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DEVELOPING A TRACEABILITY SYSTEM FOR FISH FACTORIES IN ICELAND AND TANZANIA

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ABSTRACT

This study was done to improve the Icelandic and Tanzanian traceability systems by developing an IT based traceability system. From the point of view of marketing fish products on the European Union (EU) market, the relevant EU regulations and standards were reviewed in order to get an overview on what regulations on traceability the factories in Iceland and Tanzania aiming at exporting fish products to the EU are faced with.

A field study was carried out in Icelandic and Tanzanian fish processing factories to study the current traceability systems. The traceability systems from reception of raw material to the point the product is dispatched were followed and studied, including how the information is recorded and registered in each link. Information relevant to the traceability of products in the factory was then analysed for the purpose of designing a digitised traceability system. The results are the designs of traceability systems for the factory in Tanzania, Bahari Food Ltd., and the factory in Iceland, Tros Ltd.

The design will be used in the implementation stage, which involves writing the programs for the systems which will be in the second phase. It was concluded that it is high time for Tanzania and the developing world to have an IT based traceability system as they provide information which will make the fishing industry meet, not only market and regulatory demands, but also produce products in the most efficient way.

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1 INTRODUCTION

1.1 Background

At the moment Tanzania has about 19 fish processing plants with different capacities that are approved to export fish and fish products to European Union (EU) markets as presented in Table 1.

Table 1: Distribution of approved fish factories in Tanzania (Mgawe 2005).

| LOCATION | | FISHERY | NO. OF FISH PLANTS |
|--------------|---------------|---------------|--------------------|
| 1. | Dar es Salaam | Marine | 6 |
| 2. | Tanga | Marine | 1 |
| 3. | Mafia | Marine | 1 |
| 4. | Mwanza | Lake Victoria | 8 |
| 5. | Musoma | Lake Victoria | 3 |
| TOTAL | | | 19 |

Based on the available data, there is no doubt that export of fish and fishery products have assumed an increasingly greater role in the economy of the country. Today fish and fishery products are ranked among the top five export products in Tanzania in terms of value. The export volume is valued at about US\$ 60-70 million per annum.

Trends in Tanzanian fisheries seem to follow what is going on in the whole of the developing world, where fish export is now forming the bulk of export earnings. FAO (2004) estimated that in 2002, the developing countries' share of the total fishery exports was 49% by value and 55% by quantity. At the same time, developed countries accounted for about 82% of the total fishery product imports. (Mgawe 2005)

1.1.1 Consequences faced by Tanzania due to lack of a proper traceability system

Tanzania has had two cases of food borne hazards, which had great consequences for the economy of the country. Both cases involved an EU ban on imports of fish, the *Nile perch*, harvested from Lake Victoria, which is jointly shared between Kenya, Tanzania and Uganda.

The cholera outbreak around Lake Victoria in 1997

There was an outbreak of cholera around Lake Victoria in 1997 and as a result the EU imposed a ban on all the fish exports from the Lake to the EU market. The hazard addressed in this case was microbiological involving *Vibrio cholera* bacterium. Tanzania and the other East African partner states, Kenya and Uganda, protested to the EU on the ban being unjustified, but the EU applied the precautionary principle to defend their case. Tanzania requested that WHO carry out risk analysis, which concluded that fish from the Lake did not pose a risk of a cholera outbreak in Europe.

Tanzania, along with Kenya and Uganda, embarked on a massive hygiene programme in the fish handling and processing establishments around the Lake. The programme was based mostly on the Recommended Codex Codes of hygiene for fishery

establishments and on the various EU directives on fish hygiene. As a result of this programme and under the assistance of both UNIDO and the EU, the fish handling and processing establishments around Lake Victoria managed to put in place HACCP (Hazards Analysis and Critical Control Point) systems.

The EU ban was finally lifted and Tanzania and the other countries sharing the Lake started to export fish from the Lake to the EU again. But the economies of these countries had already suffered to a great extent (Mosha and Magoma 2002).

EU ban on Lake Victoria fish imports in 1999

The hazards addressed in this case were chemicals arising from suspected misuse of pesticides in Lake Victoria as reported by Uganda, The EU again imposed a ban on all imports of fish harvested from the Lake. The ban required the countries around the Lake to demonstrate beyond any doubt that fish from that Lake did not contain pesticide residues above tolerable levels. For Tanzania, HACCP systems were put in place in the fish processing establishments to ensure the safety and quality of fish products from such establishments.

Efforts were coordinated between the three countries sharing the Lake and massive awareness campaigns were carried out at all levels from the artisanal fishermen/community level to higher political authorities in the respective areas regarding fish products' hygiene and safety. The campaign was even stretched to cover good pesticides application practices at the farm levels to ensure no pesticide could reach our waters.

Even though no samples from Lake Victoria tested in the EU demonstrated the presence of pesticide residues, it took more than a year for the ban to be lifted. This is besides the very high number of samples sampled and tested by different authorities worldwide (Mosha and Magoma 2002).

From the two cases the following lessons have been learned:

First we realised as a county that we did not have the ability and capacity to analyse the presence of pesticide residues in food and foodstuffs. As such, fish samples had to be analysed outside of the country, which involved extra costs.

Efforts have been initiated to establish well equipped food chemical and microbiological analysis laboratories in the country and we shall appreciate further assistance to this effect at bilateral or multilateral levels. The need for such laboratories is necessitated by the fact that the country needs to be prepared for responding fast to any emerging chemical hazards. Furthermore, such laboratories will generate the requisite analytical data for both regional and international chemical hazards monitoring and control.

Secondly, timely response to emerging or suspected chemical hazards is very important if the extent of economic losses is to be minimised. In this case, availability of the right expertise and infrastructure in the country would have greatly minimised the economic losses incurred by the country as a result of the ban.

The two cases have shown other countries the economic problems a country can face as a result of not putting into practice the HACCP principles as a Quality Control measure.

Timely response to a hazard is very important if costs of product recall are to be minimised. Lack of involvement of all parties at all points of the food chain was also a problem.

Apart from above noted problems, the factories also lack efficient, effective and reliable traceability systems. By having all the facilities in place, well equipped food chemical and microbiological analysis laboratories and putting into practice the HACCP principles, implementing an effective traceability system will be beneficial to the factories and to the fisheries sector as a whole.

1.2 Objectives

The objective of this project is to develop a traceability system for one of the fish factories in Iceland and map it into one of the fish factories in Tanzania (Bahari Foods Co. Ltd.).

Fish factories in Tanzania still rely on paper-based traceability systems that are not as effective and efficient as IT based systems. IT is needed in practice because of speed.

Currently traceability at Bahari Foods Co. LTD., which is one of the fish factories in Tanzania and which is going to be a reference point of this project, is done manually using a paper-based traceability system. This system makes it difficult to trace back the information of units or batches of the product through all the intermediate steps of the production flow. It is time consuming and difficult. This is especially true where the process operation involves more than one raw material/ingredient.

1.3 Rationale

The project is relevant for the development of the fisheries sector in Tanzania, as it will focus on traceability, one of the requirements regarding exports to the EU, to which most Tanzanian fish products are exported along with the US markets.

The concept of tracing products from their origin to the consumer is not a contemporary idea. Many industries including Tanzanian fish factories have incorporated product tracing in their internal operations for decades. However, the introduction of IT based traceability systems into the fisheries sector is a relatively new concept that continues to gain momentum.

This project will be used to:

- Suggest to the Tanzanian Directorate of Fisheries the implementation of IT based internal traceability systems in the fish factories.
- Recommend the implementation of chain traceability systems for fish exports based on EU regulations.

Globalisation of the food industry has expanded dramatically over the past decade due to international sourcing of raw material, advances in food processing technology and rapid developments in electronic communications (Petersen 2004).

Increasing globalisation of food supply has heightened concerns over food safety issues around the globe. Food safety has become a critical priority for the fish supply chain. In response to this growing concern, many nations are looking at food traceability as a means to restore confidence in the food supply and limit damages incurred by the sale and distribution of unsafe products (Thompson *et al.* 2005).

As a consequence, government officials and industry leaders, concerned with ensuring food safety and quality, are exploring means to provide more information on sourcing, processing, and distribution of food products within the supply chains and ultimately to the consumers.

An important aspect of quality and safety assurance is to be able to trace products, ingredients, suppliers, retailers, and processing operations or storage procedures through the food production chain. This is especially relevant when failures occur.

However, mandatory traceability for control of food security has been singled out as an area where greater vigilance and transparency is needed. The global concern for food safety and security is being addressed by development of new international standards, industry guidelines and legislation.

Food traceability, and in particular fish traceability, is today high on the agendas of fish inspection services and the fisheries industries all around the world. From January 2005, the food and fishery industry in the EU, and in third countries wanting to export food and fish products to the EU, must have implemented systems to comply with requirements of Regulation (EU) No 178/2002 of the European Parliament and the Council of 28 January 2002.

2 TRACEABILITY AND ITS APPLICATION

Traceability is the ability to trace, follow, and identify **UNIQUELY** a product unit or batch through all stages of production, processing and distribution (Derick and Dillon 2004).

It needs to show the path of that unit or batch through all the intermediate steps of the production flow and the supply chain. The International Standards Organization (*ISO*) defines traceability as:

"The ability to trace the history, application or location of that which is under consideration when considering products this can relate to the origin of materials and parts, and the processing history."

There are two categories of traceability that are commonly discussed under the same heading of traceability:

Internal traceability: relating to the traceability of a product and the information relating to it, within the company or factory.

External traceability: which relates to product information that a company either receives or provides to other members of the supply chain.

Traceability systems are record keeping procedures and therefore they are critically reliant on recording of information. Robust mechanisms are needed to facilitate the collection and authentication of any information, to enable it to be updated and shared through the chain.

EU Regulation 178/2002 describes it as “the ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution.”

Some user groups define traceability more precisely. The International Standardization Organization (ISO) considers it to be “the ability to trace the history, application or location of that which is under consideration” and “when considering a product, traceability can relate to the origin of materials and parts, the processing history, and the distribution and location of the product after delivery”(Petersen 2004).

ISO 9000: (EAN International 2002)

“The organisation should take steps to identify the status of the product/service insofar as it concerns the required measurement and verification activities and should, where necessary, identify the product and/or service using the appropriate means throughout the process. This should apply to all parties involved in the product and/or service where their interaction has a bearing on the conformity to requirements. When traceability is a requirement, the organisation should control and record the unique identity of the product and/or service. In discussing traceability, it is important that the distinction between the terms tracking and tracing is understood:

In general the term “trace” is used when the history of product origin is searched and the term “track” is used for searching its history after delivery.

Product tracking and product tracing have different meanings in the context of traceability (Derick and Dillon 2004).

Product tracking refers to the recording of information as the product makes its way through the food chain and the ability to identify in real time where the product is and what processes it has undergone.

Product tracing, on the other hand, refers to the ability to follow a product back through these processes from the consumer to their origin.

Terms used in traceability studies include:

- “A step” which refers to a discrete operation or location at which some task or process is performed on the product,
- “A chain” is composed of the sequence of these steps, and

- “A product” can be any material at any stage of processing, e.g. a live fish, a whole fish, or a processed fish product.

Interest in traceability in food processing has been increasing in recent years, primarily because of the different crises in the food sector such as mad cows disease (BSE) in 1996 in the UK and the dioxin contamination in Belgium in 1999. Authorities have focused on traceability to assure consumer safety to be able to recall defective/hazardous products and to identify the source of the problem.

Globalisation of the fish industry in terms of sourcing raw materials, processing and marketing has resulted in demands for increased traceability of products. This is due mainly to the increased length of the supply chain providing more opportunity for fishery products to either lose quality or gain the potential to cause harm to the consumer. In order to ensure both the quality and safety of products, more information concerning the sourcing and processing of the products needs to be communicated throughout the supply chain and ultimately to the consumer.

2.1 Traceability standards and legal requirements

There has always been a degree of traceability within the food industry, with individual companies able to identify both their suppliers and customers. In recent years, however, the role of traceability in the control and safety of food has been identified as requiring greater transparency and regulation. This has been achieved by the development of international standards, industry guidelines, and legislation.

Legal basis for traceability

Two principal players leading legislative efforts to require traceability of foods are the European Union (EU) and the United States (US). In Europe, the EU directive 178/2002 went into effect on 1 January 2005 and requires mandatory traceability for all food and feed products sold within EU countries. In the US, the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 went into effect on 12 December 2003 and requires the registration of all domestic food facilities, and prior notice of imported food into the country. Other organisations such as Codex Alimentarius and the International Standardization Organization (ISO) also play an important role in the development of international standards and industry guidelines for food traceability.

2.1.1 European Union (EU) regulations on traceability

EU Regulation 178/2002 also called the “food law” of the EU is the most important regulation concerning traceability of food products in the EU. (EC – European Commission Regulation No. 178/2002).

The regulation as amended in Regulation (EC) No 164/2003 [Regulation 164/2003] does not affect any aspect of traceability systems. Articles 18, 19 and 20 in EU Regulation 178/2002 are the key pieces of legislation on food traceability in the EU. The effective date for implementing Articles 11, 18, 19 and 20 in EU Regulation 178/2002 was 1 January 2005.

Article 18 lays down the general principles of traceability in the food chain within the EU. It states that:

- Traceability should be established at all stages of food production.
- Traceability should be both forward and backward in the supply chain.
- All food or feed which is placed on the market should be adequately labelled or identified to facilitate its traceability.
- Provisions for applying traceability requirements of specific sectors.

Article 19 lays down the general responsibilities of food business operators in case of a product recall situation. The article specifies that it is the responsibility of:

- Food business operators to recall a product and inform respective authorities and customers if it believes the food can be harmful to eat.
- Retailers and distributors of food to, within their limits, initiate procedures to withdraw products that are not in compliance with the food-safety requirements.
- Food business operators to immediately inform competent authorities if they believe that a food which it has placed on the market may be injurious to human health.

In addition, food business operators are also obliged by this article to collaborate with competent authorities.

Article 20 is similar to Article 19, but addresses the responsibilities of feed manufacturers.

For food and feed imported into the EU a relevant article is Article 11, which states that: *“Food and feed imported into the Community for placing on the market within the Community shall comply with the relevant requirements of food law or conditions recognised by the Community to be at least equivalent thereto or, where a specific agreement exists between the Community and the exporting country, with requirements contained therein.”*

Other directives and regulations in EU legislation affecting traceability of seafood are (Petersen 2004):

- Directive 2003/89/EC [Directive 2003/89/EC] amending Directive 2000/13/EC
- Council Regulation (EEC) No 2847/93 and Council Regulation (EC) No 2371/2002
- Directive 2001/95/EC
- Commission Regulation (EC) No 2065/2001
- Council Regulation (EC) No104/2000
- Directive 93/43/EEC
- Directive 91/493/EEC
- Council Regulation (EEC) No 2092/91
- Directive 89/396/EEC

2.1.2 *United States of America (USA)*

The Bioterrorism Act of 2002 provides new authority to the Food and Drug Administration (FDA) to protect the nation's food supply against the threat of serious adverse health consequences to human and animal health from intentional contamination (Bioterrorism Act 2002).

The Public Health Security and Bioterrorism Preparedness and Response Act

USA seafood legislation is controlled by the Food and Drug Administration (FDA). The cornerstone legislations are FDA rule 21 CFR 123 "The Procedures for the Safe and Sanitary Processing and Importing of Fish and Fishery Products".

Additional legislation covers the production and export of fish products to the USA under the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (PL107-188)

The act is divided into five sections of which Title III: Protecting Safety and Security of Food and Drug Supply has the most relevance to traceability and seafood imports. In this section the following should be noted:

- Section 305 – Registration of Food Facilities
- Section 306 Establishment and Maintenance of Records
- Section 307 Prior Notice of Imported food Shipments

All of the above will rely on the producer and processor being able to set up and operate a system of traceability or "trace-back" in the USA. The FDA has a contact address under www.cfsan.gov/...../html which gives detailed instructions and overviews for regulations affecting the importation of seafood in to the USA.

All of these regulations are concerned with traceability which make it an obligation for the food processing factories to have a proper traceability system in terms of speed and accuracy, which suggests that an IT based system is the right system for that matter.

2.2 **Traceability main objectives**

Traceability and systems to link a final product with its ingredients and processing have always formed a key part of any Good Manufacturing Practice (GMP), quality assurance scheme (HACCP) and it helps to improve them.

When implementing a traceability system, the added value of such a system needs to be considered. Traceability systems can serve many purposes. The main objectives/benefits of the implementation of traceability are as follows (CIES 2005):

- Enables safety: prevents food incidents when hazards occur, the process to trace the product back to the source of the hazard (recall) is more efficient and simplified if the partners involved in the chain have organised records and make them available on demand. This will lead to the identification of all the potentially harmful products, prevent or minimise any harm to consumers

and avoid the negative public opinion about a specific product that usually results in a reduction of sales.

- It helps the industries to improve their quality management and process monitoring: traceability is an integrated concept; it is integrated with other systems like HACCP and quality related and production management systems which have similar data. While other systems are process oriented and proactive, traceability is product oriented and reactive. The quality and production management systems tend to monitor products attributed and take corrective action to make sure the products are safe and not out of standards while traceability reacts by recalling unsafe and out of standards products from the market (Sveinn 2007).
- Improves production: implementation of traceability systems, although costly to implement, can also be an economic benefit to the producer. By linking information through the chain, it is possible to build the history of the product (harvesting area, processing, ingredients and additives, storage, transportation...) and create a feedback loop to improve product quality, yield, condition, and delivery, therefore guaranteeing food safety and quality for the consumers. Traceability information can show all trends regarding production which will make it easier for the producer to make necessary decisions for the purpose of improving production.
- Addresses concerns of food-terrorism or tampering with the food supply chain.
- Optimises the supply chain: based on historical data, it enables members of the supply chain to identify sources of problems quickly and rapidly.

2.3 Different types of traceability systems

There are a number of different systems that can be used for traceability within an organisation or throughout a supply chain, each having advantages and disadvantages. Examples include (Marshall 2004):

- Paper-based
- Computer based
- Bar code
- Radio frequency identification

A current difficulty with traceability reporting within the fisheries sector is standardisation and harmonisation. There are companies with their own in-house software and systems that provide the information they need, commercial companies trying to make software for everyone and individuals doing it their own way. For traceability to be truly effective, it needs to be standardised throughout the chain.

2.3.1 Paper based systems

This is the simplest form of recording information and tends to be at least part of most traceability systems. Paper-based systems with limited or standard computer software can be appropriate for simple processes.

The paper system relies on the user to formulate effective recording templates that can be used to record the vital parameters associated with the product.

The paper system can appear to be the most straightforward and least costly option for a small operation, however the operator must consider the time needed to record and maintain paper records and the ability to cross reference through records if a problem occurs. It is important that all the relevant information is recorded.

Disadvantages

- Slow lane perception
- Disjointed information doesn't allow information to be linked together
- Indirect cost of time needed to complete the chain
- Time needed to recall information may exceed legal expectations

Advantages

- Low direct costs
- Possibility of transfer of templates to electronic format

2.3.2 *Computer based systems*

Anything that can be recorded on paper can be captured on an information technology system. Information systems have the added advantage of being able to correlate and process data as part of an overall management system. Information systems can be developed in-house or there are a number of commercially available programmes available.

Advantages

- Information can be correlated to identify efficiencies
- Fast lane perception
- Interlinking traceability information with sales/production/accounts etc.
- Interlinking software with external partners (suppliers/customers)

Disadvantages

- Enhanced costs due to IT purchases
- Developing/purchasing systems which cannot communicate with other systems and software

2.3.3 *Use of bar-codes*

Bar coding is a relatively mature technology that has been used extensively in the fish sector. Essentially a bar code utilises a numeric or alphanumeric code as a means of identification. This code is applied to a label and is read with a contact reader.

In order to support international trade, a recent effort has been completed which defines a standard (EAN/UCC) for assigning bar code identifiers. This standard is based on merging the EAN (European Article Number) and the UCC (Uniform Council Code) standards which were the two most widely known and applied standards. The main purpose of bar codes is to identify items and eliminate/reduce human error by providing an electronic method to interface with enterprise and other corporate computer systems (Marshall 2004).

RFID is an electronic version of bar code technology in its most basic case, it is not necessary that the readers have direct line of sight to the tag since the information is passed via radio waves.

Application of bar code technology in the supply chain

Bar code technology is widely applicable throughout the value chain. Information on a bar code must be passed from one stage to another throughout the chain, therefore maintaining consistent traceability throughout the supply chain. Due to the fact that it does not withstand a risk of human error, bar coding provides an excellent mechanism across all sectors for tracing the movements from the “farm net to the consumer’s knife”.

Advantages (current applications)

- Standards for product codes (EAN/UCC)
- Mature, widely-used technology and cost effective
- Can be used to track lots/batches
- Can be used to track trays and/or individual packages
- Can record expiry (/best before) dates
- Ability to couple with RFID to provide “net-to-knife” traceability.

Disadvantages

- Farm environments are very harsh on this technology, resulting in potential loss of data
- Direct line-of-sight required for reading (making high speed reading of individual items difficult)
- Bar coding is not tamper proof

3 BACKGROUND INFORMATION: ICELANDIC AND TANZANIAN FISH FACTORIES

3.1 Icelandic fish factory: Tros Ltd.

A field study on the production, quality management and traceability system was carried out in the company Tros Ltd. focusing on haddock products. Tros was visited once for this project. The basic data about production of haddock were collected during the visit.

Tros Ltd. is based in Sandgerdi, a thriving fishing port in the Southwest of Iceland, with prolific fishing grounds just off the coast. Sandgerdi is less than a ten minutes drive from Keflavik International Airport. This eminent position makes Tros Ltd. well qualified to offer unequalled freshness.

3.1.1 Production at Tros Ltd.

Processing and packing facility in Iceland

The company’s main activities are processing, sales and marketing of fresh fillets, mainly exported by air freight to Europe and USA. In Sandgerdi, Tros Ltd. has its own processing and packing facility where fresh fish, selected and bought on the

market by company staff, is filleted, iced and packed for transport.

The raw material is mostly obtained from mainly two sources:

1. Contracted boats
2. Fish auction market

The company does not own any vessels and therefore they rely on boats which have contracts to supply fish to the company. There are six boats which have been contracted by the company, usually fishing in the same fishing ground. The fish collected is mostly one day old.

Auction markets in Iceland are connected by computer into one auction network (Tengil) with an Icelandic and English version, as there are foreign buyers participating in the market. Extracted from the fish market website, www.islmark.is (Islandsmarkaður) the operations are conducted daily where 200 – 300 buyers purchase fresh fish in real time. The company buys fish from the auction market to supplement the amount obtained from the contracted boats. Among the main factors taken into consideration when buying fish from auction are the age (days since caught), size of the fish and fishing ground.

The processing of fish is done on the second day after collecting the raw material. There are primarily two types of raw material, gutted and ungutted. The raw material is washed and then weighed to check if the weight correlates with the information given by the auction or the contracted boats.

Reception of raw material:

Fish is received from contracted boats and from fish auctions. The fish is then bled, gutted, washed properly and iced. The temperature in the cooler is kept at 0- 4°C.

Beheading, filleting and skinning:

The fish is beheaded and graded by the machine into different grades. After grading the fish are filleted and skinned manually.

Trimming and cutting:

The fillets come directly from the filleting area to the trimming lines. Each fillet is checked on a candle table. Defects regarding bones, blood spots and bruises, skin spots, black membranes and foreign objects are removed according to the quality standards.

Weighting and packing:

The fillets are weighed and packed in Styrofoam boxes ranging from 3 kg to 30 kg. (Figure 1)

Palletting:

The Styrofoam boxes are then stacked on pallets and strapped with plastic and labelled (Figure 1).



Figure 1: Packing final products at Tros Ltd. in Styrofoam boxes.

Chill storage:

Palletised products are placed immediately into chill storage at a minimum temperature of -25°C for a short period before being air freighted.

Traceability information on production

The production information collected includes:

- Name of the boat
- Weight of the raw material (a batch)
- Species
- The exact yield (weight of final product) obtained from each boat

Products

Many years of experience (the company was established in 1977) have made Tros Ltd. one of Iceland's largest exporters of fresh fish by air where quality and reliability are keywords. There is a wide range of species from the North Atlantic Ocean including cod, haddock, saithe, redfish, catfish, monkfish, lemon sole and plaice. The species also include a selection of farmed Icelandic fish, such as salmon, as well as arctic char. Strict quality measures are both applied for their own plant and products from other processors. The company sets its own specifications for processing, based on the buyers demands, and has the capacity for products from up to 40 processors in all kinds of processing.

During the visit to this plant, a study was done to have an overview of haddock processing. Figure 2 shows a flow chart of the chain for haddock processing i.e. fresh haddock products and by-products or waste of haddock.

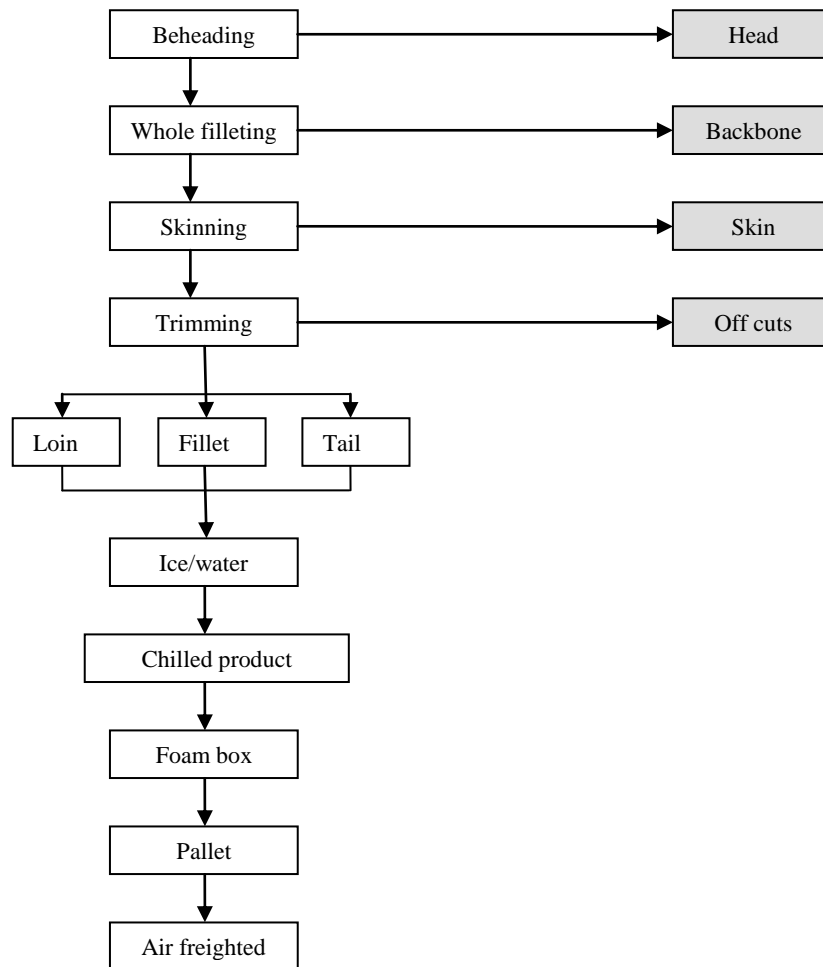


Figure 2: Flow chart of haddock processing.

Fresh products

Fresh cod products are usually called “2fly fish” in the plant because that kind of product is air freighted to foreign markets. A wide variety of fresh seafood products are exported by air for freshness on a daily basis, to the European continent, the UK and the US. Products exported to the UK account for up to 85% of the factory production, 10-12% of the products are exported to the USA and the rest are sold in the domestic market (Figure 3).



Figure 3: Loading the product at Keflavik International Airport.

By-products

The main by-products are heads and backbones, which are sold to another company to process dried products. Dried heads and backbones have a big market in Nigeria.

The information about dried haddock by-products was collected when visiting Laugafiskur Ltd. in Akureyri in September 2006 (Figures 4 and 5). The skin is block frozen and exported to produce gelatine. Cut-offs from trimming are used for production of mince and (pin bones and by-cuts) is transported to the fishmeal plant to process fishmeal.



Figure 4: Heads in Laugafiskur Ltd. before drying Figure 5: Heads in Laugarfiskur Ltd. after drying

Reception: There is quality assessment for the raw material at the reception area in Tros Ltd. The temperature of the raw material is checked and the quality of the fish is estimated accordingly.

Raw material storage:

As mentioned earlier, the raw material is processed the second day after being received at the plant. The raw material is iced and stored in a chilling room until it is processed. The temperature in the chiller is kept at 0-4°C.

Beheading and grading:

The raw material is beheaded before going into the processing line. Each size category is kept separate after beheading in a tank with flake ice water to make sure the temperature is maintained.

Inspection:

Temperature controlling is always the key factor to control fish product quality. Temperature and time have a great influence on fish flesh gaping. Samples are taken at the end of the processing line and the temperature is tested to make sure that the temperature has been well controlled during the processing

Cold storage and transportation:

When the product has been stacked on pallets, it is moved to a cold storage as soon as possible. The temperature in a cold storage shall be -25°C or lower. Care should be taken to keep the time that the product is exposed to warmer air to a minimum. For

long distance transporting on land, trucks equipped for transporting chilled commodities should be used.

Traceability information on quality

The traceability information collected includes:

- Temperature of the raw material/product (when received)
- Weight of the raw material/product
- Quality estimation of the raw material

The quality checks (where traceability information is collected) are done in the following stages:

- Reception of raw material
- Trimming stage
- Between trimming and packing
- End product

3.1.3 Traceability at Tros Ltd.

The company processes 10 -12 tonnes per day and the lot or batch in case of raw material from the contracted boats is made from the fish coming from the same fishing ground for easier traceability. In case of raw material coming from the auction market, they try to find fish coming from one fishing ground and the age (fishing days) and size of the fish also matters, the age has to be only one day old.

Batching

The 10 or 12 tonnes are then processed as different lots according to the source of raw material. For example, if the company has received 8 tonnes from four different boats and 2 tonnes from the auction, then they will be processed as five different lots and will be given different batch numbers. This is done to make it easier to trace the product through the production and distribution chain.

The factory relies on paper-based traceability but will have IT based traceability for the following reasons:

- It will be much easier to provide any traceability information needed as all the information will be in a computer eliminating the trouble of searching in folders.
- When you have all the information together in one place then it will be easier to have a full picture of what is really happening like trends in production for different years, the yield per boat etc. This makes it easier to make proper decisions regarding production.

3.2 Tanzanian fish factory: Bahari Food Ltd.

A field study on the production, quality control and traceability system was carried out in the company Bahari Food Ltd. focusing on tuna and octopus products. They have implemented a traceability system for their products and a documentation system to verify the quality. Bahari food was visited thrice for this project. The basic data about production of tuna and octopus were collected during the visits.

Bahari Food Ltd. is based in Mikocheni light industrial area in Dar es Salaam, not far from the fish landing harbour in Dar es Salaam port. Mikocheni industrial area is less than half an hour drive from Dar es Salaam International Airport. The factory currently has about 100 employees. The processing plant in Mikocheni is specialised in the production of tuna and octopus.

3.2.1 Production at Bahari Food Ltd.

The raw material is mainly obtained from two sources:

- 1 Company fishing vessels (tuna fishing)
- 2 Artisanal fishers (octopus fishing)

The company owns six fishing vessels and some of these supply raw material to the factory. Among the fishing vessels owned by the company, are tuna fishing vessels. The vessels land their catch at the Dar es Salaam harbour as iced fresh fish and the raw material is transported to the factory by trucks. There are two collection centres of octopus raw material along the coast i.e in Tanga and Kilwa. The truck brings the raw material to the factory from each centre.

Processing of octopus at Bahari Food Ltd

The processing of octopuses is done when raw material arrives at the plant. The raw material is washed and then weighed to check if the weight correlates with the information given by the collectors.

Reception of raw material:

Raw material is received from artisanal fishermen. The raw material is checked before processing starts to make sure it is of good quality. The raw material is then, gutted, properly washed and iced. The temperature is kept below 4°C.

Agitating: (octopus)

The octopuses come directly from the washing area to the agitator which is the machine used to soften the octopus muscle. After agitating, they are arranged onto the trays ready for IQF.

IQF:

The freezing trays are then placed on the racks of the fast freezers. The freezing time is usually 2.5 - 3 hours or until the core temperature has reached at least -18°C.

Weighting and packing:

After freezing, the trays of octopus are removed from the freezer and the individual pieces are weighed (Figures 6 and 7) and packed into the boxes (Figures 8)



Figure 6: Weighing of octopus at Bahari Food Ltd Figure 7. Packing of frozen octopus at Bahari Food Ltd.



Figure 8: Packed frozen octopus at Bahari Food Ltd.

Palletting:

The cartons are then stacked on pallets and strapped with plastic and labelled.

Frozen storage:

Palletised product (octopus) is placed immediately into frozen storage at a minimum temperature of -18°C .

Processing of octopus at Bahari Food Ltd

The processing of fish is done when raw material arrives at the plant. The raw material is washed and then weighed to check if the weight correlates with the information given by the vessel captain.

Reception of raw material:

There are primarily two types of raw material, gutted and ungutted. The raw material is checked before processing starts to make sure it is of good quality. The raw material is then, gutted, properly washed and iced. The temperature is kept below 4°C .

Beheading and grading:

The raw material is beheaded and graded manually into different grades.

Weighting and packing:

The fish are weighed and packed in Styrofoam boxes.

Palletting:

The Styrofoam boxes are then stacked on pallets and strapped with plastic and labelled.

Chill storage:

Palletised product is placed immediately into chill storage at a minimum temperature of -25°C.

Products

Bahari Food Ltd. processes tuna species and *Octopus vulgaris* into a variety of products: Frozen gilled and gutted tuna species, frozen gilled and ungutted tuna species, block frozen *Octopus vulgaris* and flower style frozen *Octopus vulgaris*.

During the visit to this plant, a study was done to have an overview of tuna and octopus processing (Figure 9).

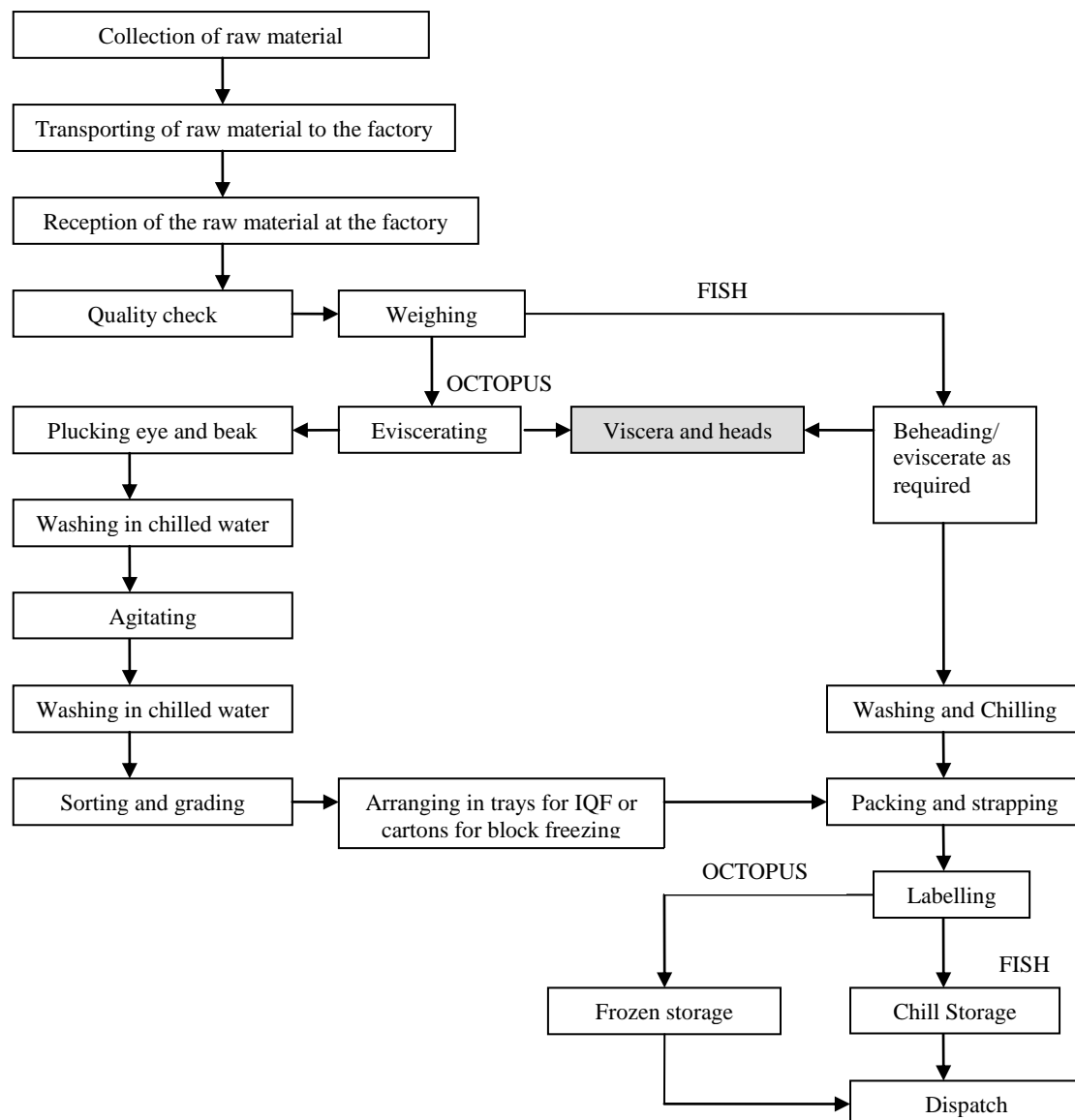


Figure 9: Flow chart of tuna and octopus processing.

Fresh products:

Fresh tuna products air freighted to foreign markets. A wide variety of fresh seafood products are exported by air for freshness to Europe, the USA, and Japan.

Waste and by-products:

The main by-products are heads and viscera, which are sold to fishmeal producers.

Frozen products:

Frozen product is the main product group in the octopus processing industry. At least two kinds of products were processed during the visit: block frozen *Octopus vulgaris* and flower style frozen *Octopus vulgaris*.

3.2.2 *Quality control at Bahari Food Ltd.*Reception:

There is quality assessment for the raw material at the reception area in Bahari Food Ltd. The temperature of the raw material is checked and the quality of fish is estimated accordingly basing on sensory evaluation.

Raw material storage:

As mentioned earlier, the raw material is processed on the second day after being received at the plant. The raw material is iced and stored in a chilling room until it is processed. The temperature in the chilling room is kept at 0-4°C.

Beheading and grading:

The raw material is beheaded before going into the processing line. Each size category is kept separate after beheading in a tank with flake ice water to make sure the temperature is maintained.

Inspection:

Samples are taken at different stages in the processing line, and the temperature is measured to make sure that the temperature has been well controlled during the processing.

Cold storage and transportation:

When the product has been stacked on pallets, it is moved to cold storage as soon as possible. The temperature in the cold storage shall be 4°C or lower. Care should be taken to keep the time that the product is exposed to warmer air to a minimum. For long distance transporting on land, trucks equipped for transporting frozen commodities should be used.

The traceability information on quality includes:

- Temperature of the raw material/product
- Weight of raw material/product
- Quality estimation of the raw material

The quality checks (where traceability information is collected) are done in the following stages:

In octopus processing:

- Reception of raw material
- Agitating stage
- Freezing stage
- End product.

In tuna processing:

- Reception of raw material
- Packing stage
- End product.

3.2.3 Traceability at Bahari Food Ltd.

Batching:

A batch is a group of similar items produced, processed or gathered together and treated as a single unit or handled together. A batch or lot has uniform quality characteristics (e.g. processing cycle).

The company processes 5-10 tonnes per day, for raw material coming from the company vessels, a lot or batch is made from fishing trips for easier traceability. For raw material coming from the artisanal fisherfolks, one truck makes the batch.

Traceability information on quality:

Temperature controlling is always the key factor to control fish product quality. Temperature and time have a high influence on flesh gaping and quality deterioration.

Other attributes traceability information on raw material:

When raw material is received at the factory the following information is recorded:

- Weight of raw material
- Temperature of raw material
- Name of fishing vessel
- Landing date and time
- Reception date and time
- Name of vessel
- Specie
- Name of the captain

After production the weight of the end product, as a result of processing the raw material, is recorded together with the temperature of the product.

Raw material from artisanal fishers:

The following is recorded:

- Name of the collection centre
- Name of the fisherman
- Collector's name
- Type of raw material
- Size
- Weight
- Collection date and time
- Departure day (the day the raw material was transported to the factory)
- Truck number
- Driver's name and ID

The factory relies entirely on a paper-based traceability system.

The following are the reasons why the company has been thinking of setting up an IT based traceability system (Personal communication).

- The main market of company products is the EU and one of the EU standards requires the producer of fish and fish products to have a proper traceability system which is efficient and reliable.
- It will be much easier to provide any traceability information that is needed as all the information will be in a computer which will eliminate the trouble of searching in folders.
- When all the information is together in one place, it will be easier to obtain a full picture of what is really happening like trends of production in different years, the yield per boat etc., making it possible to take proper decisions regarding production.
- The cost of putting everything on paper and time of retrieving the information will be reduced.

4 SYSTEM ANALYSIS AND DESIGN FOR A DIGITISED TRACEABILITY SYSTEM

Tools and techniques from object oriented methodologies have been used for preliminary investigation, requirements determination, analysis and design. Object oriented methodology has been adopted. Unified Modelling Language (UML) has been employed as the object oriented methodology for the project. The traceability system will be implemented on the following platform:

- HTML to develop front-end platform.
- The database at the back end would be MySQL.
- The development aspect of it is going to be based on web technology.
- Modelling of this system is done using object oriented modelling techniques, particularly using the UML.

An installation of the traceability system will be done at the site after thorough testing has been carried out on the system and it has been confirmed that the system functions as per the user requirements. Recovery and backup will also be done by the system.

4.1 UML (Unified Modelling Language)

The Unified Modelling Language (UML) is an “object modelling” technique. Instead of entities, it models “object classes”.

In UML certain numbers of graphical elements are combined into diagrams. Because it is a language, the UML has rules for combining these elements.

The purpose of the diagrams is to present multiple views of a system, and this set of multiple views is called a model.

Benefits of UML (Computer Training):

- 1 Your software system is professionally designed and documented before it is coded. You will know exactly what you are getting in advance.
- 2 Since system design comes first, a reusable code is easily spotted and coded with the highest efficiency. You will have lower development costs.
- 3 Logic “holes” can be spotted in the design drawings. Your software will behave as you expect it to. There are fewer surprises.
- 4 The overall system design will dictate the way the software is developed. The right decisions are made before you are married to poorly written codes. Again, your overall costs will be lower.
- 5 UML lets us see the big picture. We can develop more memory and processor efficient systems.
- 6 When we come back to make modifications to your system, it is much easier to work on a system that has UML documentation. Much less “relearning” takes place. Your system maintenance costs will be lower.
- 7 If you should find the need to work with another developer, the UML diagrams will allow them to get up to speed quickly in your custom system. Think of it as a schematic to a radio. How could a tech fix it without it?
- 8 If we need to communicate with outside contractors or even your own programmers, it is much more efficient.

4.2 Why web-based?

The use of a web-based application has many advantages to both the owner of the business and customers. Here are some of the advantages:

Global Access: A very important benefit of a web-based service is the globally accessible nature of the service. Offices from down the hall to around the world can securely access the same information. Dedicated lines between offices do not need to be established; instead existing Internet connectivity can be used. Divisions located in different geographic areas can instantly share resources such as accounting records, order status, and shipping information. Applications are distributed and accessed solely through the Internet rather than installed on company systems. Therefore it saves time.

Implementation is simple: Software that is installed on each PC in a company can be a very complex project to install and support. One of the problems with workstation software is that it can require constant attention from your IT department to address conflicts, installations and upgrades. With a web-based service changes are made instantly keeping everyone current with the most up to date software. Web-based services can be tested and evaluated with very little effort; they can also be deployed instantly to all users in an organisation. The only requirement for a web based service is a workstation with an Internet connection and web browser.

4.3 Requirements gathering

It is the initial stage in system development, the first and the foremost step that was performed and includes the information about the requirements for the proposed system of Bahari Food Ltd. and Tros Ltd. The requirements are pertained to such as resources, scope of the system, purpose of the system and the limitations. To build the right system what the client wants or the client's requirements should be well understood.

The requirements gathering process is intensified and focused especially on software. To understand the nature of the program(s) to be built, the information domain for the software should be understood, as well as its required function, behaviour, performance and interfacing. The essential purpose of this phase is to find the need and to define the problem that needs to be solved. (Computer Training)

4.3.1 Discover business processes

Here an understanding of the client's business processes was gained by interviewing the client or a knowledgeable client-designated person. The interviewees were asked to go through the relevant processes step-by-step in both fish factories, Bahari Food Ltd. and Tros Ltd.

In this stage, the activity diagram shows the sequence of activities from the point when the raw material is supplied at the factory, through processing and to the last point when the product comes out of the factory as a by-product or the final product. It makes use of swim-lanes to show the people involved in the system and the flow of activities from one person to the other. Swim lanes are parallel segments which add the dimension of visualising roles.

Deliverable: Activity diagram(s). See Appendix 1.

4.3.2 Perform domain analysis

Domain analysis is the study of the "territory" of where the application will be used and this will include understanding the environment, needs of the users, and the problems that are trying to be solved.

The clients, Bahari Food Ltd. and Tros Ltd. were interviewed with the goal of understanding the major entities in the client's domain. During the conversation between the client and the analyst, notes were taken. From the explanation given by the clients, the domain analysis started by making some of the nouns class.

Ultimately, some nouns become attributes. Verbs and verb phrases from the client's explanation become operations or labels of associations of the classes. The objective is to produce an initial class diagram.

Tros Ltd.

From the Tros Ltd. client's interview, the nouns were filtered and the following meaningful groups were formed.

The first group consists of raw material suppliers: auction market and contracted boats.

The second group consists of processing stages: reception, grading, beheading, filleting, skinning, portioning, trimming, cold store, and packing.

The third group consists of raw products: head, backbone, skin, mince, loin, tail.

The fourth group consists of customers: domestic and foreign

The following verbs were filtered: fishing, selling, store, quality check, process, dispatch order product, supply, grading, produce, place order, transport.

Bahari Food Ltd.

From the Bahari Food Ltd. client's interview, the nouns were filtered and the following meaningful groups were formed.

The first group consists of raw material suppliers: artisanal fishers and company vessels.

The second group consists of processing stages: washing, eviscerating, agitating, IQF, and packing.

The third group consists of raw products: viscera, whole fish, frozen octopus.

The fourth group consists of customers: domestic and foreign.

The following verbs were filtered: fishing, selling, store, quality check, process, dispatch order product, supply, grading, produce, place order, transport. (Developer Shed Class Relationships)

Deliverable: High-level class diagram. See Appendix 2.

4.3.3 *Identify cooperating systems*

Early in the process the development it was established exactly which systems the new system will depend on, and which systems will depend on it. This action has been taken care of. The local area network will take part in the traceability system and as the traceability system is a web-based one, the Internet interface will be implemented on the LAN's server. (Computer Training)

Deliverable: Deployment diagram. See Appendix 3

4.3.4 *Discover system requirements*

In this action first Joint Application Development (JAD) session was covered whereby system requirements were gathered and documented. This session brings together decision makers from client's organisation, potential users and the analyst. The session was moderated and the information from users on what they want the system to do was elicited. Notes were taken and the class diagram developed earlier was refined. (Computer Training)

Deliverable: Package diagram. See Appendix 4

4.4 **Analysis**

In analysis the results of the requirements segment of the two factories Tros Ltd. and Bahari Food Ltd. were refined, therefore increasing understanding of the problem. In fact, some of the actions begin during the requirements segment, by refining the class diagram.

First the use case analysis was done and a use case diagram for every package was produced.

Next the interactions among objects were discovered and analysed in the traceability system for both Bahari Food Ltd. and Tros Ltd. and collaboration diagrams were produced.

Lastly, in the analysis the interactions between the traceability systems with existing systems were examined whereby it has been suggested that the factory LAN of both factories should take part in the traceability system. A detailed deployment diagram was produced with few user interfaces introduced.

4.4.1 *Understanding system usage*

In a Joint Application Development (JAD) session with potential users, the users were involved to discover the actors who initiate each use case from the requirements JAD session and the actors who benefit from those use cases (an actor can be a system as well as a person).

A use case is a description of a system's behavior from a user's standpoint. For system developers, this is a valuable tool: it's a tried-and-true technique for gathering system requirements from a user's point of view. That's important if the goal is to build a system that real people can use. In graphical representations of use cases a symbol for the actor is used. The actor is the entity that initiates the use case. It can be a person or another system.

(Agile Modelling)

Deliverable: Use case diagram(s). See Appendix 5.

4.4.2 *Flesh out use cases*

This stage is just a continuation in working with users; the objective is to analyse the sequence of steps in each use case. The previous stage gives the picture of what the system will have to do, this is moving gradually from understanding the domain to understanding the system and the use cases have provided the bridge. Each use case has been fleshed out and the components of the traceability system are starting to materialise. The system related steps in the scenario are extremely important as they show how the system is supposed to work.

Deliverable: Text description of the steps in each use case diagram. See Appendix 6.

4.4.3 *Refine the class diagrams*

Analysis of every class gained in the previous stage (domain analysis) was done and a class diagram was refined for both systems, Tros Ltd. And Bahari Food Ltd. Names of the associations, abstract classes, multiplicities and generalisations were filled. A class is a category or group of things that have similar attributes and operations. An object is an instance of a class - a specific thing that has specific values of the attributes and behavior (Sparx systems)

Deliverable: Refined class diagram. See Appendix 7.

4.4.4 *Analyse changes of state in objects*

The model was refined by showing changes of state wherever necessary. At any given time, when an object is in a particular state. State diagrams represent these states and their changes during time. Every state diagram starts with a symbol that represents the start state and ends with symbol for the end state. For example every person can be a newborn, infant, child, adolescent, teenager or adult.

Deliverable: State diagram. See Appendix 8.

4.4.5 *Define the interactions among objects*

As a set of use cases and refined class diagrams are in place, it was time to define how the objects interact. A set of diagrams was developed which includes state changes. Collaboration diagrams and sequence diagrams belong to a group of UML diagrams called interaction diagrams.

Sequence diagram

Class diagrams and object diagrams represent static information. In a functioning system, however, objects interact with one another, and these interactions occur over time. The UML sequence diagram shows the time-based dynamics of the interaction.

Collaboration diagram

The elements of a system work together to accomplish the system's objectives and modeling language represents this through a collaboration diagram. However, instead of showing the sequence of events by the layout on the diagram, collaboration diagrams show the sequence by numbering the messages on the diagram. This makes

it easier to show how the objects are linked together, but harder to see the sequence at a glance.

Deliverables: Sequence diagrams See Appendix 9.
 Collaboration diagrams See Appendix 10.

4.4.6 *Analyse integration with cooperating systems*

This stage proceeds in parallel with all the preceding steps, and it has uncovered specific details of the integration with the cooperating systems. Here are the details of the type of communication involved and the network architecture.

Deployment diagram

The UML deployment diagram shows the physical architecture of a computer-based system. It can depict the computers and devices, show their connections with one another, and show the software that sits on each machine.

As the local area network of the factory (both Tros and Bahari Food) will take part in the traceability system, then the physical architecture of the local area network for Bahari Food Ltd. was suggested and analysed (Figure 10).

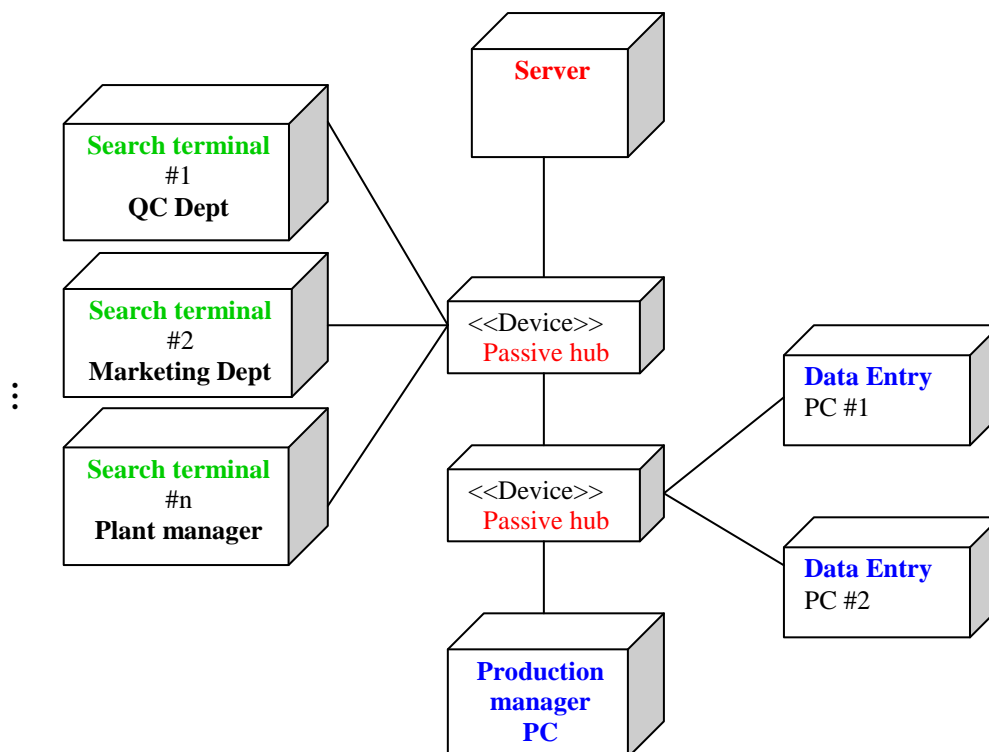


Figure 10: Suggested deployment diagram for Bahari Food Ltd. factory LAN.

From the deployment diagram above, the LAN will consist of the following hardware components:

Table 2: Hardware components of the deployment diagram above.

| Component name | Amount |
|-----------------------|--------|
| Server | 1 |
| Data entry PC | 2 |
| Production manager PC | 1 |
| Search terminals | 6 |
| Passive hub | 2 |

The server is located in one room and a cable from the server goes out from the room to the passive hub located at the corridor. From this hub cables goes to the search terminals located in the offices across the corridor.

Another cable from this passive hub goes to another passive hub located in the plant area where production manager PC and data entry PCs are located.

The possibility of implementing an Internet interface on the server was also looked at. This interface will be used locally from the search terminals, from the production manager PC and from the data entry PCs and through the Internet from customer's homes or offices. Therefore a new hardware must be implemented in the factory's LAN.

The factory's LAN will have the same structure. New hardware will be added only to the server's side, and that is a Network Interconnection Facility (NIF). The NIF consists of a "name server" (a database that validates connections), a "router" (a

device for linking networks together), and a “gateway” (a device for translating information from one communication protocol to another). The gateway allows Internet customers to access the traceability system from home or from their office.

On the customer’s side only a computer with Internet connection, and Internet browser is necessary. Also a customer must have an alias and password to access the traceability web page, as the system information needs to be transparent to the customers.

To illustrate the deployment, the deployment diagram shown in Appendix 11 has been delivered.

Deliverable: Detailed deployment diagram. See Appendix 11

4.5 Design

In this segment, the results of the analysis segment have been used to design the solution. The software system design has been produced from the results of the requirements phase. Design and analysis went back and forth until the design was completed.

This is the phase in which the (analysis work) focus lies. This is where the details on how the system will work are produced. Software design (UML) produced as diagrams, different diagrams are all part of the deliverables of this phase.

The system design created has been reviewed with the users to ensure the design meets users’ needs.

This design will serve as a blueprint for the system and help detect problems before the errors or problems are built into the final system.

In this phase of the software development process, the software’s overall structure has been defined in terms of the client/server technology, the database design, the data structure design etc. The logical system of the product has been developed in this phase.

4.5.1 *Develop and refine object diagrams*

The class diagrams of Bahari Food Ltd. and Tros Ltd. have been referred to generate the necessary object diagrams by examining each operation and developing a corresponding activity diagram.

The activity diagram can be defined as the representation of the sequence of activities that occur within a use case or within an object’s behaviour. It describes in detail the sequence of actions that occur within each transition in the state chart diagrams.

The activity diagram addresses the dynamic view of the system, it models the workflow behind the system being designed.

This activity diagram will serve as the basis for much of the coding in the development segment.

Deliverable: Activity diagrams. See Appendix 12.

4.5.2 Develop component diagrams

This stage is concerned among other things with the visualisation of the components of the traceability system and shows the dependencies among them.

In unified modeling language a component diagram depicts how a software system is split up into physical components and shows the dependencies among these components. It models the static implementation view of a system. Component diagrams can be used to model and document any system's architecture.

Physical components could be, for example, files, headers, link libraries, modules, executables, or packages.

Bahari Food Ltd. and Tros Ltd. traceability systems components are executables, and each system will be one executable file.

Deliverable: Component diagram. See Appendix 13.

4.5.3 Plan for deployment

After aiming the component diagrams, planning for deployment and for integration with cooperating systems was done for the Bahari Food traceability system. The created diagram shows where the components will reside.

Deliverable: Part of the deployment diagram developed earlier. See Appendix 14

4.5.4 Design and prototype user interface

This is a typical indication of the interplay between analysis and design. A GUI analyst works with the users to develop paper prototypes of screens that correspond to groups of use cases.

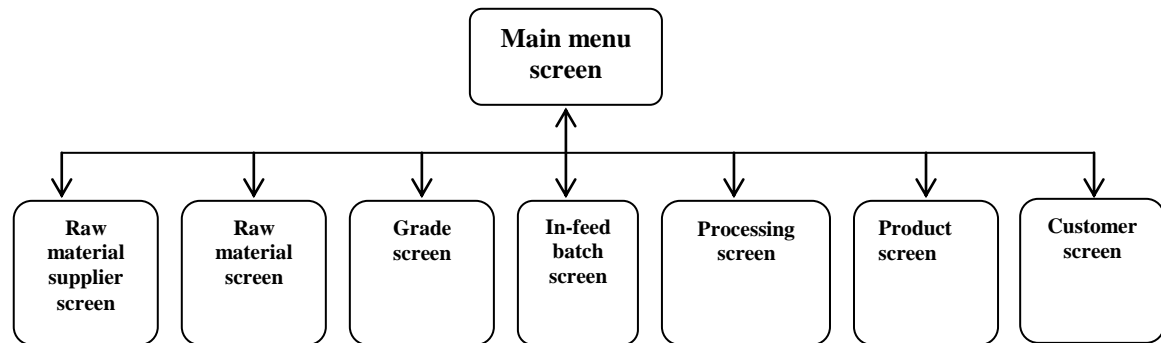


Figure 11: UML state diagram for high level screen flow in the main menu interface Tros Ltd. traceability system.

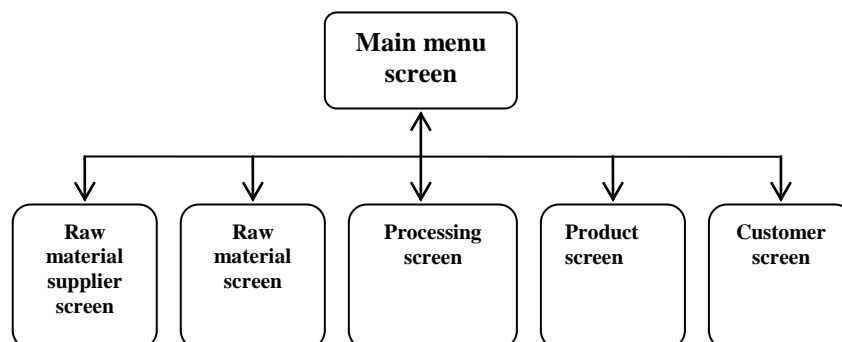


Figure 12: UML state diagram for high level screen flow in main menu interface Bahari Food Ltd. traceability system.

4.5.4.1 Interface design

“Interface is a collection of operations that are used to specify a service of a class or component and user interface is the interface through which the user interacts with the system” (Jacobson *et al.*).

Good user interface design is crucial to the success of a system. An interface that is difficult to use will, at best, result in a high level of errors. At worst, users will simply stop using the system and abandon it regardless of its functionality. If the interface looks awkward or if information is presented in a discouraging manner, users may misinterpret the meaning of the data in question.

Previously user interfaces had to be textual or form-based. Although text-based interfaces are still widely employed, computer users now expect application systems to have some form of Graphical User Interface (GUI), which supports a high resolution display and interaction using mouse as well as keyboard.

4.5.4.2 The advantages of GUIs are (Sommerville 2001)

- They are relatively easy to learn and use. Users with no computing experience can learn to use the interface after a brief training session.
- The user has multiple screens (windows) for system interaction. Switching from one task to another is possible without losing sight of the information generated during the first task.
- Fast, full-screen interaction is possible with immediate access to anywhere on the screen.

4.5.4.3 User interaction

When designing a user interface, a key issue to be considered is how information from the computer system can be presented to a user? User interaction means issuing commands and associated data to the computer system. There are several types of user interactions and different forms of interaction have been classified into five primary styles (Shneiderman 1998):

1. Direct manipulation where the user interacts directly with objects on the screen. For example, to delete a file, a user may drag it to the trashcan.
2. Menu selection where a user selects a command from a list of probabilities. In this approach, to delete a file, the user selects a file, and then selects the delete command.
3. Form fill-in where a user fills in the fields of a form. Some fields may have associated menus and the form may have an action “button” that when pressed, causes some action to be initiated. Here, deleting a file would involve filling in the name of the file, then “pressing” a delete button.
4. Command language where the user issues special commands and associated parameters to instruct the system what to do. To delete a file, the user issues a delete command with the filename as a parameter.
5. Natural language where the user issues a command with natural language. To delete a file, the user might therefore type “delete” the file names xxx.

| Interaction style | Main advantages | Main disadvantages | Application example |
|----------------------------|--|---|---|
| Direct manipulation | Fast and intuitive interaction easy to learn | May be hard to implement only suitable where there is a visual metaphor tasks and objects | Video games CAD systems |
| Menu selection | Avoids user error Little typing required. | Slow for experienced users can become complex if many menu options | Most general purpose systems |
| Form fill-in | Simple data entry easy to learn | Takes up a lot of screen space | Order processing Personal loan processing |
| Command language | Powerful and flexible | Hard to learn poor error management | Operating systems Library information Retrieval systems |
| Natural language | Accessible to casual users easily extended | Requires more typing Natural language understanding systems are unreliable | Timetable systems Information retrieval systems |

Figure 13: Advantages and disadvantages of interaction styles (Shneiderman 1998).

4.5.4.4 User interface design

When designing the Bahari Food Ltd. and Tros Ltd. traceability system user interface, it was discovered that it is crucial that physical and mental proficiency of end users be taken into account. People have a limited short term memory and make mistakes, especially when working under stress. The interface therefore employs terms and concepts that the users of the system are familiar with. Diversity of users was considered when designing the interface after all every person is unique in his/her own way of using the system.

After considering the advantages and disadvantages of several different types of user interactions, it was decided that form fill-in together with menu selection would be the appropriate interface choice for Bahari Food Ltd. and Tros Ltd. traceability systems. Figure 17 shows a sample form fill-in interface for the traceability system.

The image shows a software interface for a 'RAW MATERIAL FORM'. The form is set against a blue background with a white dot pattern. It contains several input fields and dropdown menus arranged in two columns. The fields are: 'Batch number', 'Weight', 'Date of reception', 'Specie', 'Landing date', 'Fishing gear', 'Catching ground', 'Age of fish', 'Processing method on board', and 'Temperature record'. The 'Specie', 'Fishing gear', and 'Grading size' fields are dropdown menus. At the bottom right, there is a panel with seven buttons: 'Save', 'New', 'Delete', 'Back', 'Next', 'View', 'Edit', and a larger 'Back to Main Menu' button.

Figure 14: Sample form fill in interface.

Deliverable: Screen shots of the screen prototypes. See Appendix 15

4.6 Database design

“A database is an integrated pool of information stored on a computer in such a way as to be accessible to many independent applications” (Tudor and Tudor 1998).

A database focuses on the structure and constraints on data. Management of data storage, concurrent access control and convenient access to data are the core functions expected of any database.

Databases offer the option of operating on sets of data at a time using high-level language such as Sequential Query Language (SQL) and provide the user with an attractive means of long term data storage.

Databases have been adopted and are dominant over the traditional paper-based method of record keeping for several reasons. Databases hold only one copy of data allowing different applications and users to share that one copy based on their access rights. The storage of just one copy warrants that no inconsistent data is harboured within the database, data integrity and security is also ensured. The number of large

file cabinets used to hold conventional files are extensively reduced. The machine is faster and more accurate in processing information and can thus provide the user with up-to-data.

4.6.1 *Relational model*

The relational model is a particular type of theoretical data model. It has three parts:

- A structural part: the type of structures (building blocks) from which the database is constructed.
- A manipulative part: the operations that are used for retrieving and updating data in the database.
- An integrity part: the rules that all valid databases must obey.

When compared to the other database models (the hierarchical modes and the network model) the relational model offers some important advantages:

- Mathematical vigour: everything in the structure of the database has a precise and unambiguous definition.
- Logical and physical independence: the logical and physical characteristics of the database are separated.
- Simplicity: the model is much more easily understood.
- Set-oriented: there are powerful set-oriented operators available, which enable even complex operations to be accomplished with simple statements.
- Automatic navigation: users of a relational database do not need to be aware of the physical structure in which data is organised.

4.6.2 *Database choice justification*

The Tros and Bahari Food traceability systems will be implemented using the relational database. From the advantages stated in the previous sections, it was obvious that the relational database is currently the best choice among other database models. The traceability system for the Bahari Food Ltd. and Tros Ltd. adopts SQL as the relational database management system.

4.6.3 *Mapping the class diagram to database tables*

From UML analysis the issue for database design is how to map the object model to database tables.

To develop UML analysis of Bahari food Ltd. and Tros Ltd. into relational database design the following activities were undertaken:

- Extend the three schema architecture for the object models (Figure 15).
- Formulate object models for the external and conceptual schema.
- Then translate each object model to ideal tables i.e. tables models. Views and/or interface programs connect external tables to conceptual tables. Conceptual tables convert to internal schema via SQL.

For object classes: Object ID's primary keys were used

Maps object classes to tables where each class is mapped to one or more tables (Appendix 16)

For associations:

Each many-to-many association mapped to a distinct table
Each one-to-many association mapped to a distinct table or appears as a foreign key attributes aggregation follows same rules as association.

Single inheritance:

A super class and each subclass mapped to a table with the same primary key where no subclasses, bring all subclass attributes up to super class level.

(Sparx systems)

The table structure for the Bahari Food Ltd. and Tros Ltd. database design includes all the classes with their attributes. The top most attribute is the primary key and is in bold.

The subclass attributes have been brought up to the super class level rather than having their own tables. This was done to minimise the number of tables the user has to access to get details of a particular record.

Example the supplier table includes auction number and auction ID, which in the class diagram belong to the subclass auction market. To find auction details the user will not have to access another table. Rather, the details will be obtained within the supplier table. Thus it becomes faster and more efficient.

Other advantages of using one table per hierarchy are: simple approach, easy to add new classes, you just need to add new columns for the additional data, supports polymorphism by simply changing the type of the row, data access is fast because the data is in one table, ad-hoc reporting is very easy because all of the data is found in one table.

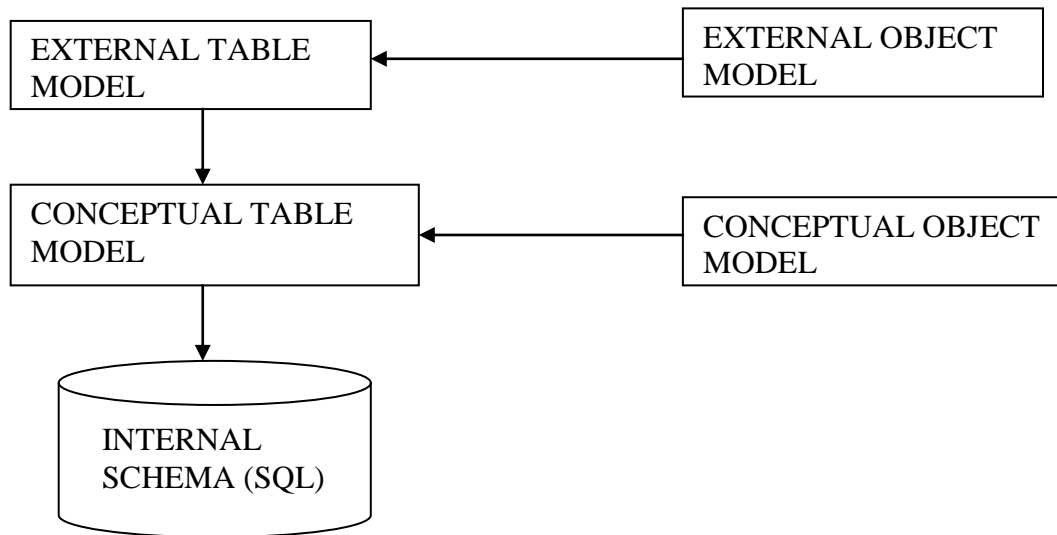
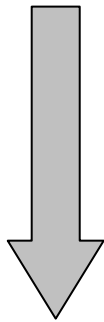


Figure 15: Extended the three schema architecture.

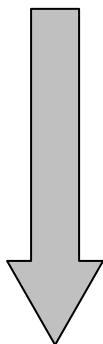
OBJECT MODEL



CLASS RAW MATERIAL SUPPLIER

| Raw material supplier |
|---|
| +supplierID +batchNumber +dateOfSupply +vesselName +vesselNumber +auctionNumber +bidNumber +buyerID +unitsBought +contractNumber +address +companyName |
| +create () +update () +delete() |

TABLE MODEL



| ATTRIBUTE | NULLS | DOMAIN |
|------------------|-------|--------|
| Supplier ID | No | |
| Batch number | No | |
| Date of supply | Yes | |
| Vessel name | Yes | |
| Vessel number | No | |
| Auction ID | No | |
| Auction number | No | |
| Bid number | No | |
| Buyer ID | No | |
| Units sold | Yes | |
| Contract number | No | |
| Address | Yes | |
| Telephone number | Yes | |
| Company name | Yes | |

SQL CODE

CREATE SUPPLIER TABLE SQL CODE

```

CREATE TABLE suppliers (
    supplierID char(30) NOT NULL,
    batchNumber char(30) NOT NULL,
    supplyDate char(30),
    vesselName char(30),
    vesselNumber char(30) NOT NULL,
    auctionID char(30) NOT NULL,
    auctionNumber char(30) NOT NULL,
    bidNumber char(30) NOT NULL,
    buyerID char(30) NOT NULL,
    unitsBought char(30),
    contractNumber char(30) NOT NULL,
    address char(30),
    telephoneNumber char(30),
    companyName char(30) ),
    CONSTRAINT suppliers_pk
        PRIMARY KEY (supplierID, auction ID, contractNumber);
(Database design)
    
```

Figure 16: Mapping object class supplier to table.

Deliverable: Database relation tables. See Appendix 16

5 RESULTS AND DISCUSSION

5.1 Class and unit links in the system

The ability to retrieve traceability data in a fast and accurate manner along a supply chain is critical. This requires the management of successive links between what is received, produced, packed, stored and shipped across the entire supply chain (CIES 2005).

An essential feature of any traceability system is the exchange of information. Traceability requires associating the physical flow of products with the flow of information about them. Any trade item and/or location, which needs to be traced or tracked, must have a unique identity. Unique identifier is the key that enables access to all available data about its history, application or location. The traceability system for Bahari Food Ltd. and Tros Ltd. have links between different stages along the production chain which are managed by allocation of unique identifiers to traceable items along the chain.

The links and identifiers are discussed and summarised in the following sections which explain the overview of the design of the digitised traceability system for Bahari Food Ltd. and Tros Ltd. The plants will have a daily report on traceability, which includes the information on the links.

5.1.1 *Raw material supplier*

Tros Ltd.

Suppliers of raw material to Tros Ltd. are contracted boats and auctions (which are also boats). Catching is a key link for traceability of the origin of products. After bleeding gutting, chilling and size grading, the fish are ice-chilled in the beginning of the whole chain. Each tub is fixed with a number on it.

This is the first unit created and labelling of each unit explains how and what data can be referenced. Raw material can be traced back to obtain the fishing date, fishing area and catching time. Information such as haul number, fishing date and fishing area will follow with each tub, so the tub number is the key to tracing back to the fishing date/area, even the exact fishing time.

Bahari Food Ltd.

The suppliers of raw material to Bahari food Ltd. are company boats and artisanal fisherfolks. Tuna normally are not gutted on board but in the factory according to customer specifications. The fish are graded and ice-chilled on board. Tubs are not fixed with numbers on them but one landing is just taken as a batch.

Therefore the first unit created is a batch though the captain records in the log book the number of hauls, haul time and fishing area. Normally the boat goes to one fishing area in each fishing trip. Raw material can be traced back to obtain the fishing date and fishing area. Information such as fishing date and fishing area will follow with each batch (Figure 16).

5.1.2 *Landing and reception*

Tros Ltd.

The batch in Tros Ltd. is defined by the number of tubs brought by one vessel in one day in the case of raw material coming from the contracted boats. On the other hand, the raw material coming from auction is also taken as one batch and it is always from the same fishing ground. Therefore the batch number of raw material is created in the processing plant when the raw material is received and processed. The products can be traced back to the raw material used by this batch no. Thus, the batch no. is the key to linking products to raw material. The plant has the detailed record of raw material used every day.

In the case of raw material coming from the auction market, the information about the raw material provided by the vessel can be accessed through the Internet. All the detailed information about the raw material is carried with the bid number whereby a bid represents the amount sold by the auction to one buyer and that is a batch which has the batch no.

Bahari Food Ltd.

The batch in Bahari Food Ltd. is defined by the quantity of catch brought by one vessel in one day in the case of raw material coming from the company vessel. On the other hand, the raw material coming from artisanal fishers, the truck load is also taken as one batch and it is always from the one collection centre. Therefore the batch number (Figure 16) of raw material is created in the processing plant when the raw material is received. The products can be traced back to the raw material used by batch no. (Figure 16). Again the batch no. is the key to linking products to raw material. The plant has a detailed record of raw material used every day.

5.1.3 *Processing*

Tros Ltd.

Different batches of raw material come from different vessels and it usually takes more than one processing day to process all tubs from each batch of raw material. In other words, several batches of raw material may be processed to produce different products in one day in the plant.

The raw material is beheaded and graded mechanically. Four size-grades of beheaded fish are put into four tanks according to size. Each tank is given a number that is a grade ID so the new unit has been created after beheading and grading in the processing plant and that is a grade.

The tanks which store the beheaded and graded fish ready to be processed are new units. They make one or more in-feed batches. The in-feed batch ID (Figure 17) carries the message which can be traced back from final product to the in-feed batch of raw material. The connection between processing line (products) and the grade ID and in-feed batch ID are recorded when beheaded and graded fish are put onto a processing line. The information carried between links by batch number, grade ID and

in-feed batch ID to final products. Beheading and grading are critical links in the plant, good labelling and recording systems make it possible to trace finished products back to its batch number with the more detailed information on the tub number.

Different batches of raw material come from different sources of raw material. Raw material from artisanal fishers arrives at the factory every day from two collection centres as a truck is leaving from each centre after one day which forms a batch. Raw material from company vessels also arrives everyday and also forms a batch. Sometimes it takes more than one processing day to process all tubs from each batch of raw material. In other words, several batches of raw material may be processed to produce different products in one day in the plant. The information is carried between links by batch number (Figure 18) to final products.

5.1.4 Packaging and labelling

Tros Ltd. and Bahari Ltd.

For each individual package, inner carton or master case the information is indicated on the label. The information listed in Table 3 can be obtained from the label when an identifier of the package is used to retrieve the information from the traceability database. In this case, master case is a new unit to link the product to the buyer. The ID of this unit, box label on the master case label carries detailed information linked to raw material.

5.1.5 Palleting

Tros Ltd. and Bahari Ltd.

Each pallet is a new unit for the product storing and transporting and it has its ID pallet no. (Figure 17) indicated by the pallet label. This is the key link for further storage and shipping. A pallet has been stacked with cases containing one product type, the product is strapped and a pallet-number label pasted on the pallet. This is a key link for further storage and shipping.

Table 3: Label information (EUROFISH).

| Attribute | Meaning |
|-------------------|---|
| Product ID | Unique identification number for each product |
| Grade ID | Unique identification number for each grade |
| Batch number | Unique identification number for each batch |
| In-feed batch ID | Unique identification number for each in-feed batch |
| Product type | Type of the product |
| Production date | Date of production |
| Company name | Name of the company |
| Company address | Address of the company that produces the product |
| Net weight | Net weight of the product |
| Product origin | Origin of the product (marine, aquaculture) |
| Pallet number | Unique identification number for each pallet |
| Unit number | Unique identification number for each unit |
| Product name | Name of the product |
| Scientific name | The scientific name of the product |
| Fishing area | The fishing area the product raw material caught |
| Country of origin | The country which produces the product |
| Best before date | The expiry date of the product |
| Storage condition | The conditions under which the product should be stored |

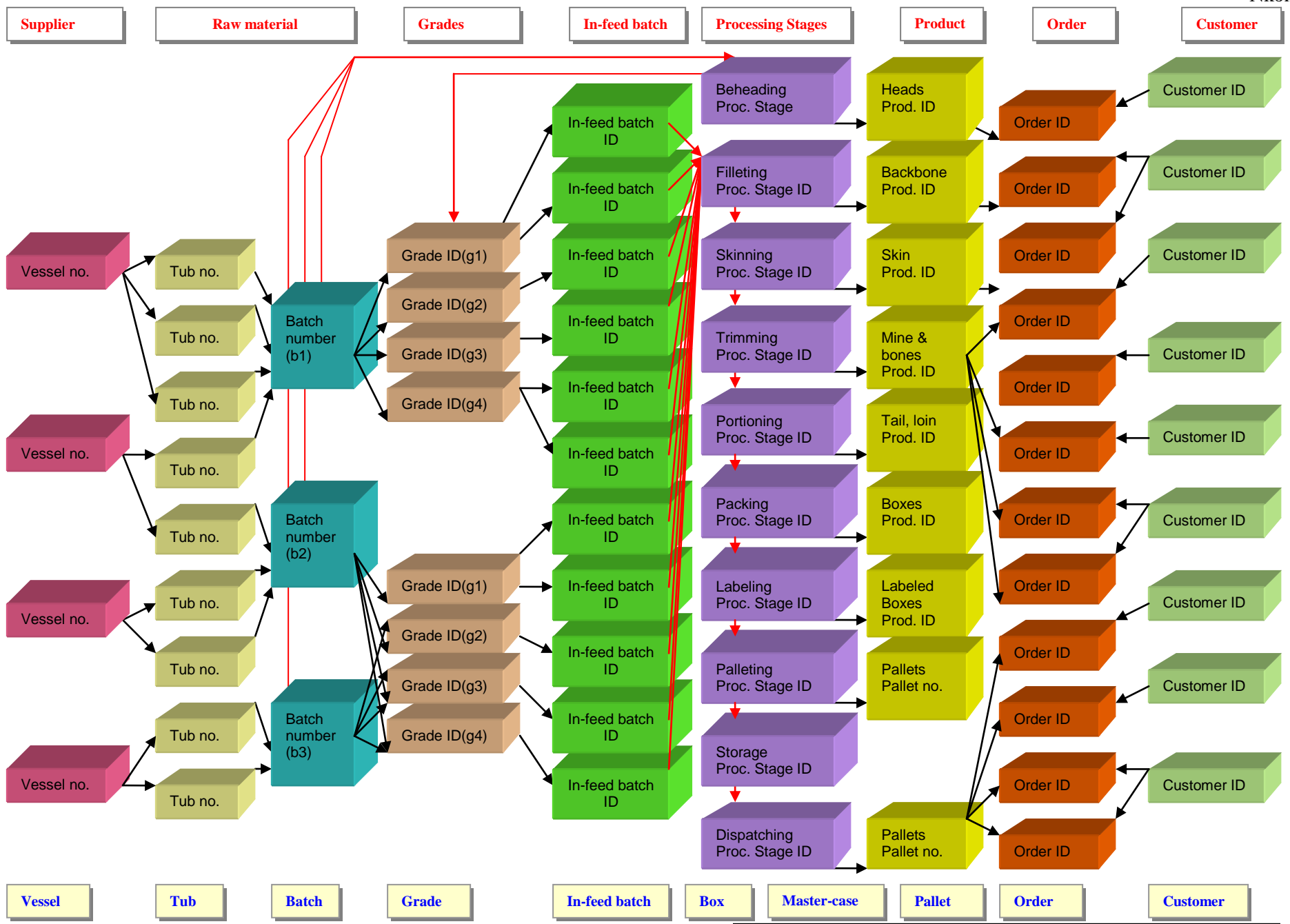


Figure 17: Classes, links and units in Tros Ltd traceability system.

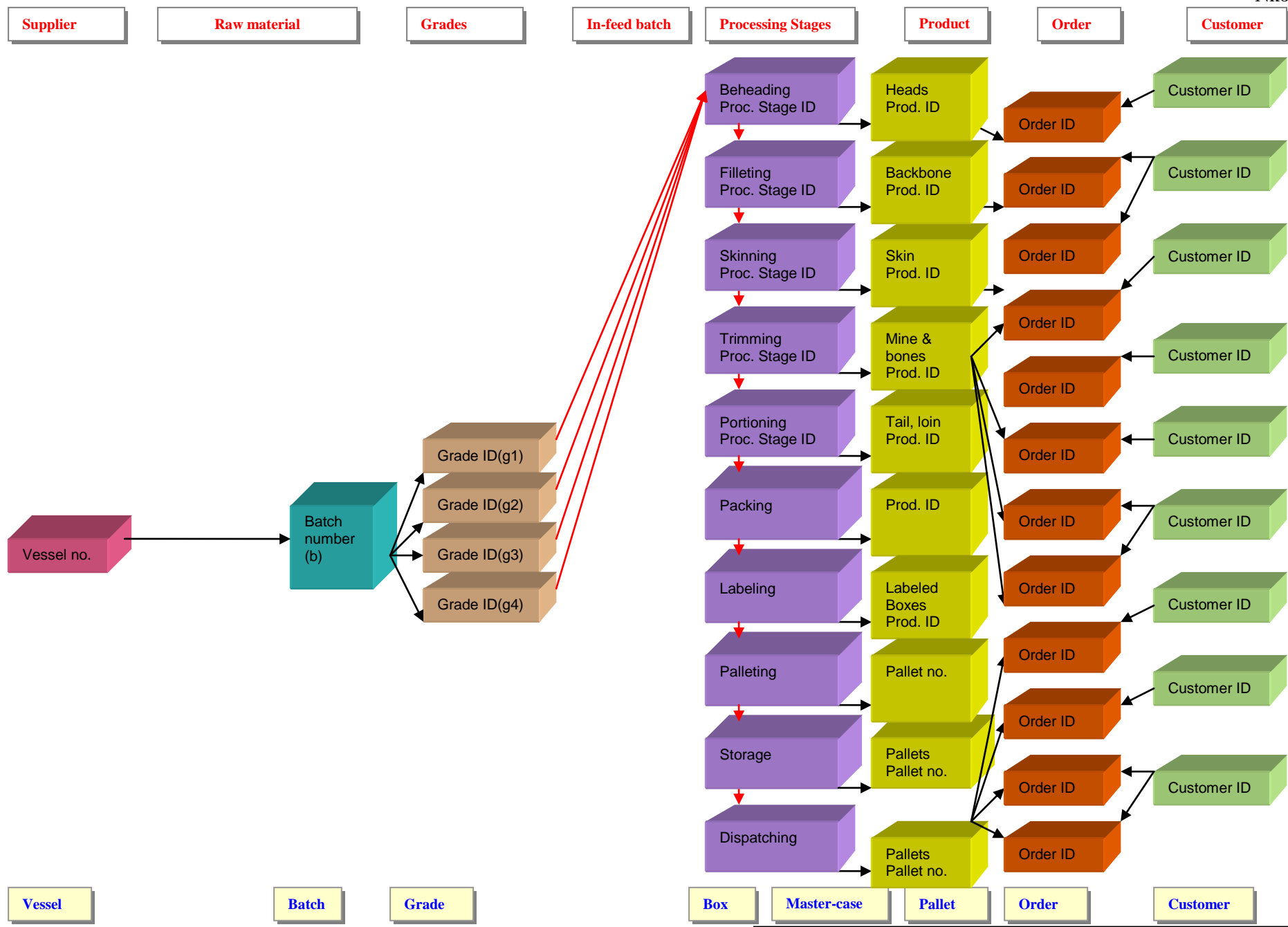


Figure 18: Classes, links and units in Bahari Food Ltd traceability system

KEY Class Units → Relationships → Processing flow

6 CONCLUSION AND RECOMMENDATIONS

Over the last three decades, technological advances in capture fisheries and aquaculture, globalisation trends and market and consumer demands have resulted in the continued growth in the production and trading of fish and fish products. Along with these trends, traceability has become a major concern of fishery industries, especially as it became a legitimate requirement in international fish trade and, more recently, in the growth of fish retailing in food supermarket chains.

Traceability is implemented in the fish supply chain in order to meet both regulatory and market requirements.

New legislation, both in Europe and the USA, which require countries wanting to export fish products to the EU or USA to implement systems to comply with the requirements of regulations, spurred the need for systems that provide full product traceability.

In the EU regulations, which the Tanzanian fisheries industry also needs to comply with, the focus of traceability is on the food safety regulatory requirements, traceability systems can be applied to ensure quality and other contractual requirements. Therefore traceability systems should be seen as an opportunity to improve overall industry management, market position and competitive advantage.

The challenge of meeting the regulations and market demands can seem a steep one, but the development of digitised systems for traceability will make it easier.

Information Technology (IT) plays a central role in food production systems, including trace back systems. A typical computerised tracking system offers a common “language” for businesses along the supply chain to capture essential product information and history.

Computerised trace back systems provide an integrated information exchange platform that can be used across the supply chain, enabling information to be retrieved at any stage before or after the product has entered the marketplace. In addition, many systems are also designed to be flexible and take into account the highly varied documentation and quality standard requirements of multiple national food safety agencies, enabling one central system to be adapted to many export markets (Food Facts Asia 2006).

The implementation of a digitised information system that is designed and developed to meet the precise requirements of the end user can deliver significant benefits. In this context the digitised traceability system will offer among others, operational excellence which can be achieved by increasing efficiency and reducing operating costs, better use of staff resources leading to improved production, quality management procedures and tracing and tracking of the product along the supply chain where some of them are passed on to the customer. In an increasingly competitive food market, traceability has become a major tool in dealing with concerns of food safety, quality assurance, risk prevention, and gaining consumer trust.

The digitised system for Bahari Food Ltd. and Tros Ltd. will offer, among other things, the advantages of traceability information on demand which will meet the regulatory and market demands. In the course of recording traceability information, other attributes which provide information on production are also recorded for instance weight of raw material of a particular batch and weight of the final product as a result of processing the raw material batch. This information at the end will provide information on yield after computing the input and output figures. On the other hand, the yield can also be associated with the fishing ground, fishing season, fishing vessel, fishing method or gear etc. All this information can be obtained by creating queries on the traceability system database which is a depository of all the traceability data.

Therefore, from this study it is concluded that the digitised traceability system is the best choice over paper-based which the Tanzanian fisheries industry is now using, as it offers a wide range of information that, apart from making the industry meet regulatory and market demands, also provides information that can improve production among other advantages.

Some recommendations are suggested for the purpose of improving the traceability systems in fish factories in Tanzania.

As information technology offers the benefits of efficiency including rapid communication and documentation in the traceability system. It is recommended that the fish factories in Tanzania should start implementing a digitised traceability system. Data cannot be managed easily and accessed efficiently with a paper-based traceability system. An electronic database offers fast access and easier data management.

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