiency of the methodology by having as current situation productivity of 75,000 Kg/m3 per year to a result of 128,905 Kg/m3 per year, which represents an increase of 71.87%, this due to the obtaining of certain equipment and formats log that optimize the control of the necessary parameters and the growth efficiency of the same trout. Therefore, these directly improve their productive times, operating times, and use of resources; that ultimately impact on improving productivity.**

***Index Terms*—Lean, Business Process Management (BPM), aquaculture, productivity, quality management**

I. Introduction

In recent years, the aquaculture sector has had several changes regarding technology to develop better tools and methods for the production of marine species, which represents a sector in constant growth worldwide (FAO, IFAD, UNICEF, WFP, & WHO, 2023). The factors affecting the development of aquaculture activities at the Latin American level according to the perception of farmers would be obtaining environmental licenses (59%), high prices of feed for fattening (34%), and poor conditions of water reservoirs (31%) (Roriz *et al*., 2017). As of 2020, the fishing and aquaculture activity has contributed 0.4% of the total GDP with 1927 million soles; however, the historical maximum value was in 2011 with 2709 million soles, what is sought with aquaculture is to be able to obtain this contribution that was had at the time that was not as developed as it is today (FAO, 2020.). Likewise, a situational diagnosis of aquaculture in Peru was carried out, which shows the current risks for aquaculture development: the impacts on aquaculture resources, the impoverishment of aquaculture farmers related to nutritional deficits, and the impacts of water quality, which provides a lower quantity and quality of production. Therefore, aquaculture development is essential to combat famine in regions of extreme poverty (Ministry of Production, 2019).

Manuscript received November 16, 2022; revised January 27, 2023; accepted March 12, 2023.

Piero Rios-Del-Castillo, Renzo Guia-Espinoza, Juan Carlos Quiroz-Flores, Martín Collao-Diaz, and Alberto Flores-Perez are with the Facultad de Ingeniería y Arquitectura, Universidad de Lima, Perú.

*Correspondence: jcquiroz@ulima.edu.pe (J.Q.F.)

The problem identified, based on literary research, is due to low investment in the aquaculture sector, reduced research, and development, and also due to sanitation problems (Berger, 2020). In addition, thanks to research around the world, the different problems occurring in the sector are made known. A study of Tilapia in Brazil presents environmental licensing and high feed prices as the main problems (Roriz *et al*., 2017). Similarly, in Costa Rica, thanks to research on shrimp, the problem of the high cost of feed for fattening and how it directly affects productivity and profitability is demonstrated (Valverde and Varela, 2020). On the other hand, a study in Norway compares the salmon supply chain with that of poultry, showing that there is less control of production processes in the harvesting of salmon (Asche *et al*., 2018). The aforementioned indicates that the aquaculture sector needs to develop sustainable production systems for the industry to advance, applying innovations to increase productivity (Valenti *et al*., 2021); for this reason, it is important to increase development in the sector and that its research continues to apply procedures to solve current problems.

Against this background, fish farmers must become more efficient in meeting their production projections. Therefore, a case study was chosen to reflect these problems of low productivity due to different factors. The points for improvement identified are reduced production capacity, high operating costs, and lack of certification of their production processes. To develop a solution, an integrated model has been chosen with tools such as lane diagram, Activity Value-Added Analysis (AVA) Matrix, Total Production Management (TPM), Total Quality Management (TQM), and process standardization, under the lean manufacturing and Business Process Management (BPM) methodologies. This model has been developed based on case studies that have successfully solved similar problems, which contribute significantly to the needs of the sector and the scientific community. The following research provides a new production model linked and applied to a constant production model. It is worth noting that there is a large amount of research from companies that have developed these methodologies (Bergesen and Tveterås, 2019). However, the number of studies on independent fish farmers and small-scale fishermen is small. All this shows that aquaculture has undergone considerable development in developed companies, which has left a very large gap for new entrepreneurs within the industry.

The scientific articles reviewed contain little information on integrated “BPM and lean manufacturing” working models for this type of producer, especially in Latin America. Therefore, the need to develop the present research arises. The present scientific article is divided into seven parts are the introduction, which breaks down the main problems and methodologies to be used to solve the problems; the diagnosis will delve into the identification of specific problems, aspirational technical gap, and detailed mapping of the process to be improved; the state of the art develops the tools to be used for the development of the model; the contribution synthesizes the function of the integrated model; results that will show the indicators that were impacted by the proposed model; the discussion will analyze the scenarios in certain groups of products or data and conclusions.

II. State of the Art

The articles selected and indexed to define the state of the art classify the main concepts to be developed in this case study.

A. Productivity

It is important to highlight that aquaculture is about adapting the key working elements for optimal production. As evidenced in several scientific articles that emphasize these determining factors that impact the efficiency of a fish farm (Rahman *et al.*, 2019). To be able to improve aquaculture productivity, the inputs, processes, and outputs of the traditional supply chain are considered as points to be investigated and based on this, an updated approach or a practical model that does not require any investment is offered. This is because the waste and reprocesses that affect production are being analyzed, as well as emphasizing the necessary characteristics of the target markets of each fish farmer (Asche *et al*., 2018; Bergesen and Tveterås, 2019; Kaminski *et al*., 2018).

B. Business Process Management

BPM seeks to develop a set of activities for the organization of the company to be employed; and thus, to analyze and develop continuous improvements in the main productive activities. In this way, to generate a competitive advantage over time to have business success (Gošnik, 2016). For this reason, it is crucial to identify each production process in the organization; since, when applying the BPM tool, it is elementary to have the collection of information of what has been used over time and to know the degree of maturity since the implementation. To assess the degree of maturity it is necessary to distinguish and detail the following factors: strategies, controls, processes, people, and technology employed (Dave, 2017; Kerpedzhiev *et al*., 2021). Furthermore, bottlenecks must be taken into account, thus predicting the execution time and making the respective improvement in that specific process (Arevalo *et al*., 2016). BPM focuses on increasing the effectiveness and efficiency of processes through their evaluation and continuous improvement to increase productivity, applying tools such as process standardization, correct decision-making, elimination of redundant activities, and rational resource management (Fernandes *et al*., 2021).

C. Lean Manufacturing

Lean manufacturing aims to optimize the use of resources in any production process by eliminating waste, focusing on improving process efficiency to ultimately impact productivity and provide a competitive advantage. Integrated models are developed for the implementation and demonstration of the effectiveness and practicality of lean manufacturing; through simulations and surveys of different companies (Dave and Sohani, 2019). Studies have focused on supply chain management, using lean compatible tools such as Just in Time (JIT) and TQM. However, these implementations are not sustainable in the long term as these tools are seen as a single improvement and not as a philosophy or way of working. Therefore, optimal lean tool relationships have been investigated to implement all of them so that these improvements last over time (Green *et al.*, 2019). In addition, it is essential to determine actions for human resources management, the relationship between these two areas is crucial to obtain better results in the company since improvements must be comprehensive and impact all stakeholders (Kitchot *et al.*, 2021). Currently, the tools most used to implement these environmental and social improvements are Value Stream Mapping (VSM) (74.93%), Kaizen / Continuous Improvement (CI) (69.5%), Total Production Management (TPM) (60.5%) and automation (50.67%) (Garza-Reyes *et al.*, 2018; Hong *et al.*, 2017).

III. Contribution

A. Model Basis

The innovation of our proposal lies in the integration of various tools developed in the state of the art, which when integrated from our model of inventory management, supply policies, and process control, which is proposed as a solution to improve the management of the supply chain that will ultimately impact on increased productivity for aquaculture producers. There are several tools to implement an improvement in the supply and inventory policy, among them we highlighted the demand planning to make the necessary purchases through the JIT, the standardization of processes through the BPM, and the control of operations to ensure quality was used the TQM.

B. Proposed Model

The proposed integrated model is based on techniques such as JIT, 5S, and VSM; through the BPM process management model supported by the TQM methodology. The latter aims to identify, analyze and improve processes in different business areas through work standardization and quality assurance.

Like other processes, inputs and outputs have been determined in our model. The inputs refer to the relevant indicators on the processes of the fish farmers. The outputs of the model are the improvement in productivity indicators and the optimization of production processes, as shown in Fig. 1.

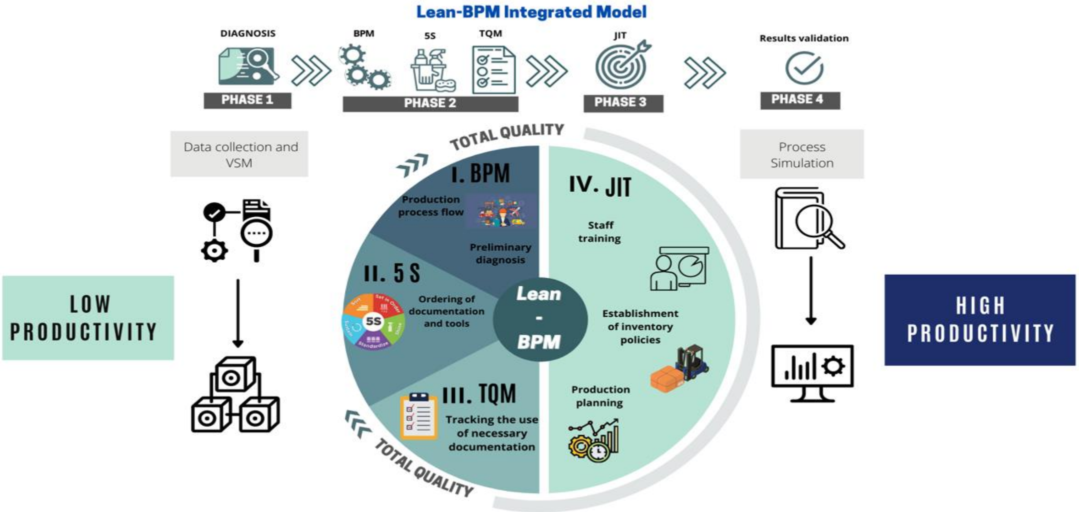

Fig. 1. Proposed inventory management model.

C. Model Components

Table I presents the proposed model components supported by the literature review and their different phases:

TABLE I: COMPARISON MATRIX OF THE PROPOSAL COMPONENTS VS THE STATE OF THE ART

Components	**Lack of information**	**Improper production process**	**Mismanagement of production capacity**
Stevens, J. R., *et al.* (2018)	Interviews, literature review.	Standardized operations	FIFO
Dave, Y., & Sohani, N. (2019)	Triple P model, expert interviews.	TQM & 5S	JIT
Green, K. W., *et al.* (2019)	Structural equation model.	TQM	JIT
Ferreira, G. S. A., *et al.* (2018)	VSM	BPM	
Proposal	**VSM and expert interviews**	**BPM, TQM & 5S**	**JIT**

The following section will describe the components of the model:

1) Component 1: Analysis of the current situation

The analysis of the current situation will be developed, where information about the usual production will be collected to be analyzed based on the process mapping that will be developed with the VSM tool. In addition, scientific articles with similar problems in the production area will be reviewed to determine the best tools for diagnosis, improvement, and validation.

2) Component 2: Process stabilization

Phase 2 is made up of the BPM, TQM, and 5S analysis tools. This phase aims to identify the main problems of the processes, to propose medium- and long-term objectives for the improvement of product quality, and to organize the workspaces.

Component 3: Supply and storage optimization with JIT.

Component 3 consists of the implementation of the JIT and First In, First Out (FIFO) tools. Once the processes are stabilized, the aim is to establish a projected demand to be able to determine appropriate inventory levels for the naturalness of the product and also to program the purchases of raw materials necessary for continuous production. This will be related to FIFO inventory management, as the products are perishable.

3) Component 4: Model validation

Finally, the Arena simulator will be used to visualize the results of the implementation of the solution model. The indicators before and after the development of the proposed model are shown.

D. Indicators

To prove the effectiveness of improvements it is necessary to measure them through indicators.

1) Productivity (P): To assess trout production over the capacity of the water body

Objective: To increase productivity by 25% in the trout production line.

$$P = \frac{Total\ weight\ of\ production\ per\ year\ (kg)}{volume\ of\ water\ bodies\ (hectare)}$$

Explanation of use: The sum of the total weight of production in kilograms in a year divided by the total volume of water bodies to be used in the production phases in hectares.

Interpretation: Measures an integer value to compare the efficiency of different trout farms.

2) Cycle time per batch: It is the time it takes to produce a production batch

Objective: Decrees the cycle time by 10% per batch.

$$CT = \frac{Production\ process\ time\ (days)}{Production\ batch\ (units)}$$

Explanation of use: The total time spent in the production process in days divided by the number of batches produced.

Interpretation: Measures the total time it takes to produce a production batch.

3) S auditory: Average score for each S

Objective: Increase compliance to 8.

$$5S\ C = \frac{\sum(sorting + order + cleanliness + standardization + discipline)}{5}$$

Explanation of use: Sum each 5S score divided by 5 to get the average score of the auditory.

Interpretation: Measures the fulfilment of objectives for the application of the 5S philosophy.

4) Record-keeping compliance: Level of compliance with production records

Objective: Increase compliance to 100%.

$$RK = \frac{Number\ of\ formats\ correctly\ filled}{Total\ number\ of\ formats} \times 100\%$$

Explanation of use: Is the total number of formats of control were correctly filled divided by the total number of formats to be filled.

Interpretation: Measures the fulfilment of the necessary records.

5) Compliance with the production plan: Level of the fulfilment of actual production vs planned production on an annual basis

Objective: Increase to 85% the fulfilment of the production plan

$$CPP = \frac{Total\ quantity\ of\ produced\ fish\ (tons)}{Total\ quantity\ of\ planned\ fish\ (tons)} \times 100\%$$

Explanation of use: Sum the total quantity of produced fish in a year in tons divided by the total quantity of planned fish production in a year in tons.

Interpretation: Measures the compliance of the planned production.

IV. Validation

A. Initial Diagnosis

The current case shows a technical gap in sales between two rainbow trout producers, where the aim is to increase the productivity of the smaller one to get closer to the best producer in the area. Currently, Julio Mantari's company has sales of 985,400 dollars per year, compared to Luis Heras' company with sales of 218,978 dollars per year. To increase productivity and consequently increase sales, the main causes of the sector's problem are addressed: (a) reduced production capacity, (b) high operating costs, and (c) lack of certifications. The results of the model applied in Luis Heras' company will be shown in Table II, where different indicators were evaluated for measurement and evaluation.

B. Validation Design and Comparison with the Initial Diagnosis

For the application of this model and its validation, a simulation will be used to compare the current situation of Luis Heras' company with the ideal situation after going through the 4 components of the model. Within the first component, the current situation is analyzed, and information is gathered through a literature review and an analysis of key performance indicators (KPI's), thus finding the main problems and causes of productivity in the sector, mapping everything in a VSM. For component 2, BPM tools are used: BPM in search of reducing the production cycle time and reach the ideal of 11 months; 5S to improve the order of the work and the place through qualifications; and TQM so that the quality controls are met at 100% and thus to stabilize the productive process of the company. Finally, to seek the fulfilment of the production plan in component 3 with the JIT tooling. In this way, increase productivity by at least 10%.

TABLE II: Indicators Result

Indicator	Current	Expectation
Productivity	75 000 Kg/ha	82 500 Kg/ha
Cycle time per batch	390 days	330 days
5S auditory	6.1	8
Record-keeping compliance	37.5 %	100%
Compliance with the production plan	Not defined	85%

C. Improvement -Proposal Simulation

The implementation of the model has developed thanks to a simulation of the Arena program to corroborate its efficiency. Two simulations were carried out, the first focused on the trout production cycle and the second on optimizing the working time of the employees.

For this, the aforementioned tools of the model were used. For the production cycle, the BPM was implemented to standardize the process, reducing time thanks to the use of equipment to improve the efficiency of the cycle, carrying out 1000 replications for a simulation of two years. The process simulation is represented in Fig. 2.

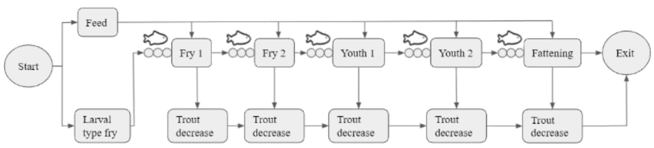

Fig. 2. Representation of the improved system.

On the other hand, in the second simulation, the 5S tool was implemented, reducing the time of the activities of the operator's thanks to the order and cleanliness, and TQM was also used to implement and make use of the quality records. And in continuity, JIT was applied to project the necessary annual food purchases required. The above-mentioned actions were implemented, and the result obtained is shown in Table III where a comparison of the current and actual situation is made.

TABLE III: Simulation Current vs Improved Situacion

Indicator	Current	Improved
Productivity	75 000 Kg/ha	128 905 Kg/ha
Cycle time per batch	390 days	325 days
5S auditory	6.1	8
Record-keeping compliance	37.5 %	100%
Compliance with the production plan	Not defined	135.78%

Thanks to the data obtained, it was possible to see a 71.87% improvement in productivity, which validates the implementation of the Lean-BPM model and demonstrates how all the indicators that its application improved.

V. Conclusions

The simulation allowed us to obtain the expected result of increasing productivity by 71.87%. The BPM used together with the Lean methodology allows to give a new approach and improve performance by applying a reengineering in the productive process; in this way, an integrated system is implemented seeking the transformation of processes thanks to continuous improvement and the use of agile tools; and thus, consequently, improving organizational efficiency (Butt, 2020; Ferreira *et al*., 2018). Thanks to the implementation of the Lean-BPM model, the production cycle time is reduced by 16.67% with the BPM tools; and hand in hand with the 5S and TQM tools, adequate control of each stage of the cycle is achieved in an orderly and clean manner. Finally, there is compliance with the production plan of 135.78%, which provides a large production slack to meet uncertain demand.

In future works, a good diagnosis is recommended because information on aquaculture is very scarce due to the informality of producers in Peru. Likewise, we recommend an extension of the data collection so that there is less variation, a reduction in the error, and the precision of the information obtained at the time of the simulation is increased.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Piero Rios Del Castillo and Renzo Guia Espinoza compiled the information on the current status of the production plant with the cooperation of the supervisor during 2021. Juan Quiroz, Alberto Flores and Martin Collao supervised this project and contributed ideas for the drafting of the document. They provided support throughout the construction of the research and approved the final version.

References

Arevalo, C., Escalona, M. J., Ramos, I., &Domínguez-Muñoz, M. 2016. A metamodel to integrate business processes time perspective in BPMN 2.0. ***Inf. Softw. Technol.,*** 77: 17–33, doi: 10.1016/j.infsof.2016.05.004

Asche, F., Cojocaru, A. L., & Roth, B. 2018. The development of large scale aquaculture production: A comparison of the supply chains for chicken and salmon. ***Aquaculture,*** 493: 446–455, doi: 10.1016/j.aquaculture.2016.10.031

Berger, C. 2020. Aquaculture and its potential in the context of Peru's sustainable development. ***South Sustain.,*** 1: 1–11, doi: 10.21142/ss-0101-2020-003 (in Spanish).

Bergesen, O., & Tveterås, R. 2019. Innovation in seafood value chains: the case of Norway. ***Aquac. Econ. Manag.,*** 23(3): 292–320, doi: 10.1080/13657305.2019.1632391

Butt, J. 2020. A conceptual framework to support digital transformation in manufacturing using an integrated business process management approach. ***Designs,*** 4(3): 17, doi: 10.3390/designs4030017

Dave, B. 2017. Business process management—A construction case study. ***Constr. Innov.,*** 17(1): 50–67, doi: 10.1108/CI-10-2015-0055

Dave, Y., & Sohani, N. 2019. Improving productivity through Lean practices in central India-based manufacturing industries. ***Int. J. Lean Six Sigma,*** 10(2): 601–621, doi: 10.1108/IJLSS-10-2017-0115

FAO, IFAD, UNICEF, WFP, & WHO. 2023. The State of Food Security and Nutrition in the World 2023. Urbanization, agrifood systems transformation and healthy diets across the rural-urban continuum. Rome, FAO. https://doi.org/10.4060/cc3017en

FAO. 2020. The 2020 world status of fishing and aquaculture. 2020. Available: http://www.fao.org/3/ca9231es/CA9231ES.pdf (in Spanish).

Fernandes, J., Reis, J., Melão, N., Teixeira, L., & Amorim, M. 2021. The role of industry 4.0 and bpmn in the arise of condition-based and predictive maintenance: A case study in the automotive industry. ***Appl. Sci.,*** 11(8), doi: 10.3390/app11083438

Ferreira, G. S. A., Silva, U. R., Costa, A. L., & Pádua, S. I. D. de D. 2018. The promotion of BPM and lean in the health sector: main results. ***Bus. Process Manag. J.,*** 24(2): 400–424, doi: 10.1108/BPMJ-06-2016-0115

Garza-Reyes, J. A., Kumar, V., Chaikittisilp, S., & Tan, K. H. 2018. The effect of lean methods and tools on the environmental performance of manufacturing organisations. ***Int. J. Prod. Econ.,*** 200: 170–180, doi: 10.1016/j.ijpe.2018.03.030

Gošnik, D., Beker, I., Suklan, J., & Kavčič, K. 2016. Management model for successful business processes: The case of transition countries. ***Int. J. Ind. Eng. Manag.,*** 7(2): 75–83.

Green, K. W., Inman, R. A., Sower, V. E., & Zelbst, P. J. 2019. Comprehensive supply chain management model. ***Supply Chain Manag.,*** 24(5): 590–603, doi: 10.1108/SCM-12-2018-0441

Hong, J., Zhang, Y., & Ding, M. 2017. Sustainable supply chain management practices, supply chain dynamic capabilities, and enterprise performance. ***J. Clean. Prod.,*** 172: 3508–3519, doi: 10.1016/j.jclepro.2017.06.093

Kaminski, A. M., Genschick, S., Kefi, A. S., & Kruijssen, F. 2018. Commercialization and upgrading in the aquaculture value chain in Zambia. ***Aquaculture,*** 493: 355–364, doi: 10.1016/j.aquaculture.2017.12.010

Kerpedzhiev, G. D., König, U. M., Röglinger, M., & Rosemann, M. 2021. An exploration into future business process management capabilities in view of digitalization: Results from a Delphi study. ***Bus. Inf. Syst. Eng.,*** 63(2): 83–96, doi: 10.1007/s12599-020-00637-0

Kitchot, S., Siengthai, S., & Sukhotu, V. 2021. The mediating effects of HRM practices on the relationship between SCM and SMEs firm performance in Thailand. ***Supply Chain Manag.,*** 26(1): 87–101, doi: 10.1108/SCM-05-2019-0177

Ministry of Production. 2019. Diagnosis of current vulnerability of the fishing and aquaculture sector against climate change. Available: https://www.produce.gob.pe/documentos/pesca/dgsp/publicaciones/diagostico-pesquero/Tomo-2.pdf (in Spanish).

Rahman, M. T., Nielsen, R., Khan, M. A., & Asmild, M. 2019. Efficiency and production environmental heterogeneity in aquaculture: A meta-frontier DEA approach. ***Aquaculture,*** 509: 140–148, doi: 10.1016/j.aquaculture.2019.05.002

Roriz, G. D., Delphino, M. K. de V. C., Gardner, I. A., & Gonçalves, V. S. P. 2017. Characterization of tilapia farming in net cages at a tropical reservoir in Brazil. ***Aquac. Reports,*** 6: 43–48, doi: 10.1016/j.aqrep.2017.03.002

Valenti, W. C., Barros, H. P., Moraes-Valenti, P., Bueno, G. W., & Cavalli, R. O. 2021. Aquaculture in Brazil: Past, present and future. ***Aquac. Reports,*** 19: 100611, doi: 10.1016/j.aqrep.2021.100611

Valverde, J., & Varela, A. 2020. Effect of stocking density on the productivity and profitability of the freshwater prawn Macrobrachium rosenbergii in the fattening phase in ponds, Costa Rica. ***Rev. Investig. Vet. del Perú,*** 31(3): 18174, doi: 10.15381/rivep.v31i3.18174 (in Spanish)