Global Journal of Flexible Systems Management (June 2020) 21(Suppl 1):S95–S104
https://doi.org/10.1007/s40171-020-00245-7

ORIGINAL RESEARCH

Understanding the Constraints on Success in Brazilian Amazon Production Chains

Gleriani Torres Carbone Ferreira[1,2] · **Jacques Marcovitch**[1] · **Maurício Jucá de Queiroz**[2]

Received: 11 March 2020 / Accepted: 27 May 2020 / Published online: 22 June 2020

Abstract *Observation of the Amazonic potential of the pisciculture production chain in the Brazilian Amazon motivated the development of this research on the competitiveness. Pisciculture presents opportunities for growth in Brazil from increasing per capita consumption, increasing production and export, inverting the current commercial deficit, which raises three essential questions: "What should be changed?", "What to change to?" and "How to bring about change?" We proved that the lack of an organised production chain results in low financial yields and retention of value generated in the Amazon region. Focusing on the Brazilian Amazon region, this study offers orientations for the development of public policy and for certification initiatives, with the construction of a replicable methodology of production chain analysis.*

Keywords Amazon · Production chain · Theory of constraints

Introduction

Amazonian pisciculture is an activity with high growth potential. The organisation of activity could be capable of combatting deforestation and promoting wealth generation in the region (Brasil 2008). The consumption of fish could also be promoted as a way of increasing food security in low-income populations and children, since fish and seafood are crucial for improving food security and human nutrition, with an increasingly important role in the fight against hunger (FAO 2018).

Independently of the high content of omega-3 and omega-6 fatty acids, substitution of foodstuffs with a high content of saturated fat such as red meat and dairy for fish is recommended as part of a diet that can prevent cardiovascular disease. From an epidemiological point of view, an increase in fish consumption is associated with lower cardiovascular mortality and morbidity (Scherr et al. 2015). This foodstuff also benefits the neural system and is particularly important during pregnancy and during the first 2 years of life (FAO 2014).

Asia, North America and Oceania consume over 20 kg per capita per year (FAO 2014), passing the level recommended by the World Health Organisation (WHO), which is at least 12 kg per capita per year. However, the Middle East, Latin America and Africa are all well below this level, with 9.3, 9.9 and 10.4 kg per capita per year, respectively (IBGE 2015). In Brazil, the Central West, South and Southeast do not even reach 2 kg per capita per year (IBGE 2015).

Over the past 30 years, production of fish in captivity increased 12-fold, with an average annual growth of 8%, making it the fastest growing food production sector (HLPE 2014). However, in the list of the thirty largest producers of fish worldwide in 2010, Latin America counted just two entrants; Peru, in the eighth position with 2.59% of global production, and Brazil in the nineteenth position with just 0.75% (Brasil 2011).

This study was motivated by the fact that Brazil has a coastline of over 7000 km, as well as 8500 km of

✉ Gleriani Torres Carbone Ferreira
gleriani@usp.br

Jacques Marcovitch
jmarcovi@usp.br

Maurício Jucá de Queiroz
mauricioj@fia.com.br

[1] Universidade de São Paulo, São Paulo, Brazil

[2] FIA Business School, São Paulo, Brazil

navigable waterways. These geographical features are natural preconditions for the production of freshwater and marine fish. However, the annual production is insufficient to attend to internal demand, and the country is incapable of changing the deficit in the export trade balance. In 2018, 722,560 tons of fish were produced, as well as 295,000 tons being imported and 32,400 exported.

Adding seafood to fish, Brazilian production reached 1,286,000 tons in 2016, behind Mexico, Chile and Peru with 1,732,000, 2,535,000 and 3,897,000 tons, respectively. Even with geographical and climate conditions that favour the activity, there is no expansion predicted by 2030 (FAO 2018).

This situation motivated the development of this research, whose aim is to identify the constraints that complicate the competitiveness (Momaya et al. 2017) of pisciculture developed in the Brazilian Amazon region. From the theory of constraints, the study first maps the production chain in order to answer three questions proposed by Goldratt (1990): (1) "What to change?", (2) "What to change to?" and (3) "How to cause the change?".

Then, the process begins with the identification of a set of undesirable effects (UDEs), i.e. symptoms of a system to be improved. A current reality tree (CRT) connects various UDEs systematically by following the effect–cause–effect diagramming principles and diagnoses what in the system needs to be changed, i.e. what is the core problem (Gupta 2003; Elias 2019).

The contributions applied to this study are geared towards the development of a competitive production chain with the potential to generate employment and income in the Brazilian Amazon region. The development of activities aimed at the production of subproducts should enhance other production chains, such as livestock feed and fashion. The adoption of best practices in sanitation should guarantee environmental protection with waste management, elimination of wastage of the fish and food safety. It is hoped that this will supply the internal and external markets, with quality products and socioenvironmental responsibility.

The academic contribution of this study is to confirm the use of the theory of constraints to identify bottlenecks in systems, pointing to the potential of this theory's application in open systems, with diverse actors, as is the case of a production chain. In this sense, the main contribution of this research is to demonstrate through a case study that:

1. A number of observed problems in market structures such as a lack of continuous supply of the determined product, lack of product in certain markets, lack of consumer knowledge about the product, lack of suitability of the product for a market, inefficient supply and demand coordination and low profitability are just symptoms originating from a few root causes;
2. There are simple solutions to apparently complex problems; however, invariably these solutions involve treatment of the root causes. The actors in a production chain can obtain a real response, by concentrating only on these main problems, instead of seeking to improve various aspects independently;
3. The theory of constraints offers a powerful way of reaching an efficient integration throughout the production chain, due to its capacity to generate solutions that benefit all stakeholders.

Correct identification of the restrictions in a system is an essential factor in making the resolution of the problems possible. Replication of the use of this theory on other production chains could orient actions to be implemented in public policy, as well as investments to be prioritised by private initiatives.

Theory of Constraints

The theory of constraints (TOC) is a management philosophy developed by Eliyahu M. Goldratt that has been unfolding since the early 1980s. Within the past 10 years, the thinking process (TP) and its set of logic tools (Goldratt 1994) have been evolving to provide a framework to help understand the existing situation, identify desirable strategies to meet goals and implement improvements within organisations (Scoggin et al. 2003).

The TOC was implemented successfully on a number of organisations, mainly in manufacturing (Eidelwein et al. 2018; de Jesus Pacheco et al. 2019; Modi et al. 2019; Urban 2019), but also notably applied to services (Aguilar-Escobar and Garrido-Vega 2016; Lewandowska-Ciszek 2018). However, the maintenance of improvements always depends on the following changes in business environments (Bauer et al. 2019).

The TOC approach to the management of change involves answering three basic questions: "What to change?", "What to change to?" and "How to cause the change?". There are many researchers working throughout the world to hone the concepts of TOC and explore the possibilities for its application (Bauer et al. 2019; Ikeziri et al. 2019) (Table 1).

The notion of a constraint is fundamental to understanding TOC and its applications. Cox et al. (2012), editors of the Theory of Constraints International Certification Organization (TOCICO) Dictionary, define constraint as the factor that ultimately limits the performance of a system or organisation. The system, in this case, is a production chain.

Table 1 Change sequence, tools and managerial utility relationships Source: Adapted Scoggin et al. (2003)

Change sequence questions	Managerial purposes
What to change?	Establish a basis for understanding system patterns that currently exist
	Identify basic conflicts, core problem(s) or the drivers for undesirable effects
	Provide entity linkages between the core problem(s) and undesirable effects
What to change to?	Validate the effectiveness of injections or proposed changes
	Identify undesirable side effects of proposed changes and their corrections
What to change to?	Identify obstacles preventing achievement of a desired course of action
	Denote necessary condition relationships involved in objective attainment
	Provide a step-by-step tactical action plan for implementation
	Communicate action rationales to others

The concept of production chains was introduced by Morvan (1985), who referred to a "chain of production" as a succession of transformative operations, separable and linked to one another to build chains of techniques and technologies. Lima et al. (2000) add that a production chain is a collection of interactive components. For Saes et al. (2014), the analysis of a production chain should approach the sequence of stages, from production to consumption.

A constraint can occur at any point and can be related to a number of factors. However, it is uncommon to have a production chain as a unit of analysis for the application of TOC. Only 7.4% of studies have this focus, showing a clear opportunity for more studies (Ikeziri et al. 2019).

The notion of "more is better" is correct only for the constraints, but is not correct for the non-constraint elements. For the non-constraints, "more is better" is correct only up to a limit, and above that limit more is worse.

The constraint can be physical or non-physical. Identification of the non-physical/intangible constraints is very important because most of the physical constraints are the result of non-physical constraints. Overcoming such constraints may not involve any or major financial investments and just by changing the relevant policies (Chaudhari and Mukhopadhyay 2003).

The next stage of analysis involves the identification of a set of undesirable effects (UDEs), that is, symptoms of a system that requires improvement. A current reality tree (CRT) connects various UDEs systematically by following the effect–cause–effect diagramming principles and diagnoses what in the system needs to be changed, i.e. what is the core problem (Gupta 2003). The evaporating cloud (EC) verbalizes the inherent conflict, surfaces the assumptions and provides a mechanism to come up with the ideas, which can be used to resolve the core problem.

This study employs a qualitative approach, allowing a deeper investigation of the studied system. It is assumed, therefore, that the restrictions on the system should be explored as a set, because the result is a new level of productivity in the whole system. In other words, the theory of constraints is a philosophy that recognises that the whole is much more than the sum of its parts and that there is a complex network of interrelations inside the system (Urban 2019).

Methodology

The methodology used was roughly based on the premises of grounded theory in that it sought to construct a theoretical based on a theme from the interaction of the researcher and the environment in analysis (Charmaz 1996). In this method, the researcher does not depart from a presupposition, instead going to the field to involve different actors, completely free of ideas that could bias or restrict the collection of information (Egan 2002).

The fieldwork was developed over six trips held between June 2018 and July 2019, totalling 47 comprehensive interviews. The first journeys in the region were essential to identify the situation problem. The trips following these were organised and directed according to the components of production chain.

Each interviewee was asked to describe their activities, commenting on their principal difficulties. Then, the same question was directed to the whole production chain in order to comment on the bottlenecks from the interviewee's point of view. Data were recorded from official industrial documents, governmental organisations and research institutes in the Amazon region.

Specialists in pisciculture at the research institutes of the Brazilian and Peruvian Amazon were also interviewed. Supporting institutions reported the actions carried out to develop the production chain in question. Representatives of governmental agencies also participated in the sample, describing the current situation and actions that could be implemented, not to mention public policies.

In dealing with links dedicated to operations, the sample included fishermen, fish farmers, refrigeration operators, feed producers and salesmen. Fishing associations, cooperatives and community leaders were interviewed to present their considerations on the possibilities for developing the chain. The collection of data in grounded theory does not have a specific duration; it continues until the researcher determines that they have reached a point of saturation (Egan 2002).

Observation of facts technique was used during visits to firms, open markets and also in following meetings between governments, private initiatives and fish producers. For Creswell and Creswell (2017), it is a way of exploring and understanding the meaning that individuals attribute to a social or human problem.

The triangulation recommended by Creswell and Creswell (2017) for the construction of links in evidence in order to increase the reliability of information gleaned in the work was implemented through interviews with a range of actors in the production chain.

The Production Chain of Fish Farming in the Brazilian Amazon

The production chain of pisciculture is composed of a sequence of phases beginning at breeding. The second phase, termed rearing, involves the growth of the animal until it reaches its ideal weight for slaughter. Actors termed "producers", regardless of the size of their production, carry out these two phases. In Brazil, pisciculture is carried out by large-scale producers with dozens of hectares of water, as well as small-scale producers engaging the whole family carry out Brazilian pisciculture.

The processing phase includes the slaughter of the animal, as well as activities like gutting, cutting and preparation of the finished product. This phase also generates the production of residues. In the case of pisciculture, the following phase pertains to the distribution and the final phase to commercialisation. The main waste products are viscera, scales and skin. Depending on the species of fish, there is variation in the quality and use of these waste products in the generation of subproducts.

Among the most common are oil and fishmeal, which are essential ingredients in cat and dog food. The scales are used for the fabrication of pharmaceuticals and some inputs to the food industry. The skin of species such as *Arapaima gigas* and tambaqui, processed by the tannery industry, are transformed into resistant leather with high potential for the fashion industry and accessories in general (Fig. 1).

The distribution link should be considered in the light of the conditions of plenty and drought that alter the landscape and logistical conditions. The high temperatures of a tropical country, combined with the large territorial extension of Brazil, also constitute challenges for the conditioning of a perishable product that requires refrigeration. Commercialisation is represented in the final chain for the link, translating market conditions influenced by legislation and tax, as well as consumption habits.

First Question: What to Change?

While the holistic vision fulfils its role of presenting a general and integrated panorama, mapping each link exposes weaknesses and orients assertive decision-making. In this sense, TOC is the science of management (Chaudhari and Mukhopadhyay 2003), because it proportions this type of individualised analysis. For Schragenheim (1998), TOC provides a way to simplify the complexity of human-based systems and still keeps the main issue and impacts under managerial control.

In this section, the scenario identified in the field research will be described and contextualised in order to respond to the first question of TOC: What to change? exactly to identify the links that could be constraints (Gupta 2003).

Brazil presents factors adjusted to the necessities of pisciculture such as the availability of rivers, availability of grain for fabrication of feed and supply of labour. However, the lack of adequate infrastructure can compromise food safety that, for this type of perishable product, requires mechanisms capable of offering transport and low-temperature storage, especially because the Amazon region experiences mostly high temperatures.

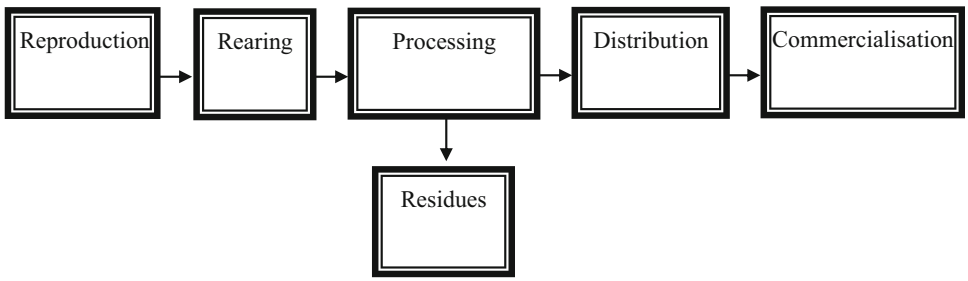

Fig. 1 Diagram for the production chain. *Source*: The authors, with research data

With the aim of discovering the quality of the product, as well as indicating good practice, Lourenço et al. (2008) study carried out a microbiological analysis of salted pirarucu commercialised in Belém-PA. The results point to the presence of bacteria in all of the samples, indicating a loss of quality of the product marked by alterations of odour and reduction in product shelf life.

Nunes et al. (2012) evaluated the microbiological and physico-chemical quality parameters in 40 samples of dried salted pirarucu on sale in the city of Belém over 12 months. The results also present unsatisfactory hygienic and sanitary conditions and consequent risk to the health of the consumer. The authors suggest standardization of the salting process and more rigour in the stages that include manipulation, storage and exposure, as well as greater control of open markets.

In Rondônia, fish farmers who keep fish in tanks encounter a serious difficulty at the moment of slaughter—it is impossible to carry out these steps because of the lack of refrigeration. There are currently two establishments in operation in the state, but they are both in vertically integrated regimes that prioritise the processing of fish raised in their own tanks.

The field research also identified the lack of refrigeration facilities in the state of Roraima, which does not have any establishments of that nature. Acre has three refrigeration facilities for beef and one for pork, while the first refrigeration facilities for fish were inaugurated in 2015.

Tocantins has 11 beef, chicken and rabbit refrigeration facilities and four for fish. However, the lack of supply of fish has led to only 50% of the installed capacity of the refrigerators. Amapá has a similar situation with two refrigeration facilities paralysed by a lack of materials and five others operating below capacity.

Such adverse conditions for producers and refrigeration operators reinforce the recommendations made by Chopra et al. (2011) about the appraisal of the success of the production chain. All of the stages should register suitable results to insure the viability of a production chain. If one or more stages fail to deliver appropriate standards, then the whole production chain underperforms. In that sense, the role of refrigeration is even more significant because, depending on the certification that it has, the processed product can receive authorisation for commercialisation in other Brazilian states or overseas.

This processing industry also has the technical capability to guarantee standardisation of the products, eliminating rudimentary practices that are still observed in all links, which compromise the shelf life of the final product. Therefore, the majority of the Amazon pisciculture production chain is conditioned towards sale in local markets, where competition for low prices due to low purchasing power predominates.

If there were refrigeration facilities with production potential appropriate for the level of supply of primary materials and to the demand of the market, the products could access more sophisticated markets where there are demanding consumers willing to place value on a quality product, whether in Brazil or abroad. Market studies in Peru have shown broad appetite for these products on international markets (FAO 2015).

It is also possible to state that there is market potential for the waste products of the fish, which as well as being ingredients for feed can drive markets interested in differentiated products, such as the exotic leather produced from the skin of the fish. For this, parallel to processing of the meat, there must be processes established dedicated to the treatment of waste products. Rendering is a process that filters, cooks and presses the residues up to the production of fish meal and oil. Tannery similarly is dedicated to the transformation of skin to leather.

Despite rendering and tannery being completely distinct activities from the routines of a refrigeration facility, there is scope for the establishment of partnerships capable of incentivising the opening of these businesses in surrounding areas. However, the field research identified that the existing refrigeration facilities do not include activities dedicated to the processing of waste products, neither are there partnerships aiming to create these links (Table 1).

The vertical integration of processing activities that are developed by a refrigeration facility, allied with the rendering and tannery industries, could raise earnings with income from valuable subproducts that, currently, are discarded in Amazonian rivers. With this, we would have the formation of a complete production chain regarding waste products (Fig. 2).

Second Question: What to Change To?

Following the Theory of Constraints, the second question should be "what to change to?", because once the weakest links are identified, they should be strengthened through good and practical solutions (Gupta 2003). The constraints found are called "undesirable effects", and the respective suggestions for relief, "evaporating cloud" (Table 2).

The low levels of fish consumption alert us to the need for companies dedicated to promoting the benefits of the product, as well as expansion of distribution and commercialisation efforts in Brazilian cities that are not surrounded by the sea or a river.

Slack et al. (2009) affirm that not all inputs from each stage are equally significant. Indeed, it is possible to attest that the bottleneck in the processing is of lower complexity to overcome when compared with the refrigeration facilities at later stages of the production chain.

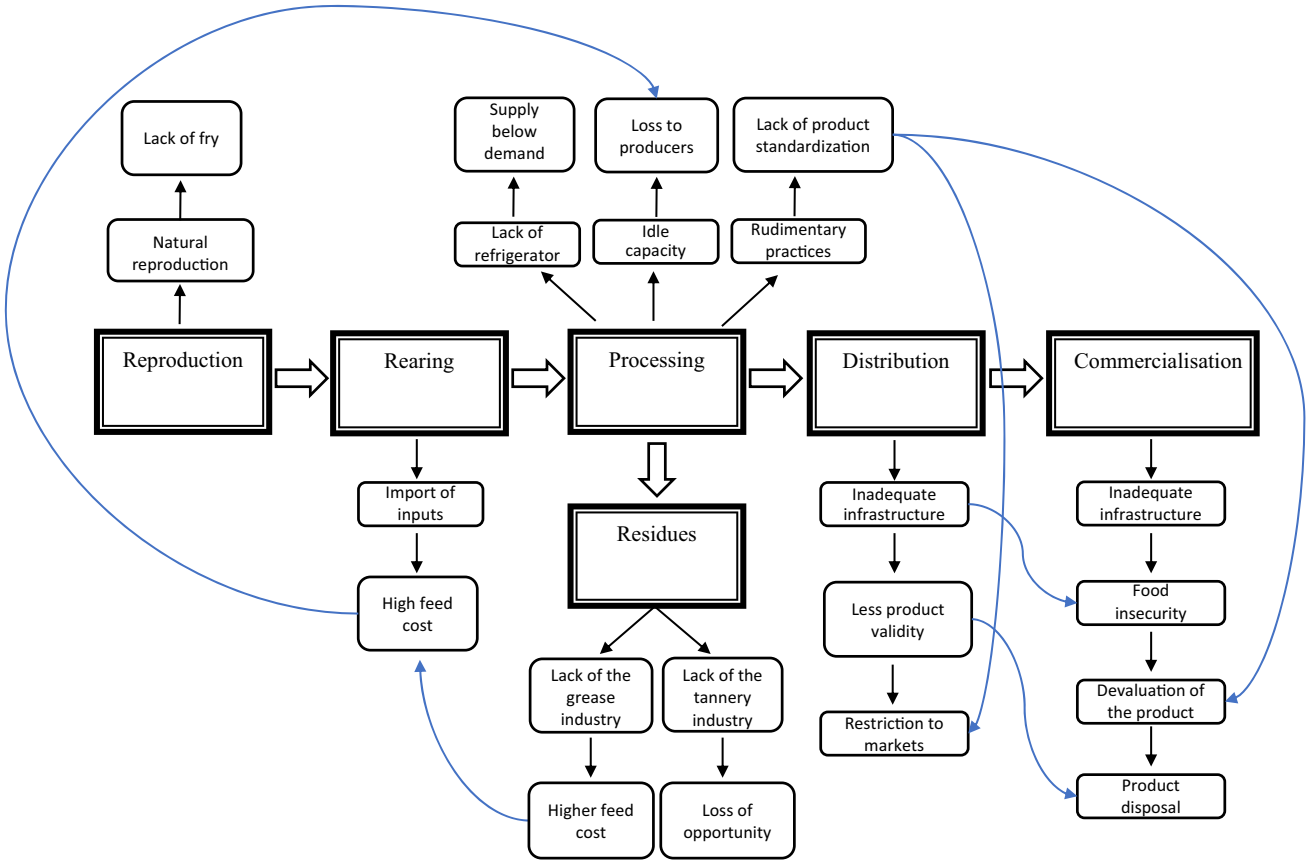

Fig. 2 Current reality tree (CRT). *Source*: The authors, with research data

Table 2 Restrictions and suggestions of relief

Undesirable effects (UDEs)	Physical and non-physical	Evaporating cloud (EC)
Low consumption of fish	Non-physical	Use of marketing tools to incentivise consumption of fish in Brazil, from recognition of its benefits to human health at all ages
Lack of refrigeration facilities for fish processing	Physical	Public policy aimed at constructing an environment capable of attracting companies to complete this link
Disposal of residues creates wasted usage of subproducts	Non-physical	Public policy to attract companies dedicated to fish oil extraction and tannery
Lack of a complete chain in the Amazon region	Physical	Incentives to install companies capable of meeting demand at all stages of the chain, especially in oil extraction and tannery

Source: The authors, with research data

However, public policy can orient investors into the need for this type of industrialisation, pointing to specific technical conditions and a map of the locations of industrial centres, target markets and paths for the flow of goods.

In the same way, it is estimated that such procedures can involve orientation for the processes of oil extraction and tannery. The study points out that the processes in current slaughter methods, inside and away from refrigeration facilities, for the most part do not include use of the waste products, although there are subproducts with broad potential usage in different production sectors such as leather in the fashion and shoe industry, scales for the chemical and cosmetic industry, viscera for the feed industry, among others. Specific credit lines and assistance for opening these markets in Brazil and abroad could also compose the set of efforts to eliminate the main constraint represented by the lack of industrialisation in pisciculture.

These efforts would guarantee a complete industry in the Brazilian Amazon region, including correlated and support activities. With this, there would be increased working

conditions and income generation, environmental protection and regional development.

Third Question: How to Cause Change?

The third question proposed by the Theory of Constraints, "how to cause change?", intends to identify the changes that should be implemented to reach the necessary changes (Gupta 2003). Beyond just presenting a panorama, this study aims to contribute with reflections capable of motivating improvement actions for the production chain of pisciculture in the Amazon region.

The Strategic Thinking Process that makes up the protocol of the TOC considers the current condition and defines actions necessary to improve the system. In that sense, this study suggests four conditioning elements for entrepreneurial action in production chains established in the Amazon region: nature, the individual, science and federal law (Table 3).

(a) *Nature:* This suggests the establishment of indicators capable of accompanying the evolution of the scenario of the natural resources used by the production chain. This way, environmental preservation will be protected and assured with a view to the sustainability of the business itself. The indicators will hopefully act as an evaluation instrument to be used by local governments, in order to be used in analyses for the renovation of fiscal incentives.

(b) *Individual:* This would reverse the logic that attributes the greatest gains to the final links of the chains, recognising that often knowledge among the local populations of the forest is the point of departure for the development of business. Therefore, the second element seeks to value the individual, in order to guarantee better living conditions for traditional communities, constructing a scenario capable of reverting the logic of deforestation and favouring its preservation with the original populations.

(c) *Science:* The third element is the construction of a science articulated among the different actors to favour the sharing of discoveries and the directioning of future studies for the densifying of knowledge. The challenge resides in the creation of a channel of communication and in a change in behaviour that comes to favour trading complementarities. The current system of measurement of performance of the academic community recognises the classification of the journal in which the research was published, but does not value the relevance or applicability of the study results. Communication between actors who develop research would also be useful to elevate the efficiency of resource allocation by institutions and governments, in order to avoid overlap and avoiding the possibility of non-coverage of a link in the chain.

(d) *Legislation:* The fourth element is the importance of public policy in the development of a sector, orienting the individuals about the obligatory and prohibited procedures, as well as offering orientation and legal security to investors, thirsty for clear regulations, followed by organised controls. Such an environment does not only ensure the absence of exploitative practices that steal resources from the Amazon individual (what pertains to the *Individual* element), as well as guaranteeing good practices of environmental protection (pertaining to *Nature*).

Transition Trees (TTs)

In the final stage, Theory of Constraints proposes transition trees (TT) with a plan of action indicating the step-by-step for the implementation of changes (Scoggin et al. 2003). In this sense, the four parameters and their respective actions are detailed with their respective expected results (Fig. 3).

Action 1: Development of New Businesses

The detailed study of the links in the production chain of pisciculture reveals opportunities for new businesses. The main constraining link is processing, with potential to establish new productive units in a number of Brazilian states. Such leverage should follow standards capable of guaranteeing certification and food safety, for both the domestic and export markets.

Table 3 Strategic thinking process

Parameter	Action	Objective
Nature	Indicators to monitor natural resources	Environmental protection
Individual	Valuing local knowledge	Income generation and development
Science	Strategy and densification of knowledge	Scientific and technological revolution
Legislation	Public policy for investors and incentives for local production	Investor attraction and development of complete chains

Source: the authors, with research data

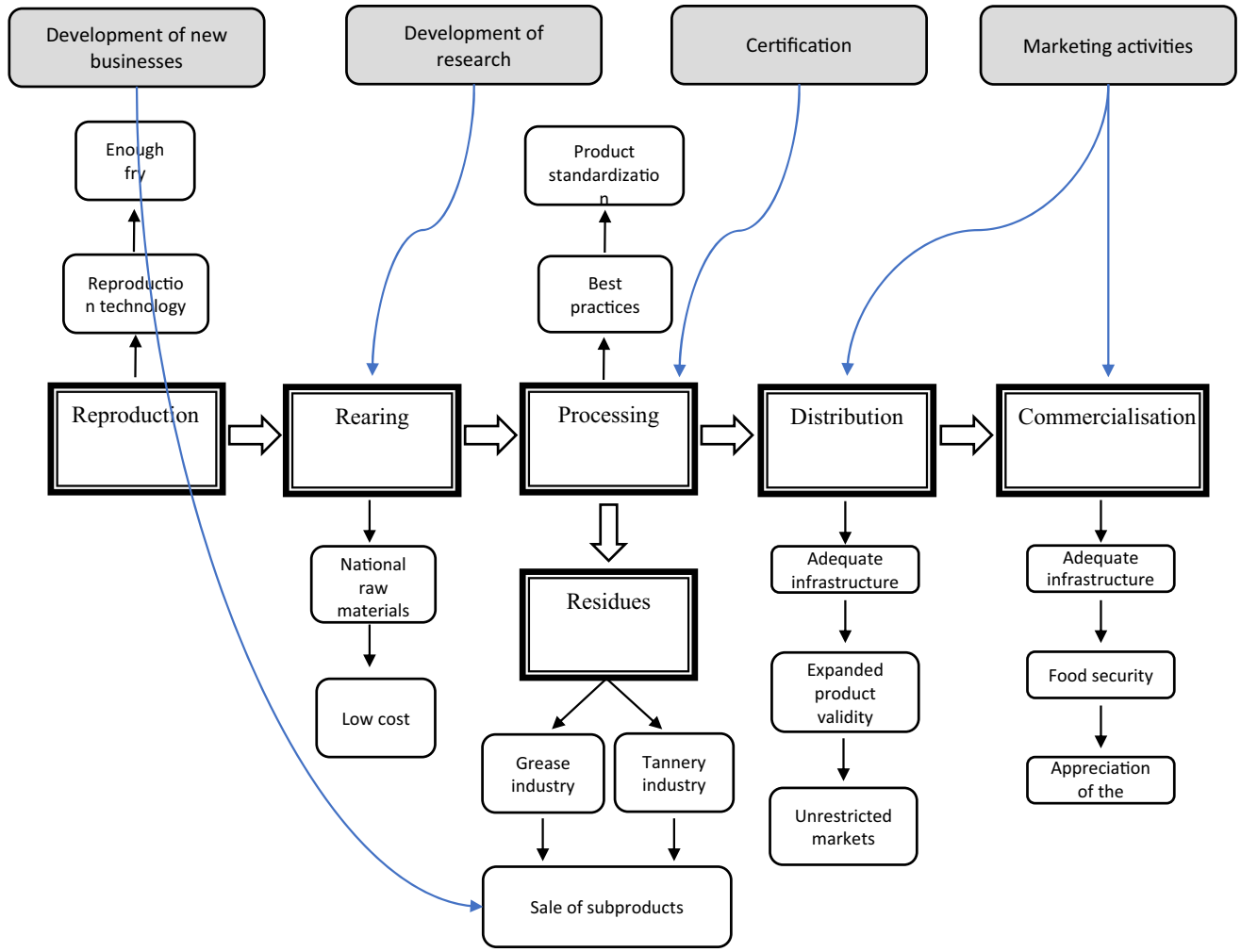

Fig. 3 Transition tree (TT). *Source*: The authors, with research data

The gain in scale will be able to raise the volume of inputs for fabrication of subproducts, mainly from the oil extraction and tannery industries. The processing of residues associated with vertical integration for animal feed can reduce the value of the feed and, as a consequence, the cost of production.

Therefore, for the producer, cost reduction is assured, as well as increased income from the expansion of business with the sale of subproducts, ending the exclusive dependence on the sale of fish.

Action 2: Development of a Certification for Companies and Products in the Brazilian Amazon

The development of a competitive fishery production chain that is able to supply national territory and exploit export markets should support itself with auditable criteria. This improves production practices throughout the entire organisation. Certification, established on auditable criteria, would require traceability, food safety and animal well-being to align with international standards in order to make export viable. Environmental impacts must be monitored, as well as the social indicators that must accompany the evolution of local development. In addition, international standards must be respected in order to facilitate the export of products.

Action 3: National Integration and International Partnerships for the Development of Research on Production Chains in the Amazon Region

It is suggested that the development of research on the Amazon region should be guided by national calls, able to attract researchers from other states to act in partnership with local researchers. In the same sense, participation of foreign researchers should be incentivised, whether from countries which also have an Amazon biome or not.

The research themes should go through prioritisation criteria oriented by a national alignment that would substitute the current situation where each institution chooses

its research priorities. In dealing with production chains, a survey of the regional products that lack studies is suggested, in order to establish an agenda of actions to be developed.

In dealing with the results of research, as well as publications in communication channels used by the scientific community, the results should be widely promoted to regional actors in order for them to benefit from the reflections and conclusions of the studies.

Action 4: Marketing Activities

The promotion of the benefits of a diet rich in fish should stimulate consumption, especially in non-coastal cities where there is no habit for eating this product. The differentiation of fish species for different dishes that can be prepared should provide recognition and willingness to pay higher value in products with less fat content and free of bones, for example.

Efforts must also prioritize the social benefits and environmental preservation achieved throughout the production chain, ensuring information and the possibility of tracking products. In this sense, certification seals and the presence in foreign markets attest to the good quality and leverage new opportunities.

Finally, the dissemination of fish by-products will attract consumers and the revenue will no longer be exclusively from the sale of meat.

Conclusions and Final Considerations

The scenario found in the field research points to the lack of refrigeration facilities in sufficient quantity and capacity in fish-producing regions in the Brazilian Amazon. The lack of public policy aimed at the development of this production chain has wasted competitive advantages, in addition to generating losses for local producers. The recommendations presented in this study also deal with the use and improvement in waste products.

The interviews demonstrated that the results achieved are commonly shared; however, sharing the techniques adopted only occurs in cases of pre-established partnerships for the development of the research. Likewise, there is a lack of research with systemic analysis, necessary for the development of the competitiveness of the production chain, from the initial links to the aspects related to distribution and commercialisation that make up the final stages.

It has been proven that the lack of a properly organised production chain can cause serious damage to certain links, while other members take advantage of opportunistic actions to increase their profit margins. Likewise, the absence of a complete production chain prevents the value generated in the region from being retained.

The set of actions dedicated to the chain is concentrated predominantly in the initial links of the production chain, out of step with the efforts attributed to the final links. In view of the expertise developed in decades of operation, it is suggested that institutions share their efforts in order to offer service to all links in the production chain, correcting the current gaps in the intermediate and final links.

In this sense, TOC proved to be valid for mapping links and identifying restrictions. The following steps express the improvement actions and the implementation plan, also adjusted to reality. Thus, the methodology should be replicated in other production chains, especially in countries with favourable natural conditions for agricultural production and still in need of processing industries.

The academic contributions were reached when validating the use of TOC for analysis of the constraints on open systems, such as production chains. In the same way, the range of problems arising from a few constraints was shown, in other words, those arising from a few root causes. Concentrating on them, it is possible to obtain responses that impact positively on a number of links of the production chain.

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Key Questions

1. In this context, what are the restrictions that hinder the success of the fish production chain in the Brazilian Amazon?

Gleriani Torres Carbone Ferreira PhD in administration from Universidade de São Paulo (USP). She develops research related to the mapping and evaluation of production chains, as well as analysis and design of business managemnt indicators.

Jacques Marcovitch Professor at the Universidade de São Paulo (USP) dedicated to the study of business pioneers, strategy, and innovation with a focus on economic growth. Master of management from Vanderbilt University (USA), doctor of administration at FEA/USP and postdoctorat at the International Management Institute (Switzerland).

Mauricio Jucá de Queiroz PhD in administration at the Universidade de São Paulo (2008). Is currently the Professor of the Professional Masters and Director General at FIA Business School.