REPORT ON THE INTEGRATED EVENT-DRIVEN FRAMEWORK FOR DATA COLLECTION

PROJECT
REPORT
D4.1

VALUMICS - UNDERSTANDING FOOD VALUE CHAINS AND NETWORK DYNAMICS

NOVEMBER 2018

VALUMICS
Food Systems Dynamics

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ABOUT

VALUMICS stands for value chain dynamics and is a research project funded by the EU H2020 programme. VALUMICS will enable decision makers to evaluate policy impact on food value chains

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VALUMICS

Understanding food value chains and network dynamics

Start date of project: 01/06/2017 **Duration: 48 Months**

VALUMICS Internal Project Report

Deliverable 4.1

Report on the integrated event-driven framework for data collection

Food Systems Dynamics

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SUMMARY

This report Del.4.1 *Report on integrated event-driven framework for data collection* is a deliverable for Task 4.2 and presents the event-driven methodology framework for process mapping and data collection for case studies. In this report, the salmon case study is used to demonstrate the methodology and model the different stages of salmon value chain in Norway. The technique presented in this document can be used to integrate key value chain indicators such as the product, process and sustainability data. This report also identifies the decisions made at different levels such as company, sector, national, EU to regulate the food value chain and optimise the production. The applications of the EPC model is further described in this report and specific examples on how the data availability and gaps can be identified are provided.

GOALS

The goal of this deliverable is to present the methodology of Event-based process chain to understand the functioning of the selected case studies in the VALUMICS project and to identify the factors that affect decisions in the value chain. This report also aims to provide a framework for collection of data required in the various tasks in work package 2, 4 and 5.

METHODS

The modelling technique Event-based process chain has been applied in this report to develop a model for salmon value chain. Development of the model for different stages of salmon production is based on secondary data and semi structured interviews with the industry. The application of EPC in data collection process and modelling work in other work packages in VALUMICS has been collaboratively defined by some work package leaders and task leaders in the project. Several bilateral meetings were arranged with the partners to facilitate this process.

MAIN OUTCOMES

EPC models for the salmon value chain for all stages including feed production, juvenile production, grow-out/farming, processing and distribution.

Outline of most important factors that influence the decision of value chain actors.

A framework for identifying data availability, gaps and requirements for the tasks in other work packages in the project.

NEXT STEPS

By using the EPC models for salmon value chain as an example, similar models will be developed for the other case studies selected in the VALUMICS project. It is expected that each case study will be different in nature and hence the EPC models for all case studies will have variations depending on the information available to model, production method and data needs.

1. INTRODUCTION

The VALUMICS project is based on a holistic systematic approach. A system dynamics methodology is implemented as a key driver of the overall project work. The project structure is highly integrated and trans-disciplinary drawing on the expertise of internal and external stakeholders. Case studies on different food chains are an integral part of the VALUMICS project.

WP4 on food system case studies groundwork focuses on prioritisation of the selected food system groups and case studies to be worked on, and defining a set of primary and secondary data for a series of food system chains needed for the causality analysis identified in WP2, and use the data sources to provide design parameters for the quantitative model to be developed and coded in WP7. The approach involves mapping of the value-, supply- and decision chains for each case study and data collection related to specific parts of the chain.

This document is a deliverable for Task 4.2 and presents the event-driven methodology framework for process mapping and data collection. The salmon case study is used to demonstrate the methodology. The event-based technique presented in this document can be used to integrate key value chain indicators such as the product, process and sustainability data. Each key indicator can be linked to a specific supply chain resource and event (e.g. raw material acquisition, processing, transport, storage, distribution, etc.).

This report also presents a detailed process map of the salmon supply chain which is a good starting point to understand the functioning of the chain and indicate the external factors like regulations, environmental factors, trade tarrifs and market that influence the value chain.

2. METHODOLOGY

Event-based process chains (EPC) is a process modelling technique used for modelling, analysing and redesigning business processes. An Event-driven Process Chain is a semiformal, graphical modelling technique which was developed by G. Keller, M. Nüttgens, and A.-W. Scheer in 1992 for a research project of the SAP AG but widely accepted and used by many companies for modelling, analysing, and redesigning business processes today[1].

The language is used to describe processes at the level of their business logic and easy to understand and use by end users. In addition, the same EPC models can be used for the requirements definition of an information system.

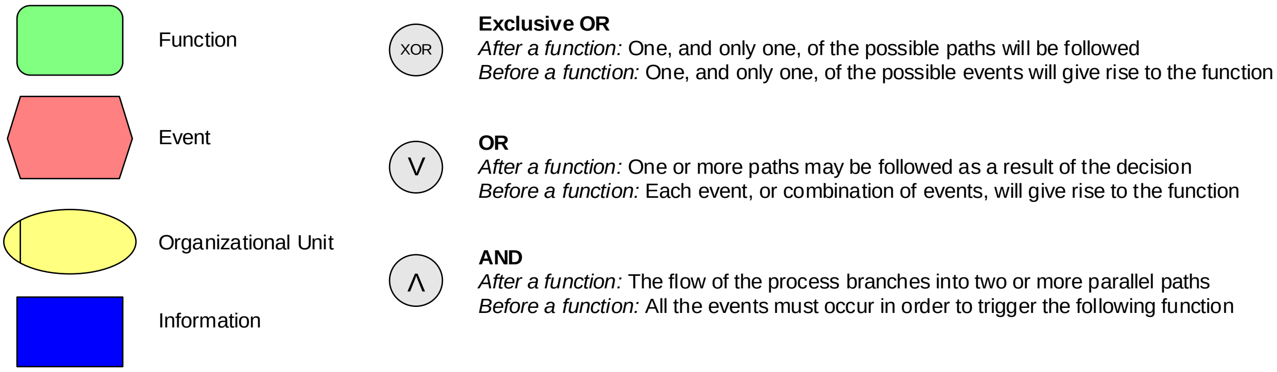
EPC method was developed within the framework of Architecture of Integrated Information Systems (ARIS) which is an enterprise modelling approach.

An EPC consists of different elements to graphically display process flows which are explained as following:

- **Function:** Functions are active elements (processes) and describe a task or activity within the company. They transform input to output data – from an initial state to a resulting state. Furthermore, they can be refined into other EPCs down to elementary functions. They are labelled by − [verb in infinitive]+[topic/object], e.g. “Order the material”.

- **Events:** Events are passive elements and represent occurred economical or technical states. They trigger functions and describe under which circumstances a function works or which state the function results in. There are two kinds of events:
  Activating event, labelled by
    − [topic/object]+”is to be”+[past participle],
    e.g. “The material is to be ordered”
  Final event, labelled by
    − [topic/object]+(“was”+)[past participle],
    e.g. “Material (was) ordered”
- **Control flows:** A control flow connects functions, process paths or logical connectors creating a sequence and interdependencies.
- **Logical connectors:** Connectors can be used to connect activities and events. In this way, the control flow is specified and they can be used to split the control flow from to two or more flows or to combine two or more flows into one control flow. There are three types of connectors: Λ (and), XOR (exclusive or) and V (or).
- **Organization unit:** Organization unit is used to describe which organization is responsible for a specific function.
- **Information:** Information refers to information, material or resources connected to a function.
- **Information flow:** Information flows show the connection between functions and input or output data.

The various EPC elements are described in Figure 1.



Exclusive OR
After a function: One, and only one, of the possible paths will be followed
Before a function: One, and only one, of the possible events will give rise to the function

OR
After a function: One or more paths may be followed as a result of the decision
Before a function: Each event, or combination of events, will give rise to the function

AND
After a function: The flow of the process branches into two or more parallel paths
Before a function: All the events must occur in order to trigger the following function

Figure 1: Elements of the Event-driven Process Chains

2.1 EPC EXAMPLES

No standardized procedure exists for producing EPC models, but Scheer, Thomas, and Adam (2005, pp. 136{137) describe a set of steps that help create EPC in a structured manner:

i. Define a unique title of the business process, to make clear which process is modelled.
ii. Derive initial and final events from the process title.
iii. Look for relevant verbs in the process description, translate them to a function flow, consisting of functions, logical connectors and process interfaces where applicable. The elements should be arranged in the order they are executed in. Where necessary, add logical connectors to split or join the execution.
iv. For each transition between two functions, define one or more events in such way that the preceding function produces the event, and the event triggers the next event.
v. Verify the model for structural correctness and perform validation with key stakeholders in the process.

EPC represents a sequence of events and is used to specify temporal and logical relationships between activities of a business process. It is very useful in capturing other elements of a process such as process outcome, information outcome, key performance indicators, etc.

The following examples demonstrate the functionality of the EPC technique. Figure 2 illustrates a simple EPC model for checking the feasibility of a received customer order while Figure 3 illustrates an EPC model for checking the quality of a received shipment which uses a logical connector to divide a process into alternative flows.

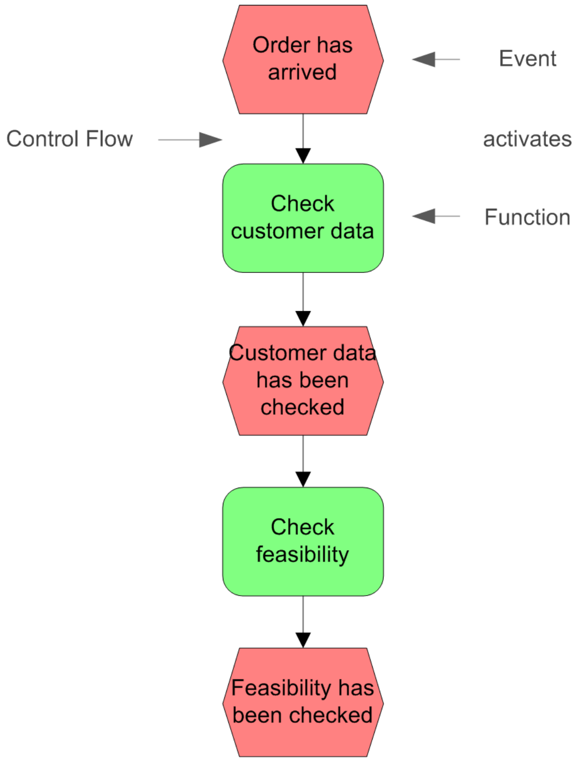


Figure 2: A simple EPC model

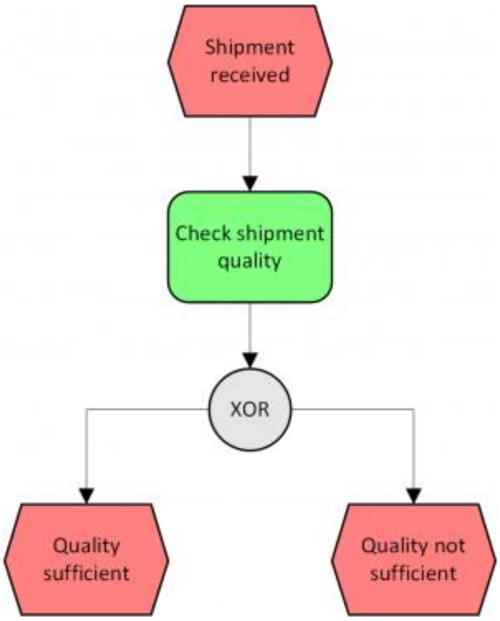


Figure 3: EPC model with alternative flows

2.2 EXTENDED EPC (eEPC)

EPC models can be extended to describe the entire organization and not only single business processes. In the VALUMICS project, we use the eEPC methodology to describe the entire food supply chain system, decision rules linked to different events and processes and connect additional elements such as information objects such as input and output data. An example of eEPC is shown in Figure 4.

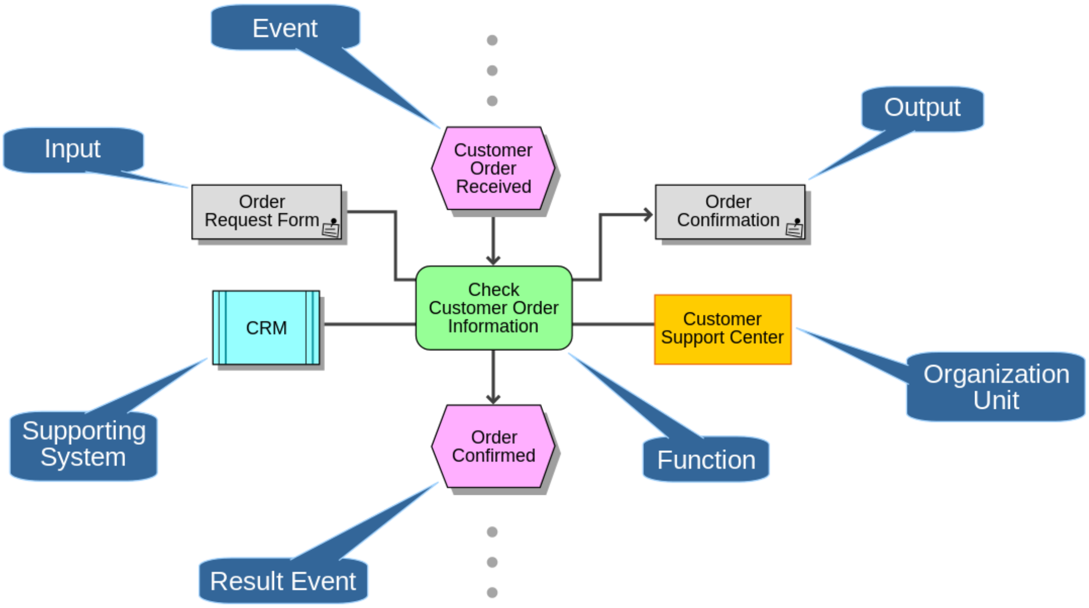


Figure 4: eEPC model with additional elements[2]

The salmon supply chain is used to illustrate the application of extended EPC methodology in the VALUMICS project for mapping of the supply chain, mapping of decision rules and identification of points for data collection.

2.3 DATA COLLECTION FOR SALMON CASE STUDY

The EPC models for all stages of the Salmon supply chain are based on secondary data, literature and semi structured interviews with the industry. During the development of the EPC models, semi structured interviews were set with a feed producer company and asalmon farming and processing company. National statistics and export statistics by the Norwegian Seafood Council have also been used to model the distribution stage of the salmon supply chain.

3. SALMON CASE STUDY

3.1 DESCRIPTION

The Food and Agricultural Organization of the United Nations (FAO) projects that, within 2050, 70% more food must be produced globally to meet increasing demand[3]. Aquaculture is considered an important part of the solution. According to the World bank by 2030, 62% of all seafood consumed will be farm raised. The Norwegian aquaculture industry has witnessed a tremendous development through recent years, with a total revenue growth of more than 200% for the last 10 years. Prices have increased, continuously following the growing demand in existing markets and evolvement of new markets[4]. About 70% of the world's salmon production is farmed. Most farmed salmon come from Norway, Chile, Scotland and Canada. The total freshwater production cycle takes approximately 10-16 months (juvenile production) with the seawater production cycle (grow-out phase) lasting around 14-24 months, giving a total cycle length of 24-40 months[5].

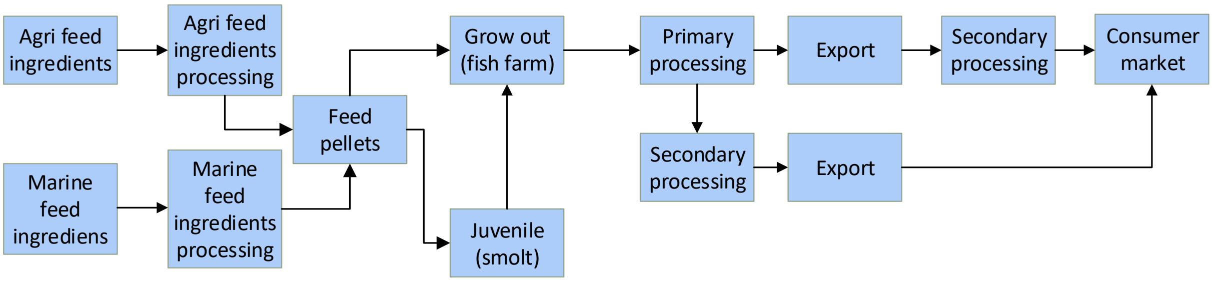


Figure 5: Atlantic-salmon supply chain

The Atlantic-salmon supply chain truly represents a global food system with a complex logistics network taking feed inputs from one part of the world and distributing products to different parts of the world after processing them in various locations. For instance, the Norwegian salmon industry sources feed ingredients from crops and marine systems worldwide and supplies products to various markets including Europe, Asia and America. Some of the secondary processing is carried out in hub markets Poland and France that re-export to other EU countries. Thus, salmon feed and subsequently the salmon product are associated with a wide range of environmental impacts on many ecosystems and with other social and environmental conflicts.

Salmon production has gone through major changes over the past decades in terms of dependence on feed. From 1990 to 2012, the share of vegetable ingredients increased from less than 10% to 67%[6]. The corresponding reduction in the share of marine ingredients has reduced the impact on marine ecosystems, per unit of salmon produced, but shifted environmental burdens to terrestrial ecosystems. Salmon aquaculture is also heavily influenced by political decisions in terms of regulation of where farm sites and slaughter plants are located and legislation regarding feeds and medication (antibiotic use)[7]. In addition, there are indications that the various megatrends such as *empowered customers, health reimagined, resourceful plant and urban world* will affect the global aquaculture industry[2].

The complexity of the supply chain, combined with environmental, socio-economic, regulatory and market considerations, makes Atlantic-salmon a perfect case study for the VALUMICS project.

3.2 MAPPING USING EEPC

The first stage is to study the AS-IS situation for the salmon supply chain system. The AS-IS model was developing with the eEPC methodology. The salmon farming production cycle lasts about 3 years. The first year of production takes place in controlled freshwater environments, and then the farmed salmon is transported to seawater cages. Once the farmed salmon reach a harvestable size, it is transported to processing plants to be prepared for sale. For consumers, most farmed salmon is sold as salmon fillets, although the whole fish is sold in some markets[8]. The production cycle for atlantic salmon is shown in Figure 6.

The following stages of the Norwegian salmon supply chain were mapped using the eEPC methodology:

- Feed production
- Juvenile production
- Grow-out phase
- Primary processing
- Secondary processing
- Distribution

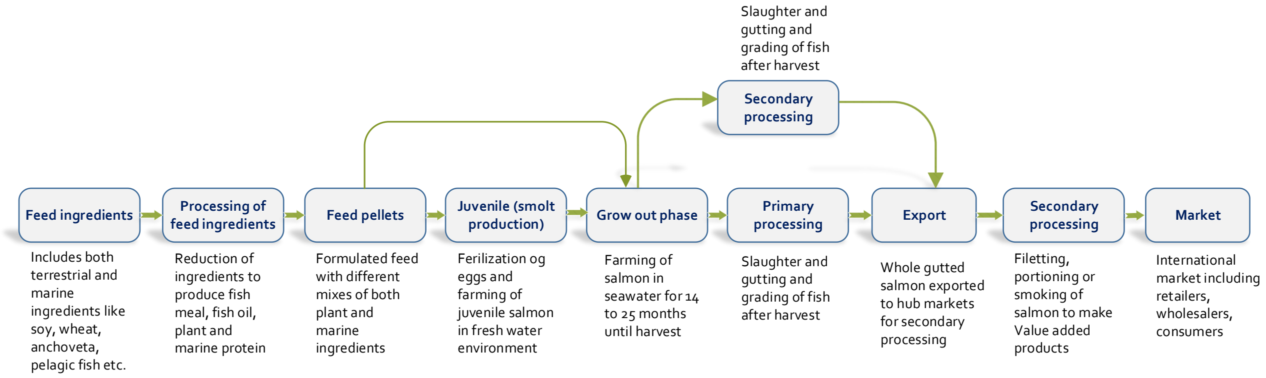


Figure 6: Atlantic-salmon production cycle[5]

3.2.1 Feed production

Salmon feed is produced from a mix of plant based and marine based ingredients such as anchoveta, fish oil, fish meal, soy protein, plant oils and other additives. The feed is formulated based on nutritional requirements of salmon and palatability[9]. Feed pellets are produced in different sizes and quality depending on the growth phase of the fish. Benchmark nutritional information is specific to each company and species. Inventory levels are generally held at a bare minimum but can be increased with number of custom orders[13].The raw materials for feed production are procured from approved suppliers mostly based in South America, Asia and Norway[10]. Regular on-site audits and desktop audits are conducted to evaluate the suppliers[13]. At the feed production plant all the ingredients are blended and extruded as pellets. In case where quality of ingredient is not satisfactory, the ingredient can be blended in small quantities or is completely eliminated. These pellets are transported to sea to the farming sites by barges. The pellets are either carried in bulk or individual bags depending on the order. The farming sites have their own storage for feed, varying in its capacity. For bulk orders the pellets are often transfered to the silos at farming sites mechanically while for smaller order, individual bags are manually transfered[13]. The feed stock at the farming sites is replenished every week or every other week depending on the season. Figure 7 describes the feed production process.

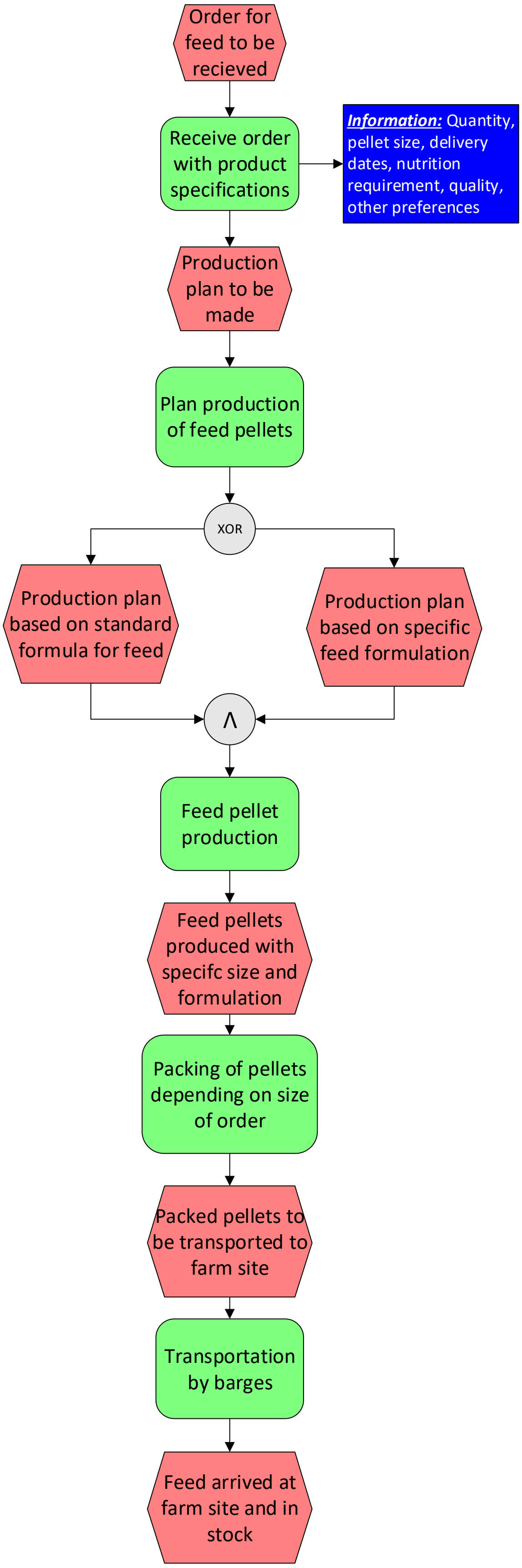


Figure 7: EPC for feed production

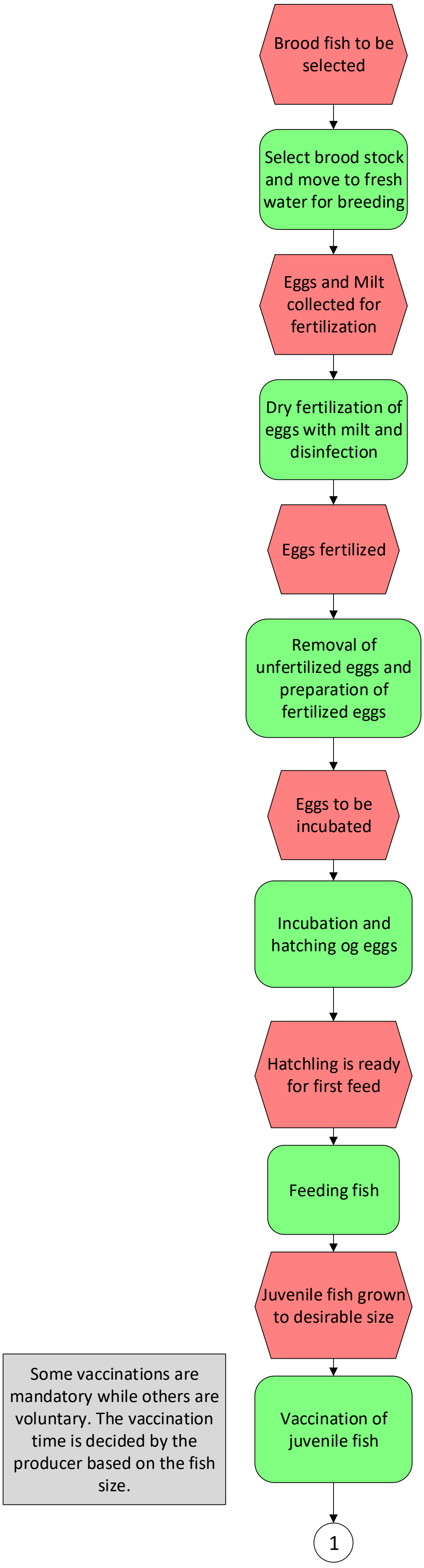
The EPC models represent various decision points in the chain and the decision rules related to the feed supply chain are decribed in Table 1.

Table 1. Decisions related to the feed production stage of salmon value chain

Decision	Corresponding regulation (if any)	Description	Decision Level	Cost/Profit
Benchmarking nutritional content of feed		The benchmarking of minimum nutritional values of the feed is company specific and forms the basis for the different feed quality levels that are available in the company catalog	Company and batch specific	N/A
Selection of feed ingredients		The selection of ingredients is based on the following criteria[11]: - Palatibility of feed ingredient - Regulations regarding fish feed - Price - Availability - Safety and reliability - Consumer perception about new ingredients - Environmental efficiency	Company and country specific	The decision at this stage affect the price of the feed
GMO policy for feed ingredients	Regulation on feed products, Ministry of Trade, Industry and Fisheries[12]	The use of GMO ingredients in feed production is prohibited in Norway	National	N/A
Selection of ingredient suppliers		The selection of suppliers are based on certain requirements[13] - Approved on-site audits - Raw material portfolio - Sustainability assessment - International certifications - Stakeholder requirements (e.g. specific value of VLC Omega-3s, consumer perception, etc.)	Company specific	The selection and evaluation of suppliers is an added cost to the feed producer.
Pellet-production planning		The production planning is done based on forecast on volumes and type of feed for next production cycle as well as seasonal variability in consumption of feed[13]	Company specific	N/A

3.2.2 Juvenile production

The juvenile production of salmon is carried out on land and starts with eggs from a brood stock that is specially maintained for egg production. The brood stock is thoroughly selected based on the resistance to diseases and parasites as well as overall quality of fish[15]. The eggs and milt are collected from the brood stock and eggs are fertilized in a controlled environment. The eggs are then incubated until they hatch. After hatching the salmon grows through its different freshwater development stages until it is achieves desired size (ca. 100g) and is ready for migration to the sea. It is then made to go through a physical transformation to be able to survive in salt water and the transformed fish is called smolt. This process is referred to as smoltification where the body shape alters and its ability to regulate salt level changes[16]. When the smolt is ready, it is distributed either by land or sea to the farms where it grows further until it is harvested for slaughter. The transportation to the farm sites on sea is carried out by well boats. The process from producing smolt from egg takes up to 10 -16 months[20]. Figure 8 describes the juvenile production phase and transport of juvenile to sea.


Brood fish to be selected
Select brood stock and move to fresh water for breeding
Eggs and Milt collected for fertilization
Dry fertilization of eggs with milt and disinfection
Eggs fertilized
Removal of unfertilized eggs and preparation of fertilized eggs
Eggs to be incubated
Incubation and hatching og eggs
Hatchling is ready for first feed
Feeding fish
Juvenile fish grown to desirable size
Some vaccinations are mandatory while others are voluntary. The vaccination time is decided by the producer based on the fish size.
Vaccination of juvenile fish
1

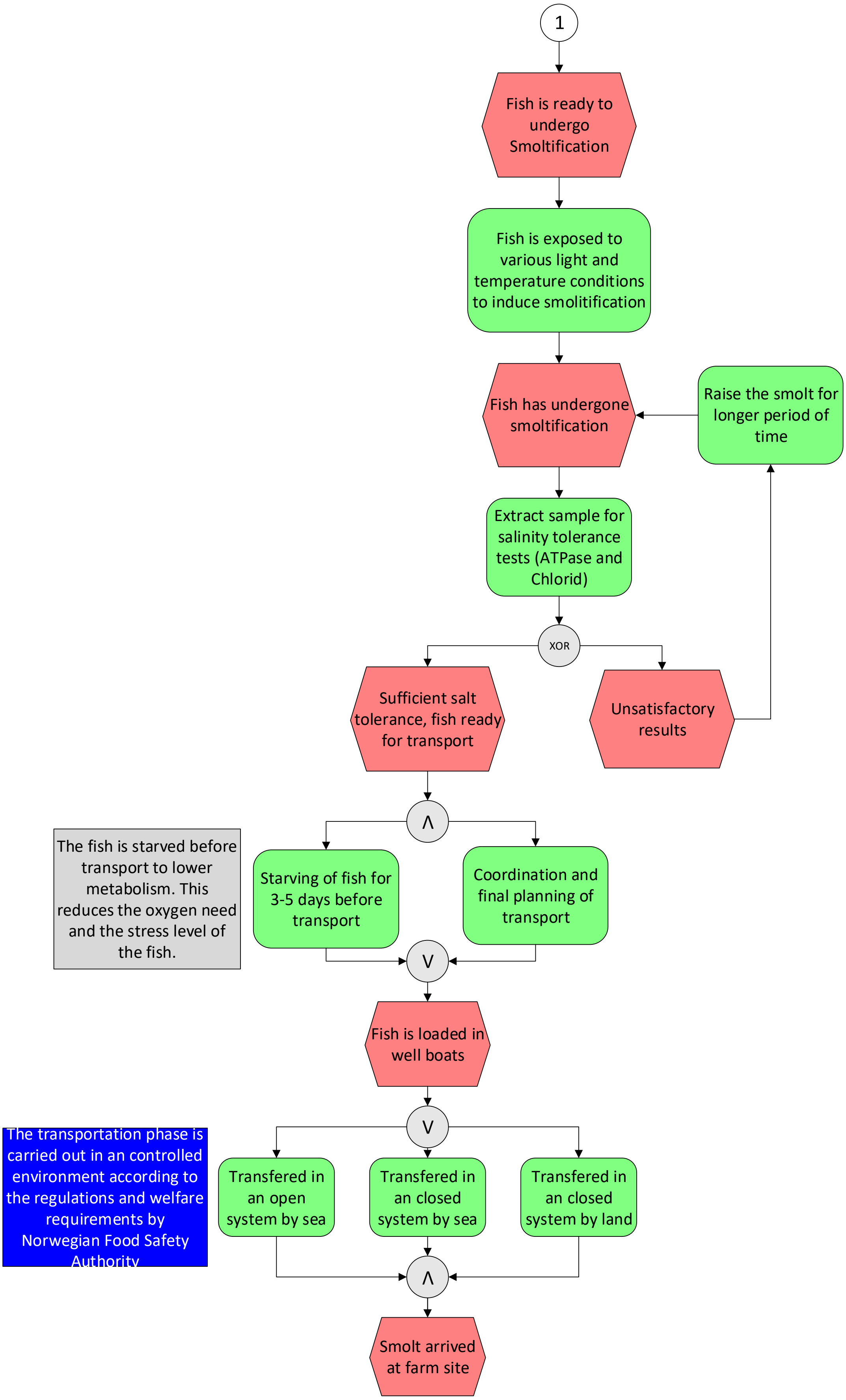


Figure 8: EPC for juvenile production

The EPC diagram illustrates various decision points in the chain and there are several decision rules that affect the juvenile production phase.The important decision rules related to the this phase are described in the Table 2.

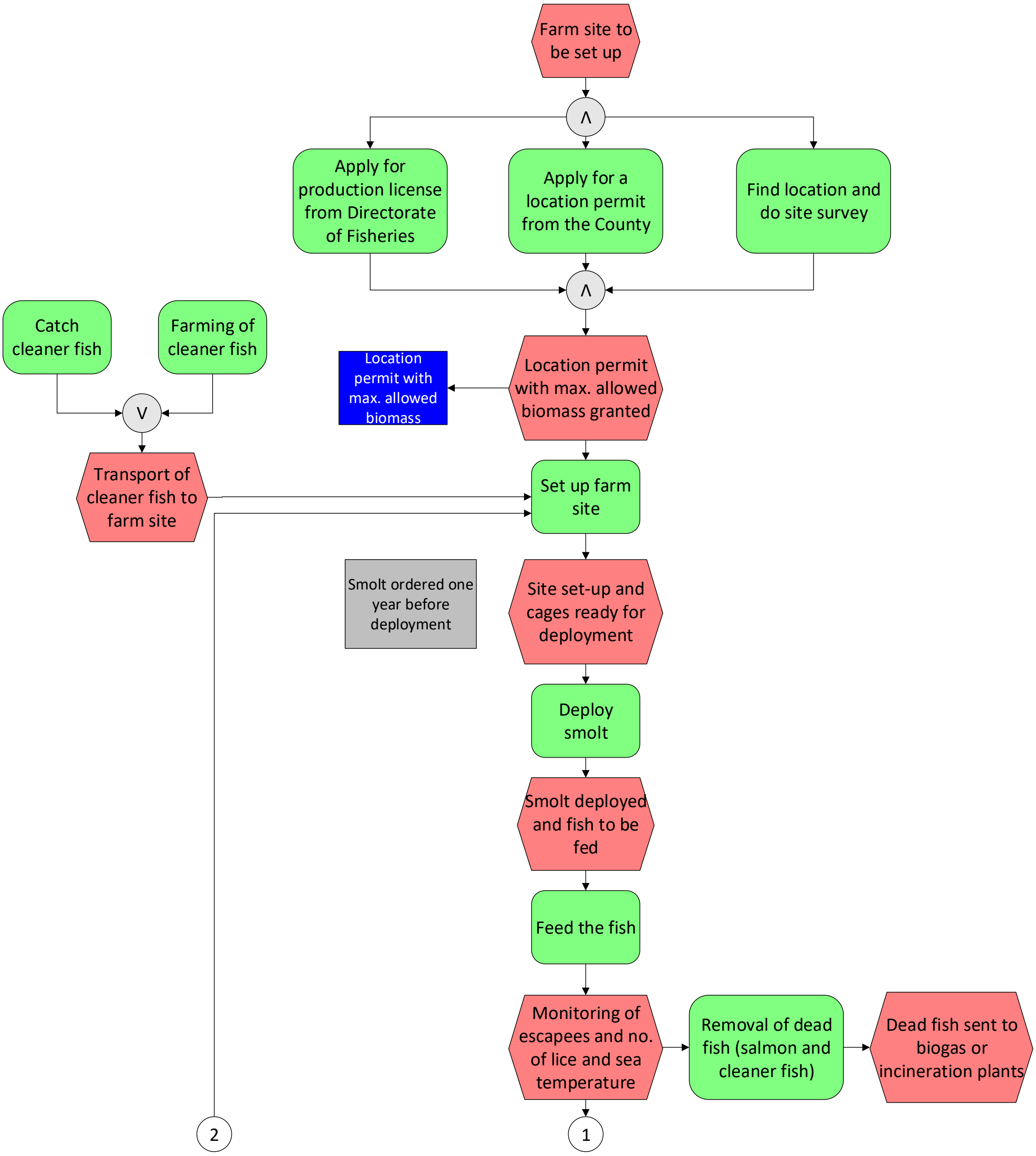
Table 2. Decisions related to the juvenile production stage of salmon value chain

Decision	Description	Decision Level	Cost/Profit
Maximun allowed biomass	Regulatory limitations on the no. of smolt that can be produced per unit and per county[14].	National level	This regulatory decision limits the company's will to increase production
Selection of brood stock	The brood stock used for egg production is genetically selected based on several criteria to produce a robust and optimal quality salmon[15]: - Growth rate - Weight and physical appearance - Virus and disease resistance - Immune response to vaccines	Company specific	N/A
Production planning and growth parameters	The juvenile salmon production is controlled by several parameters to ensure optimum growth and delivery of smolt on time irrespective of seasons. - Source of brood stock (harvest from offshore/onshore farms)[15] - Photoperiod and use of light to enhance growth[16] - Feed requirements and quality of feed[17]	Company and batch specific	N/A
Smolitification	To optimise the delivery time of smolt to farmers, a combination of Photoperiod exposure, light and temperature parameters are used to induce early smoltification or delay smoltification.	Company specific	The decisions at this stage can affect the profit if any big losses occur during the Smolitification.
Vaccination	The vaccination strategy varies at company level. However, according to mandatory requirments all smolt shall be vaccinated against furunkulose, vibriose and cold water vibriose. Additional vaccination can be done if there are site specific or company specific requirements[18].	National, company and site specific	This is a cost to the company
Transport of smolt to farm site	The transport method of the smolt from nursery to fish farm is decided based on the following considerations:	Governmental & Batch	The decisions at this stage can affect the

	- Regulations on transport of Aquaculture animals[19] - Land or sea based - Open or closed system - Time frame - Cost - Weather conditions - Biomass count - Heath status - Route	specific & company	profit if any big losses occur during the transportation to seawater.
Deployment of Smolt	The deployment of smolt to the farm site is a critical stage that required coordination between the smolt producers and farmers. The factors that can affect decisions in this process are[20]: - Weight of smolt - Deviation in delivery time and date - Maximum allowed weight of smolt being 250g[14] - Seasonal changes and weather conditions - Losses due to desmoltification	Company specific	The decisions at this stage can affect the profit if any big losses occur during the deployment of smolt in seawater

3.2.3 Grow-out phase

In Norway, three types of production licenses can be granted that include Regular Concession, Development Concession or Green Concession[21]. Smolt is ordered one year before deployment and the grow-out phase takes place in seawater and lasts for 14-25 months. Once the smolt is deployed in the net pens in the sea, the fish is regularly monitored and fed according to the requirement and growing conditions. The fish population is also controlled and examined for disease outbreaks and lice attacks. Regular monitoring and registration of any escapees is mandatory according to the Regulation on Control of Sea Lice in Aquaculture[26]. In case of lice or diseases, the fish is treated by different methods including biological, chemical or thermal treatment[22]. When the fish reaches the average weight over 1 kg, fish from one cage is split into two cages. The fish is fasted before harvest so as to clean the digestive tracts and reduce metabolic before transport to the slaughter house on land. The grow-out phase is described in Figure 9 starting from setting up of the farm site, deployment of smolt to harvest of fish.


Farm site to be set up
Λ
Apply for production license from Directorate of Fisheries
Apply for a location permit from the County
Find location and do site survey
Λ
Catch cleaner fish
Farming of cleaner fish
V
Location permit with max. allowed biomass
Location permit with max. allowed biomass granted
Transport of cleaner fish to farm site
Set up farm site
Smolt ordered one year before deployment
Site set-up and cages ready for deployment
Deploy smolt
Smolt deployed and fish to be fed
Feed the fish
Monitoring of escapees and no. of lice and sea temperature
Removal of dead fish (salmon and cleaner fish)
Dead fish sent to biogas or incineration plants
2
1

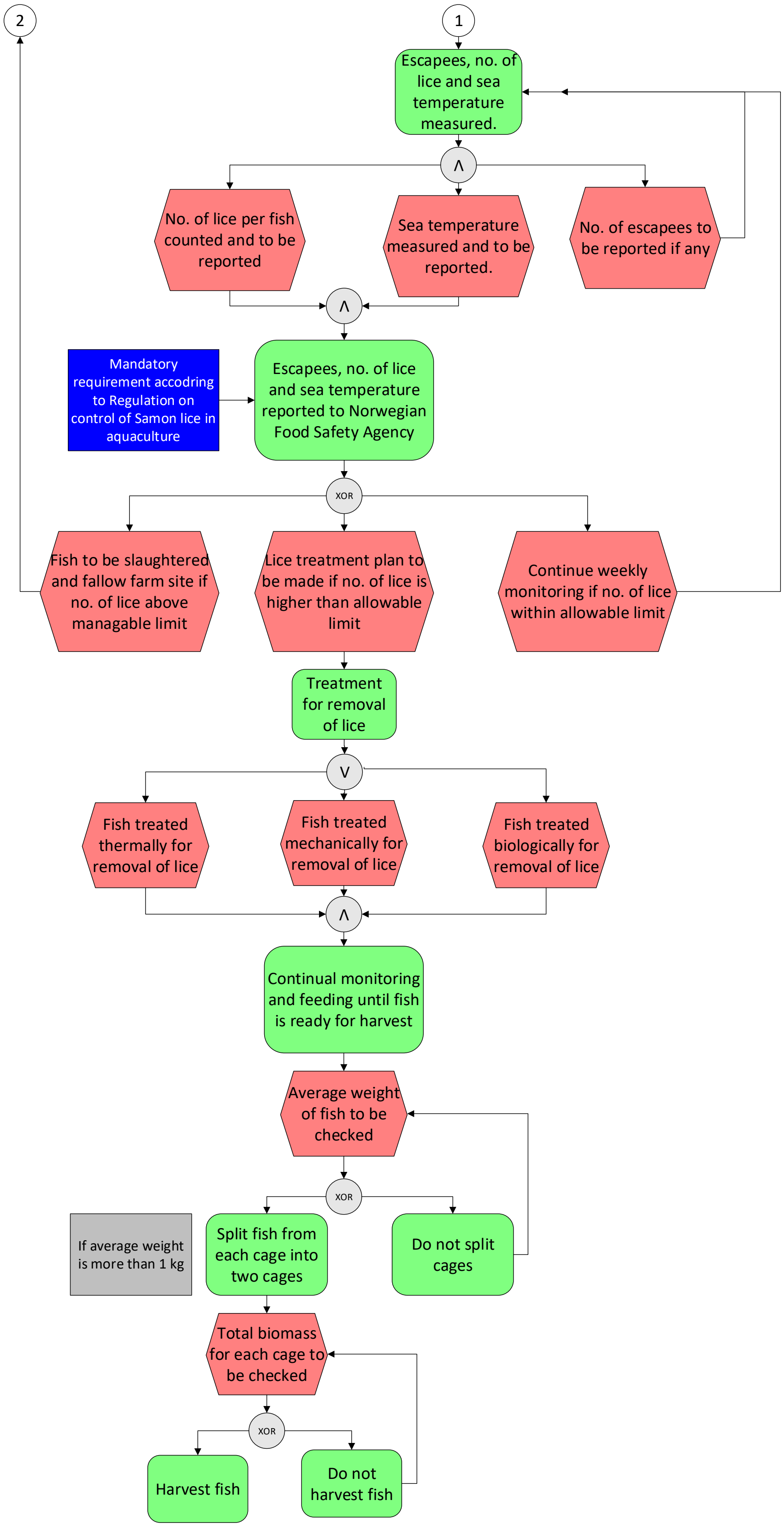


Figure 9: EPC model of the grow-out phase

The EPC diagram illustrates various decision points in the chain and there are several decision rules that affect the farming phase.The important decision rules in the salmon chain are related to the farming phase and influenced by national regulations on production quantities and monitoring of lice and disease outbreaks. These decisions that influence costs and the agents that take the decision are outlined in the Table 3.

Table 3. Decisions related to the grow-out stage of salmon value chain

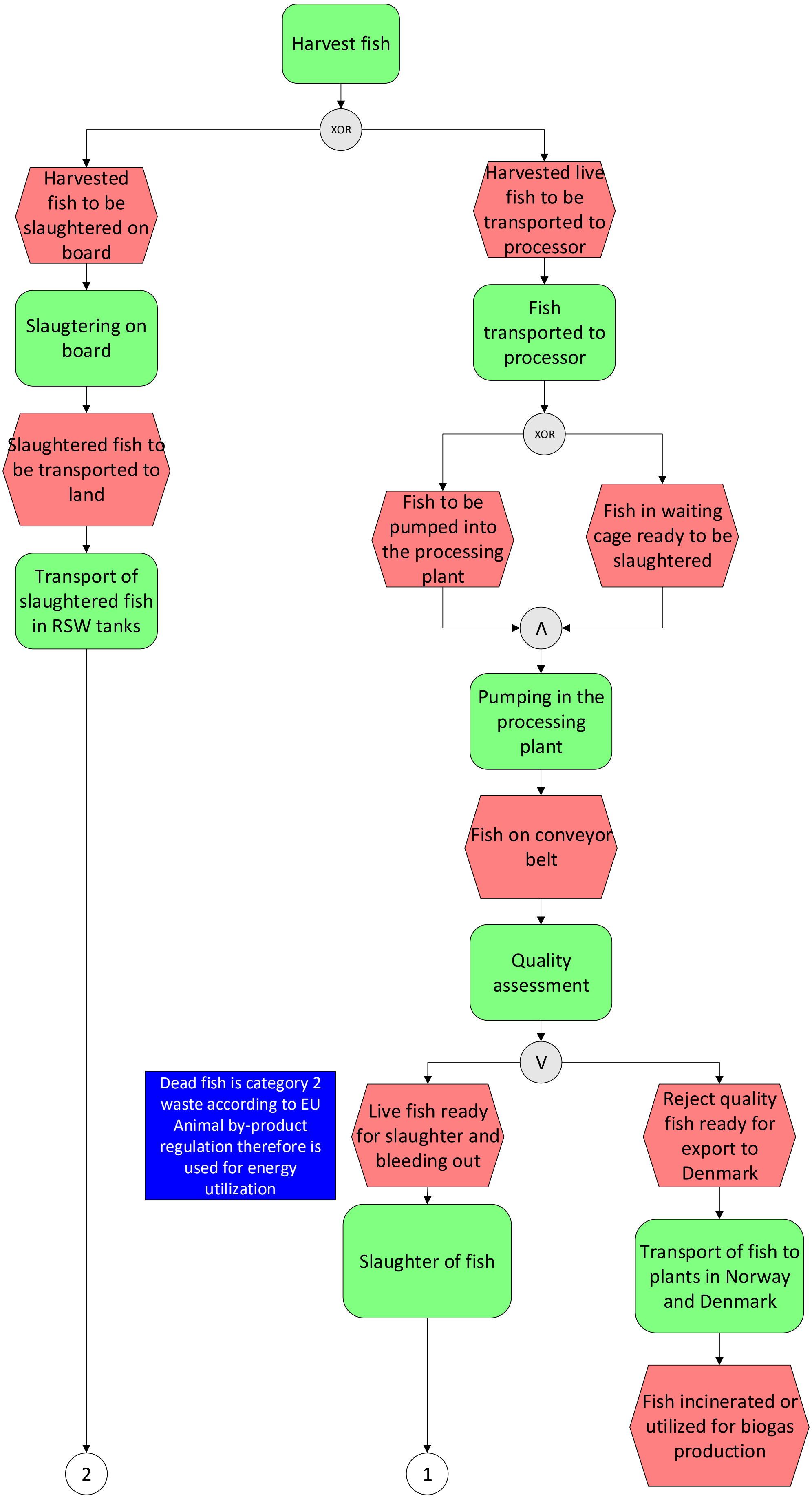
Decision	Corresponding regulation (if any)	Description	Decision Level	Decision Maker	Cost/Profit
Grant of license	The Aquaculture Act, Norwegian Ministry of Fisheries and Coastal Affairs[23]	Regulations under the Act govern the allocation of licences, the species to be produced, the geographic areas or sites where production is to take place and the maximum biomass permitted at a given location. Aquaculture licences are granted in allocation rounds determined by the Ministry. Applicants with the highest bids are granted the licenses. There are years during which no licences are granted. An aquaculture licence is approved in perpetuity but may be withdrawn in case of breach of conditions set out in the licence, in the Aquaculture Act or in environmental legislation.	Obligatory, company and site-specific	Directorate of Fisheries	This is a cost for the company in terms of licensing fee Influences the decision “will to farm”
Selection of production site	The Aquaculture Act and Traffic light system	The product site is specified in the license and must meet the environmental regulations.	Obligatory, site-specific	Directorate of Fisheries and Farming company	N/A
Production Limit	Maximum Allowable Biomass (MAB)[24]	Maximum volume of fish a company can hold at sea at all times. In general, one license is currently set a MAB, of 780 tons (945 tons in the counties of Troms and Finnmark). The sum of all license-MAB in each region is the farming company's total allowed biomass in this region. In addition, each production site has a MAB and the total amount of fish at each site will have to be less than this limitation. Generally, sites have between 2.340 and 4.680 tons allowed MAB.	Obligatory, company and site-specific	Directorate of Fisheries	This decision limits the willingness of the company to increase production
Production Limit	Traffic Light System[25]	As of 30th October 2017, eight of the thirteen production areas have been awarded the colour green. A regulation has been proposed that will allow existing fish farms in these areas to increase their production capacity by 2 per cent. The	Obligatory, site-specific	Directorate of Fisheries	This decision limits the willingness of the company to

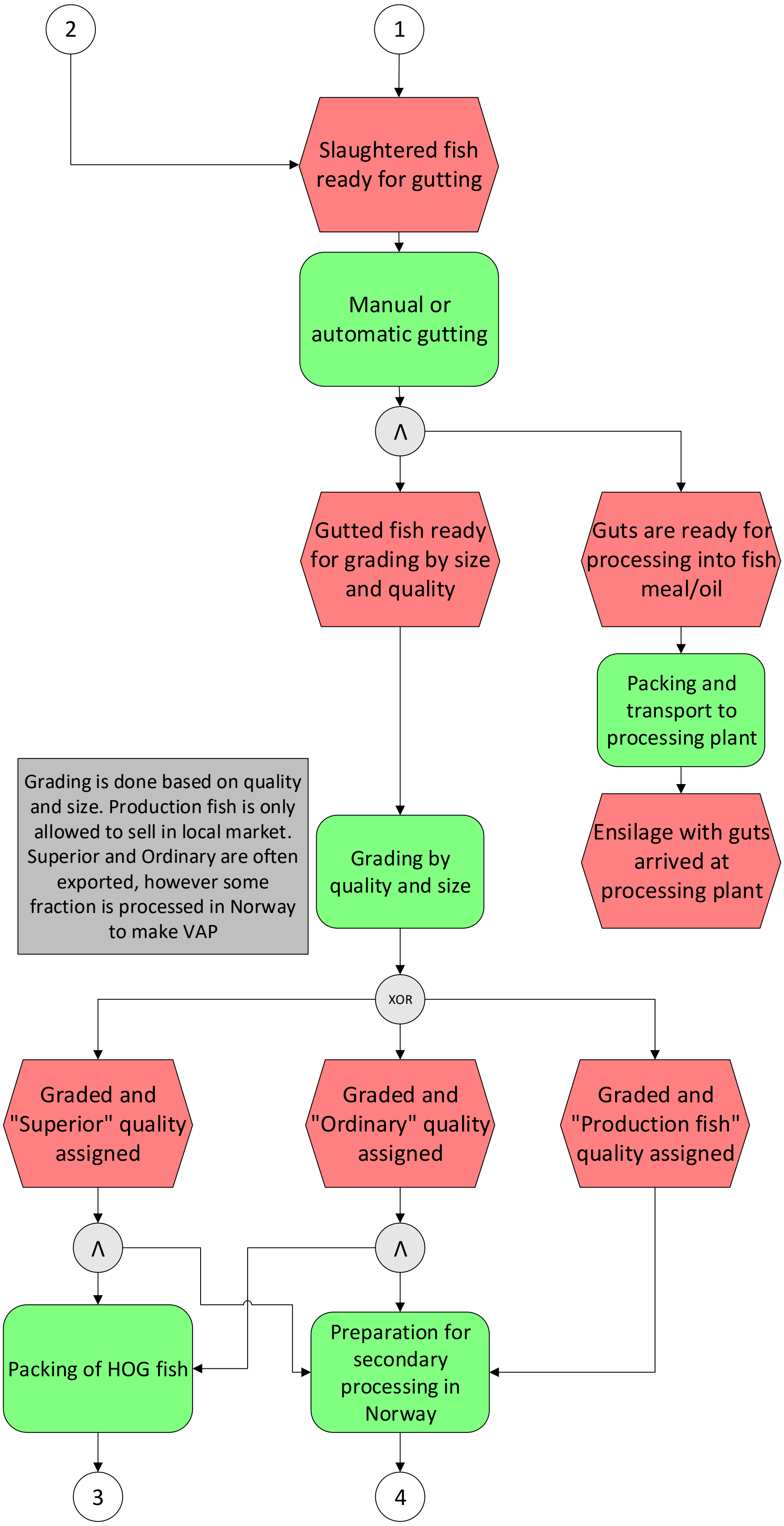
		government is also intending to auction new licences, increasing total production by 6 per cent. The five remaining production areas are coloured yellow or red, and fish farms there are only allowed to expand up to 6 per cent if they fulfil certain predefined criteria.			increase production
Smolt release		Smolt release plan is based on the production cycle. Smolt needs to be ordered one year before the planned deployment.	Company and site-specific	Farming company	N/A
Lice count limit	Regulations on the control of salmon lice in aquaculture plants[26]	Norwegian regulations specify that there must be fewer than 0.5 adult female lice per fish on average in a facility. The fish farmer is responsible for keeping numbers below that limit, and failure to do so may mean the stock must be slaughtered. The Norwegian Food Safety Authority can permit a higher louse limit for broodstock during the last half-year while the fish are in the sea. It can also specify different limits in zones.	Obligatory, site-specific	The Norwegian Food Safety Authority	This is a significant cost for the company to monitor lice and conduct treatment according to the guidelines.
Splitting fish into two cages		Split the fish into two cages when the average weight of fish is more than 1 kg	Site-specific	Farming company	This is an added cost to the company
Feeding	Norwegian Food Safety Authority[12]	The feed must be safe and not have a direct adverse effect on the environment or animal welfare. The starvation period before slaughter should be as short as possible. The use and composition of feed would vary depending on growth phases and health requirements of fish in order to optimise the costs of feed and maintain fish health.	Site-specific	Farming company	Decisions regarding quantity and quality of feed directly affect the profit as feed is one of the major costs for Salmon producers.
Harvest		The optimal harvest weight is between 4-5 Kg. However, fish are commonly marketed in the range between 3.5 and 7 kg. Volatile salmon prices make the timing of harvest an important factor for profitability. The farmer has to decide whether to harvest the fish at a known price or to continue to feed until a later harvest and market a larger fish at an unknown future price[27]. However, delaying harvest comes at a price. The farmer has to pay to keep the fish in the pen, a cost consisting both of extra feed expenses[28].	Site-specific	Farming company	Harvest decision are dependent on the will to acheive maximum profit from the harvest. Influences the decision "will to harvest"

		In general, fish is harvested if atleast one of the following conditions is true: Either total biomass ≥ max. allowed biomass OR Market demand for the available fish is present (in turn reflected in the production plan of the processor) OR In case of a disease outbreak			

3.2.4 Processing and distribution

Primary processing consists of slaughtering and gutting. This is the point in the value chain in where standard price indexes for farmed salmon are related. Sorting is done based on quality and size. Fish of larger size fetches higher price than smaller fish[28]. Secondary processing includes filleting, fillet trimming, portioning, different cuttings like cutlets, smoking, making ready meal or Packing with Modified Atmosphere (MAP). The products that have been secondary processed are called value-added products (VAP). Most of the fish is exported in fresh head on gutted (HOG) form to EU[29]. A very small fraction of fish is filleted and further processed in Norway due to high production costs and custom duties for export of value-added products to the European market. Several processing plants in Norway only produce fresh, bled and gutted Salmon while other companies prefer to transport the fresh, bled and gutted Salmon to secondary processing plants located in countries like Poland and France. The post-rigor filleting takes place in these secondary processing plants - typically carried out 2 to 4 days post mortem. To make the filleting and deboning process easier, the bled and gutted Salmon is stored in ice-slurry for a few days until it reaches post rigor state. Whole fillets, loins and portions are then packed, chilled and marketed. In some cases, whole salmon is sold to local processors where it is further filleted, salted or smoked. The by-products from primary and secondary processing are further processed into fish oil and fish protein and are either used for human consumption in form of pharmaceuticals or dietary supplements or used an ingredient for animal feed[30]. The by-products that are not suitable for either of them is used for energy utilization according to the regulations on Category 2 by-products[31]. Figure 10 describes the processing and distribution stages.


Harvest fish
XOR
Harvested fish to be slaughtered on board
Slaugtering on board
Slaughtered fish to be transported to land
Transport of slaughtered fish in RSW tanks
Harvested live fish to be transported to processor
Fish transported to processor
XOR
Fish to be pumped into the processing plant
Fish in waiting cage ready to be slaughtered
Λ
Pumping in the processing plant
Fish on conveyor belt
Quality assessment
V
Dead fish is category 2 waste according to EU Animal by-product regulation therefore is used for energy utilization
Live fish ready for slaughter and bleeding out
Slaughter of fish
Reject quality fish ready for export to Denmark
Transport of fish to plants in Norway and Denmark
Fish incinerated or utilized for biogas production
2
1


2
1
Slaughtered fish ready for gutting
Manual or automatic gutting
Λ
Gutted fish ready for grading by size and quality
Guts are ready for processing into fish meal/oil
Packing and transport to processing plant
Ensilage with guts arrived at processing plant
Grading is done based on quality and size. Production fish is only allowed to sell in local market. Superior and Ordinary are often exported, however some fraction is processed in Norway to make VAP
Grading by quality and size
XOR
Graded and "Superior" quality assigned
Graded and "Ordinary" quality assigned
Graded and "Production fish" quality assigned
Λ
Λ
Packing of HOG fish
Preparation for secondary processing in Norway
3
4


3
Λ
HOG fish ready for direct export
HOG fish arrive in wholesale Norwegian market
HOG fish ready for secondary processing in hub market
Fresh HOG is transported either by air frieght or road depending on geographical connectivity
Transport to importing countries
Transport to secondary processing plants
Λ
HOG fish at secondary processing plants in EU
HOG fish in Asian market
HOG fish in European market
HOG fish in other international market
Secondary processing into fresh and smoked fillet/portions and other VAPs
Value added products ready for EU market
Transportation to EU market
Value added products arrive in EU market

Figure 10: EPC model of the processing and distribution stages

The important decision rules related to the processing and distribution phases are described in Table 4.

Table 4. Decisions related to the processing stage of salmon value chain

Decision	Description	Decision Level	Cost/Profit
Assign Quality	Grading is done based on size and quality (colour, texture, etc.) and fish is divided into four quality grades: Superior, Ordinary, Production fish or Reject	Company and batch specific	The criteria for quality influences the decision "will to supply"
Product mix (primary processing)	The quality (colour, texture) and size of fish decides the product mix	Company and batch specific	N/A
Production planning (primary processing)	The production plan depends on the following factors[12]: - Quality of harvested fish - Size of harvested fish - Customer demand - Market price - Spot sales volume constraints - Contract fulfillment constraints - Capacity constraints - Inventory constraints	Company and batch specific	Optimal production plan avoids any losses and maximises profit.
Production planning (secondary processing)	The production plan depends on the following factors[32]: - Quality - Demand of value-added products - Market price - Shelf-life considerations - Supermarket campaigns - Seasonal considerations (e.g. holiday period etc.) - Contract fulfillment constraints - Capacity constraints - Inventory constraints	Company and batch specific	This decision is taken to acheive maximum profit from sale of products.
Distribution planning	The distribution plan depends on the following factors: - Shelf life - Cost - Transportation availability (capacity constraints) - Feasibility of transportation mode across the distance - Demand - Customer contracts, volume and delivery times	Company specific	Transportation is a significant cost and is time consuming therefore decisions are taken to optimise routes and avoid losses.

4. APPLICATIONS OF EPC

The following sections describe the application of EPC to the Causal Loop Diagrams developed by WP2, to Life Cycle Assessment and for identification of data needs for further modelling work in the project.

4.1 EPC AND CAUSAL LOOP DIAGRAMS (CLD)

Causal loop diagrams (CLD) are used for mapping in terms of causalities and provide a way of understanding the dynamic and interconnected nature of a system and to provide an overview of the problem to be modelled. In the context of VALUMICS, CLDs will be used to describe the stocks and flows in a supply and a value chain linked by decisions. In a value chain, these decisions can include the following:

- Decision (or will) to produce
- Decision (or will) to sell
- Decision (or will) to purchase

These decisions in turn are influenced by various factors such as supply, demand, market price, cost, capacities, etc. which can be modelled based on knowledge on behaviour influencing decisions. The CLD approach as shown in Figure 11 is enriched by information from “functions” and “events” in the EPC.

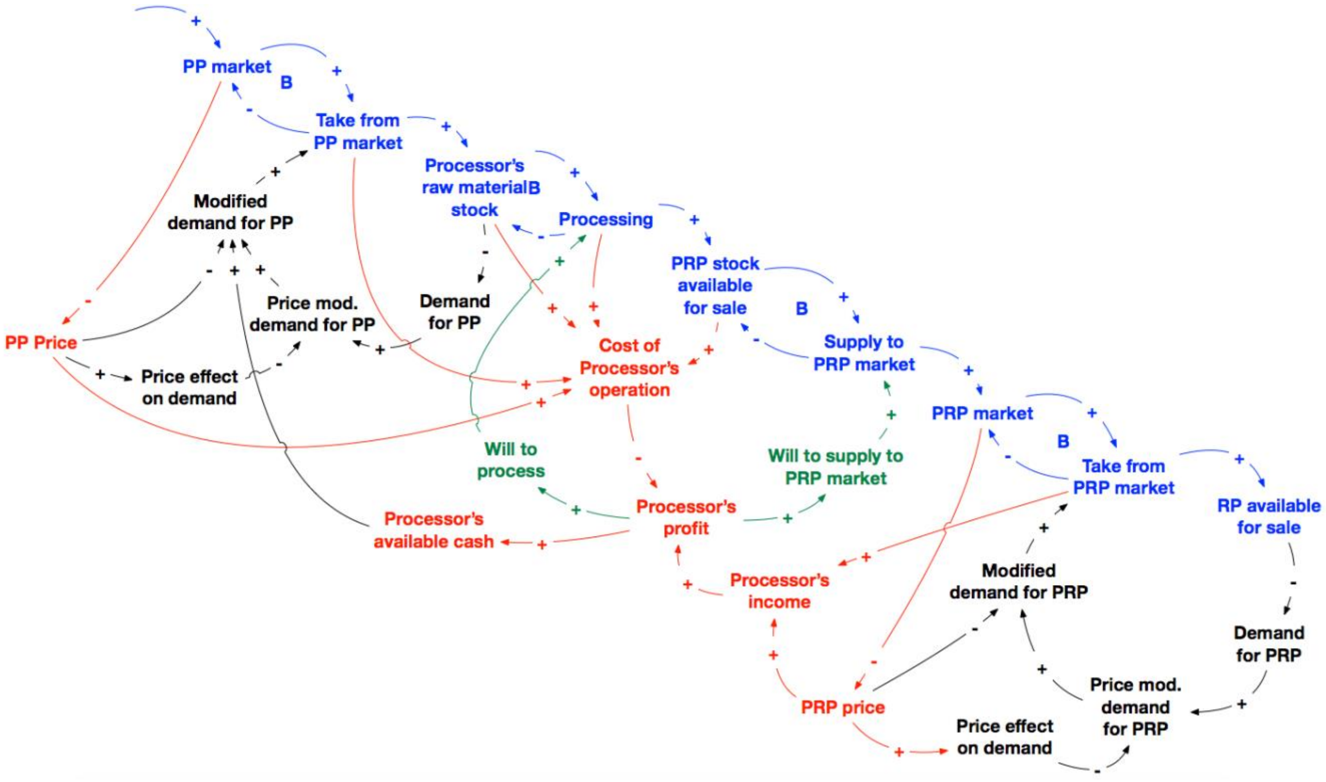


Figure 11: CLD of processor part of the salmon chain showing the market dynamics with the different layers of physical flow (blue), money flow (red) and decisions (green) (From Gudbrandsdottir et al., 2018)[33] (PP primary product, PRP primary processing product)

4.1.2 *Connecting the decisions in the two models*

EPC models present a sequence of events and the flow can be split by use of logical connectors that can be used to depict different decisions in the system. The decision rules in the salmon supply chain have been mapped using the EPC methodology as shown in the Table 1, 2, 3 and 4. These tables also describe how these decisions affect profit directly or indirectly. For e.g. The obligatory requirements on the control and monitoring of sea lice is based on a national decision and poses a significant cost for the farming company. Hence this decision directly affects the profit expected by the farming company. Such relevant decisions that influence e.g. cost and market dynamics will be operationalised to include in the system dynamic model which is based on the CLDs.

4.2 EPC AND LIFE CYCLE ASSESSMENT (LCA)

Life Cycle Assessment (LCA) is an ISO standard tool for quantifying the environmental performance of products taking into account the complete life cycle, starting from the production of raw materials to the final disposal of the products, including material recycling if needed[34]. Figure 12 illustrates the 4 stages of the LCA methodology based on the ISO standard 14040, 2006.

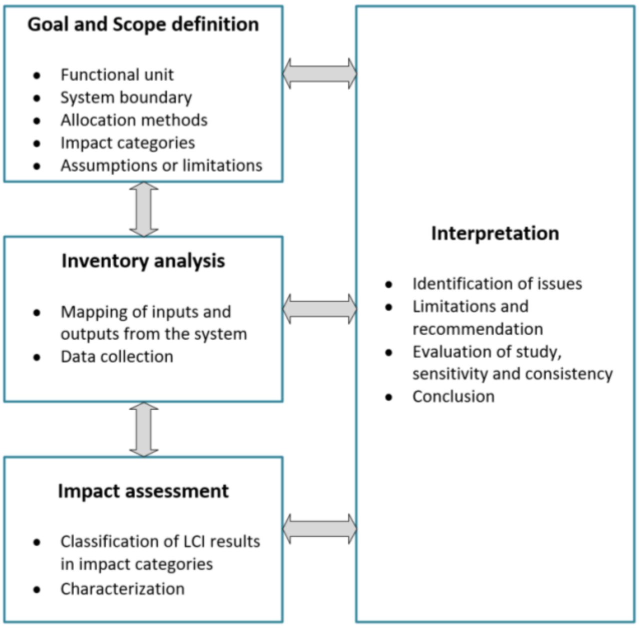


Figure 12: LCA methodology

The LCA methodology can also be used to quantify impacts of products or process on the society and its economy by conducting a Social LCA. A social and socio-economic Life Cycle Assessment (S-LCA) is a social impact (and potential impact) assessment technique that aims to assess the social and socio-economic aspects of products and their potential positive and negative impacts along their life cycle[35]. The Social LCA indicators focus on the impacts on stakeholder categories like workers, local community, consumers as well as value chain actors. Total Production Cost or Total working time required are some examples of economic indicators included in a Social LCA.

The EPC model can provide the description of all the processes occurring along the supply chain and the order in which they are organised and can assist in initial steps of describing the system for an LCA. Moreover, the EPC model can help to identify the different points at which information is recorded and more importantly what type of information is recorded. This can give a very good comparison of the data available to conduct an LCA and the type of data required for the LCA. The EPC model also give information on the resolution of data for each supply chain stage specifying if it is national level data, company level data or others.

In the VALUMICS project, EPC model for Salmon has been used as a base to identify the data available for the LCA of Salmon. For example, as shown in Figure 13, the mapping of processes such as license application and setting of farm-site in the case of salmon aquaculture helps to identify the different costs involved in the value chain. This information is important to quantify the socio-economic indicators like total production cost and total working hours.

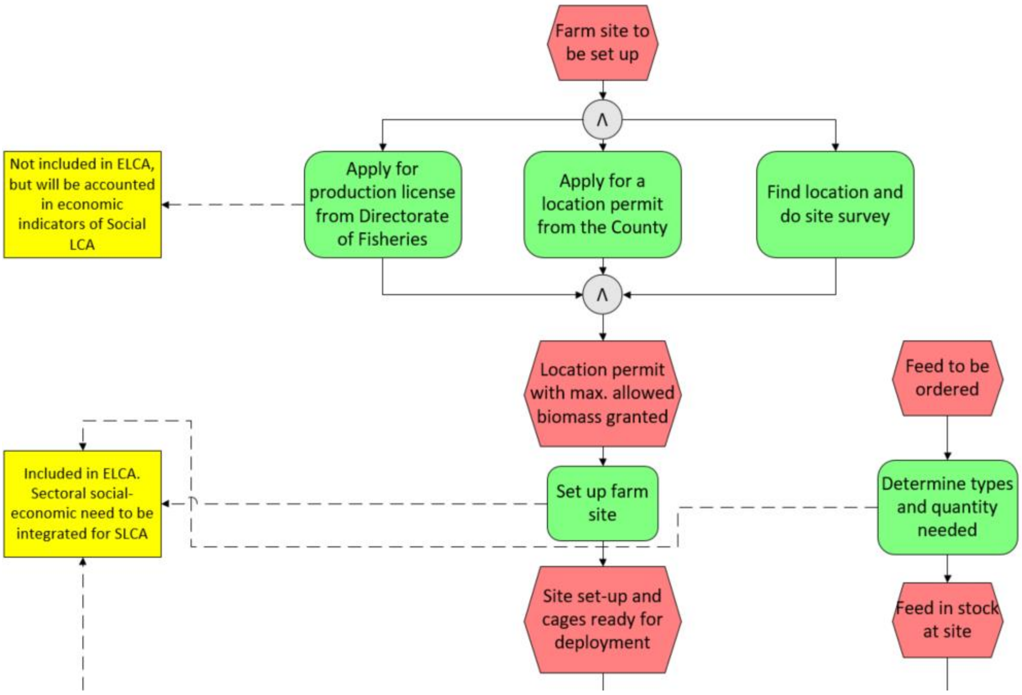


Figure 13: Stages in the EPC model for establishing the farm

The EPC model can allow mapping of different production lines or methods for the same end-product. For example, slaughter of farmed salmon can be done on land in a processing plant or on-board the harvest as shown in Figure 14. The EPC model describes different scenarios for LCA. In case of slaughter of salmon, the proportion of fish slaughtered on board is small, therefore this method might be not be considered in the LCA.

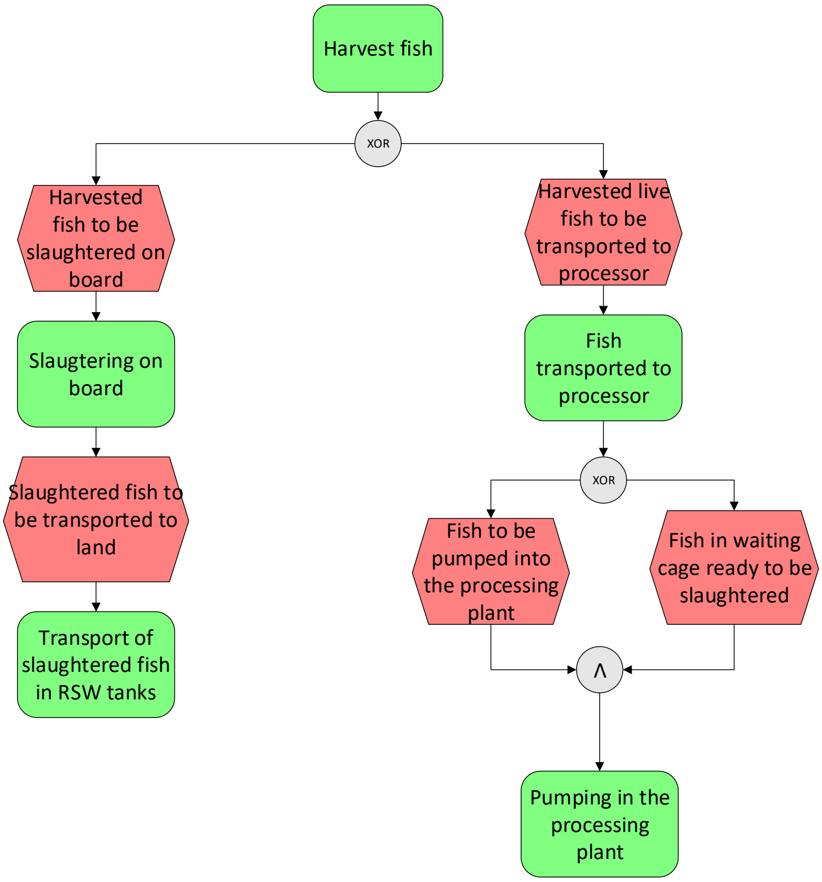


Figure 14: Two pathways for slaughter of farmed salmon

4.3 DATA COLLECTION

The EPC models can be used to identify critical points (processes, events or decisions) where specific data needs to be collected. This section describes the type of data required for the different tasks and synergies in data collection.

WP4 and WP5 relation in data collection

The main connection between activities in WP5, in particular T5.3 and 5.4, and EPC model could be seen at the level of price inputs and price outputs mentioned in the salmon EPC case study. Namely, coefficients obtained from the price transmission and market power analysis could be integrated in the EPC and applied for parametrisation of the CLD model, and further transferred to the LCA (economy sub-module). This integration between results obtained in WP5 and models developed in WP4 and WP2 will be done through the task 4.2. in WP4 and the task 5.2 in WP5.

The EPC model created for each case study will serve as a starting point for identifying critical points for which additional data should be collected in order to enable the analysis in WP5. As an example (Figure 15), the EPC model created for the salmon case study (Section 3 in this document) was used to identify critical points at which additional data should be collected for performing the price transmission analysis along the salmon value chain (WP5, T5.3). The set of available secondary data was developed within T4.3. When needed, primary data will be collected within each CS in coordination with WPLs.

For analysis in WP5 on e.g. price transmission, the secondary and primary data collected in Task 4.3 are aggregated data. However, the data need may vary depending on the scope of the analysis e.g. if it is based on company to company data or aggregated data. Therefore, it would be advantageous to tailor the EPC representation to the different needs, that the different analyses require. For LCA annual or average data on production from actors /suppliers in the chain, is used for the analysis.

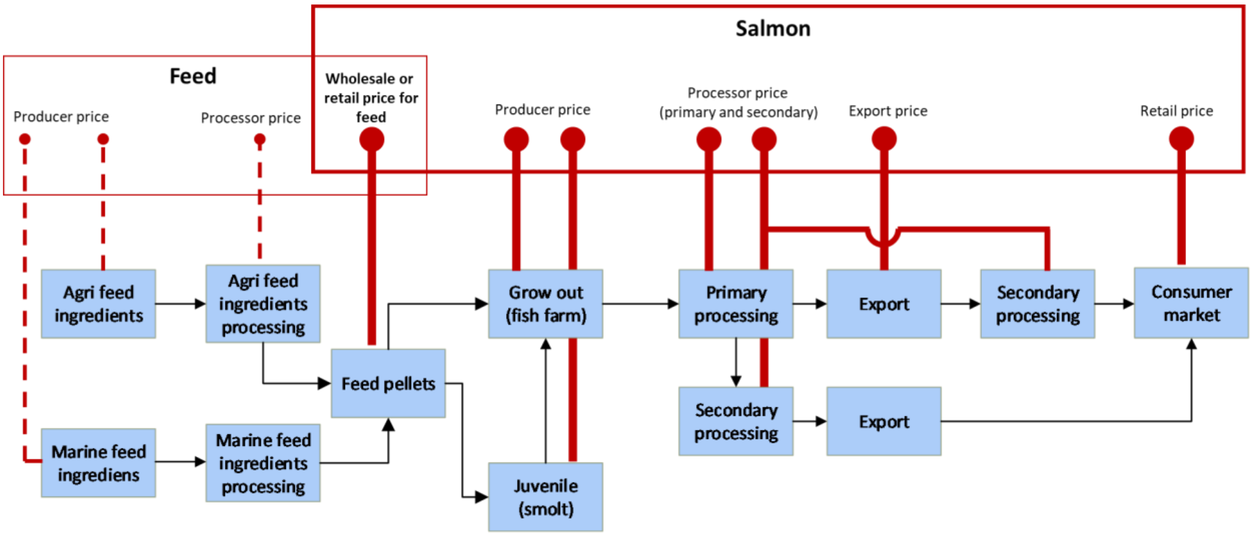


Figure 15: Example of data needed for price transmission analysis (WP5, T5.3) at each level of the salmon value chain

There may be synergies in data collection between the validation of the integrated model based on the CLDs and the inventory for LCA studies. Although, decisions in the chain are generally based on profit considerations, they can also be influenced by for example environmental factors and capacity constraints. The main environmental challenges of the salmon supply chain have been included in the CLDs (as reported in D 2.5) and the associated mitigation cost that may have an impact on the profitability. Feed contributes to the main environmental impacts of salmon products from the use of fertilizer and pesticide and use of energy (fuel) and water for crop cultivation. In the fisheries chain, fuel use is the main environmental hotspot when considering climate change impact (CO_2 emission). The use of energy, water and packaging in processing and fuel use in logistics are the main contributors of environmental impacts.

Data on the input of biotic and abiotic resources and output emissions are quantified in LCA (Task 4.5) for all steps in the supply chain. Information from the inventory on input and output for example feed use, energy use, water use, use of packaging, transport etc. and output emissions to air, water and soil e.g. amount of waste and wastewater may also be needed for the mass balance or efficiency to operationalize the quantitative model.

Also, information on cost of the operation in all steps in the supply chain would be useful to assess the impact on profits for the quantitative model and would be needed for Task 5.5 Economies of scale and technical change along the food chains (CZU) and Task 5.6 Statistical analysis of agribusiness profitability (UNEW).

5. CONCLUSIONS AND NEXT STEPS

The EPC model for salmon has helped to visualise the data availability and gaps and assists in further data collection for the salmon case study in the project. The EPC model developed in this task has also helped to identify the different costs in food value chains and the decisions made by value chain actors to minimise the costs. This helps to understand the agent behaviour which will be important in further modelling activities in the project.

Information on the different regulations that govern the salmon value chains and how they affect costs for the producer and processer have also been outlined in this report.

To continue the work in Task 4.2, EPC models for selected case studies will be developed in collaboration with the case study leaders in VALUMICS. The level of information available to model the other case studies as well as the data requirements for other tasks in the project may be different. Hence the models for other case studies may have some degree of variation compared to the salmon case study. Each case study model may also be distinctive based on which value chain stages are in focus and where the most critical decisions are taken.

With the help of other case studies, the synergies in the data collection for the tasks in work packages 2, 4 and 5 will be addressed in detail.

6. REFERENCES

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[1] PART 3: MODELLING BUSINESS PROCESSES – EVENT-DRIVEN PROCESS CHAINS (EPC) in Information Management II / ERP: Microsoft Dynamics NAV 2009

[2] https://en.wikipedia.org/wiki/Event-driven_process_chain

[3] FAO, 2011: Global Food Losses and Food Waste. http://www.fao.org/docrep/014/mb060e/mb060e.pdf

[4] The Norwegian Aquaculture Analysis 2016, Ernst & Young AS http://www.ey.com/Publication/vwLUAssets/EY_The_Norwegian_Aquaculture_Analysis/$File/EY-The-Norwegian-Aquaculture-Analysis-web.pdf

[5] Marine Harvest, 2017, Salmon Farming Industry Handbook 2017. http://marineharvest.com/globalassets/investors/handbook/salmon-industry-handbook-2017.pdf

[6] Norwegian Seafood Federation, F. (2013). ENVIRONMENTAL REPORT Norwegian Seafood Industry Emphasizing facts and figures from 2012 up to July 2013. FHL. http://fhl.no/miljorapport-2013/

[7] Ziegler et al., 2012. The Carbon Footprint of Norwegian Seafood Products on the Global Seafood Market. Journal of Industrial Ecology, 17 (1): 103 - 116.

[8] https://globalsalmoninitiative.org/en/what-is-the-gsi/what-is-salmon-farming-and-why-do-we-need-it/

[9] Ytrestøyl, T et. al., 2015, Utilisation of feed resources in production of Atlantic salmon (Salmo salar) in Norway. Aquaculture, 448: 365-374. https://www.sciencedirect.com/science/article/pii/S0044848615300624

[10] Cargill Aqua, 2017, Nutrition Sustainability Report, https://www.cargill.com/doc/1432118057937/aquaculture-sustainability-report-2017.pdf

[11] Biomar Group. (2018). *Integrated sustainability report 2017*

[12] Ministry of Trade, Industry and Fisheries,(2002). Regulation on feed products, FOR-2018-03-05-298, https://lovdata.no/dokument/SF/forskrift/2002-11-07-1290

[13] Vidar Gundersen, Feed production interview with Biomar, 2018

[14] Ministry of food and fisheries, 2008, Regulations on operation of Aquaculture facilities, FOR-2008-06-17-822

[15] Aquagen. Broad selective breeding goals, Aug 2016, https://aquagen.no/en/2016/08/26/a-new-generation-of-salmon/

[16] Stefansson, Sigurd & BTh, Björnsson & Ebbesson, Lars & McCormick, Stephen. Smoltification. *Fish Larval Physiology.* Bergen : s.n., 2008, pp. 639-681

[17] Stefansson, S et. al. Physiological properties of roe, alevin and smolt(norwegian only: Fysiologiske egenskaper ved rogn, yngel og smolt. [book auth.] Vilhem Bjerknes (redaktør). *Vannkvalitet og smoltproduksjon.* Trondheim : Juul Forlag, 2007, pp. 94-123

[18] Ministry of Food and Fisheries, 2008, Regulations on Regulations on the sale of aquaculture animals and products of aquaculture animals, prevention and control of infectious diseases in aquatic animals, FOR-2008-06-17-819

[19] Ministry of Food and fisheries, 2008, Regulation on transport of Aquaculture animals, FOR-2008-06-17-820.

[20] Marine Harvest, 2018, Salmon Farming Industry Handbook. http://marineharvest.com/about/news-and-media/news_new2/marine-harvest-osemhg-2018-salmon-industry-handbook-/

[21] The Norwegian Aquaculture Analysis 2017, Ernst & Young AS, https://www.ey.com/Publication/vwLUAssets/EY_-_The_Norwegian_Aquaculture_Analysis_2017/$FILE/EY-Norwegian-Aquaculture-Analysis-2017.pdf

[22] Norwegian Food and Safety Authority, 2016, Facts about salmon lice and combatting salmon lice. Reviewed on 26.11.2018. https://www.mattilsynet.no/fisk_og_akvakultur/fiskehelse/fiske_og_skjellsykdommer/lakselus/fakta_om_lakselus_og_lakselusbekjempelse.23766

[23] Ministry of Fisheries and Coastal Affairs. (2007). Strategy for a competitive Norwegian aquaculture industry. Norwegian ministry of fisheries and coastal affairs.

[24] Directorate of fisheries, Sept 2016, Biomass, https://www.fiskeridir.no/Akvakultur/Drift-og-tilsyn/Biomasse

[25] Ministry of Trade, Industry and Fisheries, Oct 2017, Press Release, Regjeringen skrur på trafikklyset, Ministry of Trade, Industry and Fisheries

[26] Ministry of Food and Fisheries, 2013, Regulation on the control of salmon lice in aquaculture plants, FOR-2018-04-19-674

[27] Guttormsen et al., 2004. The Value of Information in Salmon Farming: Harvesting the Right Fish to the Right Time, Aquaculture Economics and Management 10 (3).

[28] Denstad, A. G. (2015). *Production planning and sales allocation.* Norwegian University of Science and Technology.

[29] Norwegian Seafood Council, 2018, Weekly export statistics on Salmon and Trout.

[30] Richardsen, R et. al. 2017, Analyse marint restråstoff, 2016 – tilgang og anvendelse av marint restråstoff i Norge, SINTEF, https://brage.bibsys.no/xmlui/handle/11250/2446152

[31] European Parliament, 2002, Regulation (EC) No 1774/2002 on Animal by-products not intended for human consumption. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM%3Af81001

[32] Marine Harvest, 2017, Integrated Annual Report, Risk and Risk Management

[33] Guðbrandsdóttir, I. Y., Olafsdottir, A. H., Sverdrup, H. U., Bogason, S. G., Olafsdottir, G., & Stefansson, G. (2018). Modeling of Integrated Supply-, Value-and Decision Chains within Food Systems. Proceedings in Food System Dynamics, 341-348.

[34] PRé sustainability, Introduction to LCA with SimaPro, 2016

[35] UNEP-SETAC, 2009, Guidelines for Social Life Cycle Assessments of Products.