UNIVERSITY OF ZIMBABWE

GRADUATE SCHOOL OF MANAGEMENT

Linear optimization of Fish Processing: A Case Study of Lake Harvest Company, Kariba, Zimbabwe.

BY

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R174080D

A RESEARCH PROJECT SUBMITTED IN PARTIAL FULFILMENT OF

THE REQUIREMENTS FOR THE MASTER OF BUSSINES ADMINISTRATION

FEBRUARY 2020

UNIVERSITY OF ZIMBABWE

APPROVAL FORM

The undersigned certify that they have read and recommended to the University of Zimbabwe for the acceptance of the research project entitled "***Linear optimization of Fish Processing: A Case Study of Lake Harvest Company, Kariba, Zimbabwe.***" Submitted by ***DHUBE IAN*** in partial fulfilment of the requirements for the Master of Business Administration.

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PROJECT WAS PRESENTED : MASTER OF BUSSINESS ADMINISTRATION

YEAR THE DEGREE GRANTED : 2020

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APPENDIX ONE: PARTICIPANT CONSENT FORM

I, DHUBE IAN, am a graduate student at the University of Zimbabwe carrying a research project entitled, "***Linear optimization of Fish Processing: A Case Study of Lake Harvest Company, Kariba, Zimbabwe***". This study aims at coming up with a planning model that would help managers to make prompt decision and the company to minimise loss and maximise profitability. It also seeks to give possible solutions to these problems to improve practice and implementation. As a participant you shall be engaged in answering the questions through the interview using the questionnaire as a guideline shall be conducted and providing the required company documents to be used. You may withdraw your participation during the course of the research. You are **kindly** asked to fill in and sign this consent form to show that you are willing to participate in this research project.

For further information you can contact me on: contact address: 16 George Road. Hatfield. Harare. Cell number: 0772 954532. Email:idhube@gmail.com

Sign.. Date..

DEDICATION

I dedicate this research project to my father (Rev P Dhube), my siblings Anthony, Loveness, Precious, Karen and my late mother (E Dhube).

Acknowledgements

This research would not have been possible without my supervisor, Dr Chagwiza, whose guidance; patience and encouragement are gratefully acknowledged.

I would particularly like to thank my brother (Anthony) and his wife, friends and family who supported and always had faith in me; I would also like to thank the staff of Lake Harvest Kariba in Zimbabwe for their ceaseless support that made it possible for the research to be finished. Last but not least I want to extend my heartfelt gratitude to all the respondents who participated in this research. Thank you all for believing in me.

Abstract

The aim of this study was to develop a Net Profit Contribution maximisation model that can be used as a decision tool to aid production managers in determining how best to allocate materials for fish processing, allocate labour hours, meeting customer demand while also preventing inventory build-up. The data was obtained from the operations data obtained from the company's internal reports availed by management. Analysis was done using the linear programming (LP) model. LP is a renowned tool for the purposes of optimisation when faced with resource constraints, yet profits are to be maximised. Two LP models were developed, to determine the processing allocation that maximises Net profit contribution and examine if it was profitable to use overtime with the available production capacity. Several assumptions were made, which are common when formulating LP models. First is that of linearity of variables. The expression to be optimized and the inequalities are assumed to be linear functions of the variables. Second, it was assumed that prices are fixed, for the period under consideration, and possible returns were fixed. The result show that the company stands to realise a high objective value when there is no overtime (Model 2). This indicates that the costs associated with overtime are not offset with the associated benefit. As such, in financial terms, it is advisable that the company do away with overtime. However, management also should consider other factors such as the need to continue providing products which could be forgone by discontinuing overtime. When overtime is avoided, model 2, more of product type B is produced and less of product type A. As such, the need to keep the customers loyal to product type A may compel management to continue with overtime, however at the expense of a declining objective value.

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CHAPTER ONE

1.0 Introduction

This chapter presents the background to the study, problem statement, Aim of the study, the Objectives, scope of the study and delimitation, significance of the study, definition of terms and conclusion of the chapter.

1.1 Background of the Study

The world population is growing rapidly, suggesting that the need for protein food is eminent. United Nations (2012) report estimates the world population to be 9.6 billion in 2050. Current statistics indicate approximately a million people are suffering from chronic malnutrition (FAO, 2014). Furthermore, 70% of the Earth's surface under water, but surprisingly enough only 6.5% of the proteins consumed by human beings comes from fish (Marine Harvest, 2014b). According to FOA(2014) fish trade accounted for about 10% of total agricultural exports in 2012, and predicts total production from both capture and aquaculture to exceed beef, pork and poultry combined in the next decade or so (Mathiesen, 2012). FOA(2014) report suggest that increase in fish processing was necessitated by the introduction of multistage stochastic optimization model for fish processing planning. For example, commercial salmon aquaculture was adopted in Norway in the late 1960s. Using this model fish production in Norway has experienced extraordinary growth and today salmon aquaculture is the fastest food production system in the world (WWF, 2015), producing 2 million metric tonnes (MT) per month, surpassing gas and oil as the major foreign currency earner in Norway (Regjeringen, 2015).

The world over most production systems, planning is based on sales forecasts. Market fluctuations are the basis or roots of most decision problems are made and raw are materials are ordered as needed. This is the case of all production processes, except for fish. In fish processing the process is reversed, due to the randomness of raw materials received from on daily basis that cause the most difficult decision problems. Every morning comes with new and unique situations to the production manager, who has to make flexible decisions about product mix which is a difficult task. While agriculture is activities related to cultivating of soil and animals, aquaculture deals with production of farm bred marine species (National Geographic, 2015). In 2012, fish trade represented about 10% of total agricultural exports and 1% of world merchandise trade (FAO, 2014). For the next decade, total production from capture and aquaculture is expected to exceed the production of beef, pork and poultry combined (Mathiesen, 2012).

The commercialization of aquaculture started with salmon aquaculture in the late 1960s. Since its inception the industry has experienced enormous growth and has dominated the world market since 1999 (Marine Harvest, 2014b). Furthermore, the industry has grown to become Norway to become Norway's largest export commodity after gas and oil (Regjeringen, 2015). The introduction of linear programming models as a production planning aid is posing an interesting modelling challenge globally. Since 1994, 70% of salmon farming companies in Norway have been liquidated (Kontali, 2014), the belief being that they failed to utilize the significant potential derived from using operational research in fish production planning. Generally, as companies develop the size increases and may become global, suggesting that the planning process become increasingly more sophisticated, compelling companies to adopt better decision support tools and portfolio management.

In Zimbabwe Lake Harvest, is the largest tilapia producer in Africa for domestic consumption and export to the European Union Since its inception in 1997 the company has experienced tremendous growth in harvest volumes. For example from 2 500 tonnes whole fish produced in 2010 to 11 500 tonnes whole fish equivalence in 2013 and about 8 000 tonnes to date. However, despite the notable growth and worldwide consumer at its disposal, Lake Harvest does not have a planning model at its plant. The fishing industry features a fast paced and ever changing environment where in recent years development of high-tech equipment have occurred in the processing sector resulting in a wider range of product possibility as well as increasing production capacity. Significant changes have occurred in fish processing where advanced machines and software are now used to control everything from sorting raw material to packaging the final raw material. Customers of fish can place an order and expect its delivery at the end of the day. This fast pace requires fast decisions; therefore the need for decision production planning tools (models) to aid production managers in making prompt decisions is inevitable.

1.2 Problem Statement

Lake harvest has been expanding since its inception in 1997, However it has been operating without a planning model of production. Hence this research seeks to develop a Net Profit Contribution maximisation model that can be used as a decision tool to aid production managers in determining how best to allocate materials for fish processing that will aid managers on costs as well as reduce inventory built up.

As companies grow both in size and geographical presence, the planning process becomes increasing complex. This makes it difficult for managers to make optimal and prompt decisions on how best to allocate raw materials to maximize Net Profit at minimum cost of production without a production planning model in place. The situation is made worse by the sensitivity of fish themselves to environmental conditions. Furthermore, the demand for fish is increasing faster than that of beef, pork and poultry. Developing models that aid managers to make prompt decisions depending of environmental circumstances may help Lake Harvest create its own comparative advantage in the global market. The fish industry is ever evolving and volatile making it difficult for managers to always make correct decisions nearly always. Consequently, the need for optimization model analysis can be beneficial as a decision making tool for production manager in an evolving, fast paced and volatile environment.

1.3 Aim of the study

The aim of this study was to develop a Net Profit Contribution maximisation model that can be used as a decision tool to aid production managers in determining how best to allocate materials for fish processing, allocate labour hours, meeting customer demand while also preventing inventory build-up.

1.4. Objectives

1. To determine the processing allocation that maximizes the Net Profit Contribution.
2. To examine if it is advisable to work overtime with production capacity available

1.5. Research Questions

1. Which processing allocation should Lake Harvest produce per month to maximize Net Profit Contribution?
2. Is it advisable to work overtime considering production capacity?

1.6 Scope of the study/Delimitation of study

This research will be done and limited to Lake Harvest in Kariba Dam, about 355.9 Km North West of Harare the Capital City of Zimbabwe, on the border with Zambia, though some references would be made to other organizations to get a broader insight. The study focused on daily or monthly production statistics, costs incurred and net profits from January 2019 to December 2019 respectively. Furthermore, only permanent employees based at Lake Harvest processing plant in Kariba and management at the Lake Harvest Head Office in Harare were the targeted population.

1.7 Significance of the study

This study is important in that the researcher seeks to investigate a subject that has been scantly explored in Zimbabwe. The researcher will identify fish production planning processes that maximize profits by reducing costs of production for the fish industry in Zimbabwe. In addition adoption of a model for fish will help the company gain a competitive edge in the export market by increasing its quota, thus increasing its profit margins. With increased export comes with increase in foreign revenues for the government. Also more foreign currency means company expands and more people will be employed, reducing the unemployment rate in Zimbabwe.

Introduction of linear model for Lake Harvest means company will continue to operate and not close due worldwide competition. Seventy percent (70%) of the salmon fish farming companies in Norway have closed business because they don’t have a model (Kontali, 2014) due to reasons associated with operational research. The introduction of multistage stochastic optimization model for fish processing planning, prompted by these closures has enabled the salmon fish industry to be the third foreign currency earner for Norway.

Furthermore, Findings from the research will help the company identify other products which may increase its profits margins at minimum cost. This may entail creation of downstream industries and better performance of the company.

Lastly, this research was of significance to the researcher as it was part of the master of business and administration (MBA) course requirement, a program which the researcher was undertaking.

1.8 Chapter summery

This chapter presents the background to the study, problem statement, Aim of the study, the Objectives, scope of the study and delimitation, significance of the study, definition of terms and conclusion of the chapter. The next chapter will focus on the literature review.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

The previous chapter highlighted the background of the study, identified the problem, its significance and the scope of the study. In addition, the objectives, research questions and the hypotheses which will help examine the problem were also outlined. It was observed that the fishing industry feature a rapid paced and continuously changing environment which has necessitated the high-tech equipment development for the quick production of a wide variety of products and increased production capacity from the fish's biomass. As alluded in the introduction chapter, Lake Harvest does not have a linear model to process its biomass to maximum profits from optimum cost of fish processing. This section of the study presents an overview of operations research (OR) projects internationally. The literature concerning fishing industry is normally divided into three sections namely fish stocks and harvesting, fish processing and fish marketing (Randhawa & Bjanason, 1995). The current study will review studies involving fish processing sector that is the production planning processes models of fish's biomass until it reaches the consumer. According to Olafsson (1995), in 1966 the first Operational Research project was done and employed a computer simulation model of fishing and landing of herring. The chapter starts by presenting the historical development of linear models, fish processing value chain, types of linear models and some case studies where linear programming models have aided production managers in the fish production processing planning.

2.1 Background of Linear Models

Mikalsen and Vassdal in 1981 were the first to design a linear processing (LP) model for production planning in the fish processing industry. The model was designed to assist fish production planning for a period of one year in Norway. The one year was subdivided into five periods. The major objective of coming up with the model was to increase profitability in Norwegian fish processing industry with minimum optimum costs. Jensson (1988) improved the Mikalsen and Vassdal model coming up with a more user friendly model that proved to aid production managers in their daily production planning and sufficiently closer to real situations.

Furthermore, Jensson in 1997, developed the Jensson and Maack model similar to 1988 LP model, but this time introduced the duality theory which graphically explained production managers make prompt decisions in fish production processing. The problem of Jensson and Maack study had two characteristics: manpower and raw material. From the two bottlenecks the study showed how the net profit contribution per unit of bottleneck was calculated and information would be aid production managers in making decisions about overwork or what to sell or what raw materials to buy.

Gunn, Millar, & Newbolt (1991) analyzed how to coordinate fishing and fish processing in Canada. A major LP model was designed that demonstrated what should be caught and what products should be produced to satisfy market demand. Gunn and others postulated extensive LP models could be more useful in tactical planning in large fishing enterprise. Randhawa and Bjarnason (1995) conducted a study on integration fishing and fish processing with the intention to develop a simulation model and LP optimization model which would duality role of optimizing net revenue and aiding production planning. The role of the simulation model was to generate data to the LP model which decisions about labour requirements, inventory levels and production levels. Research findings suggested the usefulness of the system in making decision aid for production planning for fisheries.

The above highlighted studies were done some decades ago, since then, the technology of fish processing has rapidly developed and in most cases artificial intelligence has taken over human functions in some work centres, which has made significant changes in production planning. The current study takes into account the developments in automation and wants Lake Harvest to develop its own linear model by viewing machines as bottlenecks rather than the manpower. Several research studies have been devoted to studying decision making tools when catching and processing Icelandic cold. Many of these studies have utilized the same data set on fillet yield, grapping and parasites collected from 2002 to 2005. Along with the collective data sets these studies shared a common objective to increase the value of seafood along with enhancing productivity and profitability. Based on the data set Margeirsson (2003) did not make any conclusions but advised that more data should be collected and further analysis conducted. Guomundsson (2006) and others developed a multicommodity flow network model and an LP model using the data set mentioned above. The major aim of the study was to evaluate the effect of seasons and catching areas in the Icelandic ocean affect the quality of fish. Findings revealed that the quality features: mainly fillet yield, gaping and nematodes were linked to profitability. In addition buying leased quota, different product mix as well as product price were other factors that emanated to be key drivers to profitability. Furthermore, Guomundsdottir (2007) made a mixed integer linear programming model (MIP) for scheduling a seasonal divided aggregated plan.

In addition, Guðmundsdóttir (2007) made a mixed integer linear programming model (MIP) for scheduling a seasonal divided aggregated plan.

Findings from Margeirsson (2008) revealed that catching cold in certain seasons and areas can increase profit. Results were obtained using statistical modelling and optimization model. Statistical analysis showed that quality factors affect the fish depending on catching condition, storage and labour. The information of analysis was the used as the input to the model. Margeirsson (2010) used the data set and adding additional data on new catching grounds. A strong correlation between variables for profitability in the fish industry and catching ground, catch method and age of raw material when processed. Olafsson (2013) developed optimization models for both long and short-term planning. A linear optimization model was adopted to describe a vertically integrated fisheries company with long term planning, while a mixed integer linear optimization model was developed for short-term vessel trip planning. Both models were tested and validated at a fishery in Iceland and yielded good results.

Bakhrankova, Methuen, & Uggen (2014) developed an integral scholastic model based on a case study in Northern Norway that combines fishing fleet operations with plant processing. Utilization of the two models concurrently, helps remove uncertainties in raw material and market prizes with restriction on fish quality and shelf-life. Bakhrankova (2014) came to the conclusion that in order to increase profit it is essential to take into consideration uncertainties in raw material quantities during the fish production planning process.

The main purpose of this study is to develop a model to aid production managers in allocation of resources for maximum profitability using optimum input in the fish production planning process. The characteristics being investigated are primary processing of biomass, secondary processing of biomass and work overtime and their impact on Net Profit of Lake Harvest. In addition, the study will seek to identify other value addition chain products that Lake Harvest can produce from its biomass may increase its Net Profit margins. Bakhrankova (2014) concluded that in order to increase profit, for fish production planning it is essential to take into consideration uncertainties in raw material quantities. Consequently, the current assumption is that by adopting a linear model for fish production planning, uncertainties due to raw material allocation will be considered thus increasing profitability.

2.2 Fish processing value chain

This section of the study discusses the value chain of fish, from harvesting to marketing of the product. The value chain of fish of focus is composed of three parts namely: raw material (biomass), processing (primary and secondary) and market. Each value chain stage will be briefly described focusing on optimization in the processing sector of the value chain. However, it is paramount that the overall value chain process be comprehended as a whole as this may enable opportunities for improvement in one part of the chain prior or following activities. For example an improvement in the manner in which the raw material is handled can be identified and fixed resulting in improved quality of processing leading to positive market outcomes (Jensen, Neilsen & Larsen, 2009).

Company activities in value chain of fish processing depend on the type of fish be processed and whether the company is vertically or horizontally integrated. In vertically integrated models the company carries all the activities from of fish value addition from acquiring raw materials to provision of finished products to the consumer. Horizontally integrated involves a partnership relationship the fish value addition chain where a company is involved in one or more activities in the chain (Margeirsson, 2008). Lake Harvest is vertically integrated.

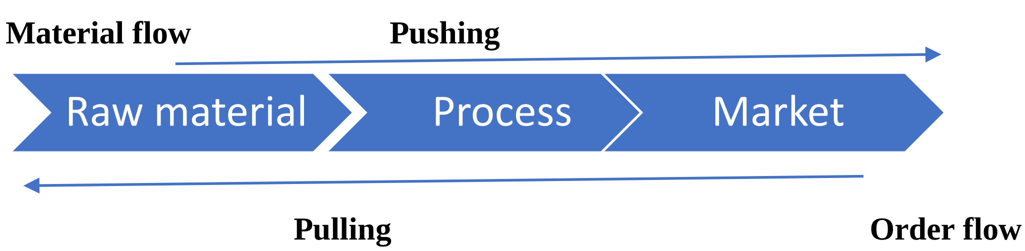

Fig 2.1 Value chain of fish (Margeirsson, 2008), (Jensen, Neilsen & Larsen, 2009)

2.3.1 Raw material

The fishing industry operates in an environmental surrounded by uncertainties on daily basis due to the sensitivity of fish to climatic conditions. One of the major uncertainties is whether fish as raw material will be available for processing. Fisherman are like hunters and gatherers who seek wild fish in the sea (Jensen, 2009) where amount of fish to be harvested is relative parasites or other undesirable attributes (Margeirsson, 2008). The fisherman themselves are not sure of the quality of fish they catch, consequently after each haul, the fish are sorted according to different sizes and species expected in each haul for accelerated processing. The way the raw materials are handled throughout is an important predictor of the prize the fish product will fetch in the market. It is worth mentioning that some unnecessary processes such as unnecessary transportation, correct handling to include: gutting, bleeding, cooling and significant others which may lower the quality of the finished product should be minimized to a larger extent.

2.3.2 Processing

Due to volatility of fish, the raw material should be processed the instant it is out of fresh water as its quality decreases with time once exposed to air. The processing of fish involves both primary and secondary processing. This includes splitting raw material, the fish, into a variety of products like fillets, loins and other various portions of the fish (Jensen, 2009). Bill of materials (BOM) is often used in assembly processing, it provides a recipe of required components, on stock, for the final product. On the other hand the structure of fish processing can be described with a reverse bill of material (Jensen, 2009), where each raw material is split into various products shown in Fig 2.2 below.

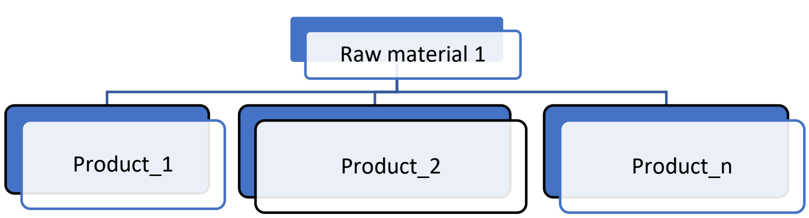

Figure 2.2 Reverse bill of material (Cardos & Miralles)

Fish production planning is influenced primarily by the supply of fish, raw material properties and the age of the fish when it arrives at the processing plant. Furthermore, the capacity of the processing plant is also a key determinant in influencing the product mix to be produced. In addition, pressure on what is to be processed is under the influence market forces where some contracts are made before hand and some orders are requested on short notice particularly for fresh products.

2.3.3 Market

Traditionally, the market entails the distribution and sales where the final product is delivered to the customer. The market in today's fish industry is ever changing and increasing due to the high demand of fish as a source of protein, depending on customer requirements and other market variables, making the value chain change alongside with it. The market may predict how raw materials flow through the value chain. Fig 2.3 shows that orders flow in the opposite direction of the material flow. Pushing and pulling effects on and from the market determine the impact of flow in both directions. Pushing means products are pushed to the market, in some cases the product may not be the customer preferences. In which case, the process/value chain begins in the first step of the chain, raw material (biomass), allowing flexibility in processing, while on the other hand pulling means that the customer requests a specific product, resulting in the value chain beginning at the end of the chain, the market, is putting pressure on the first two steps in the chain. (Margeirsson, 2008). It has shown that each activity in this simple fish processing value chain, described above, depends on the other. This gives an insight into the importance of a good production plan when reacting in this rapidly changing environment.

2.4 Linear Models

A linear programming model is an algebraic description of the objective to be minimized and the constraints to be satisfied by the variables is presented. Linear programming is a simple technique where we depict complex relationships through linear functions and then find optimum points.

Applications and use of linear programming can be at professional and personal. Linear programming is used for obtaining the most optimal solution for a problem with given constraints.

2.4.1 Overview of Theory

This section presents an overview of important terms and concepts that may contribute to the understanding of the models that will be used to develop the linear model for fish production process planning at Lake Harvest. A short introduction to stochastic programming and stochastic modelling and the relevant theory on forecasting and how it may be used in conjunction with scenario generation are presented.

2.4.2 Representing uncertainty

Linear programming is based on the Uncertainty theory. Uncertainty is present in many real life decisions, be it in supply and demand, revenues or costs, production, uncertainty is a factor that has to be accounted for. In operational research two dominant modelling approaches have put in place to deal with uncertainty namely deterministic approach and the stochastic approach. In general the deterministic models are most chosen even when the model poorly describes the reality, just because it is simple. However, uncertainties become complex the deterministic models fail to give an adequate description of the reality, and a model that takes the stochasticity into account may be necessary (Birge and Louveaux, 2011). While deterministic programming is the most common method used in early operations research, stochastic programming has increased in popularity during recent years due to technology development and increased computing power (Kaut and Wallace, 2007). The current study will utilize the stochastic programming model.

2.4.3 Introduction to stochastic programming

As highlighted, the simplest approach to model uncertainty is by using a deterministic problem formulation. This is only possible in scenarios where every possible future uncertainty is known. Uncertainty is then not included explicitly, but rather represented implicitly by replacing all uncertain variables by their expected values. When all uncertain variables in the problem are replaced by their expected values, one obtain what is called the expected value problem or mean value problem. The solution is known as expected value (EV) solution.

A sensitivity test can be used to test the model robustness by varying the uncertain parameters and inspecting the outcomes changes in the optimal solution. Alternatively, a scenario analysis, a set of scenarios are created and solved individually by using the expected values of each scenario. The decision maker can generate many scenarios based on the individual's knowledge to come up with the best solution to the problem.

An alternative to deterministic approach in implicit representation of uncertainty is the scholastic approach. In scholastic programming the model is structured in such a way that when decisions are made emphasis is on available information to the decision maker. In Figure 5.1, the uncertainty is represented by ω, which influence the decision on y. All decision variables x are not subject to uncertainty and are thereby treated deterministically.

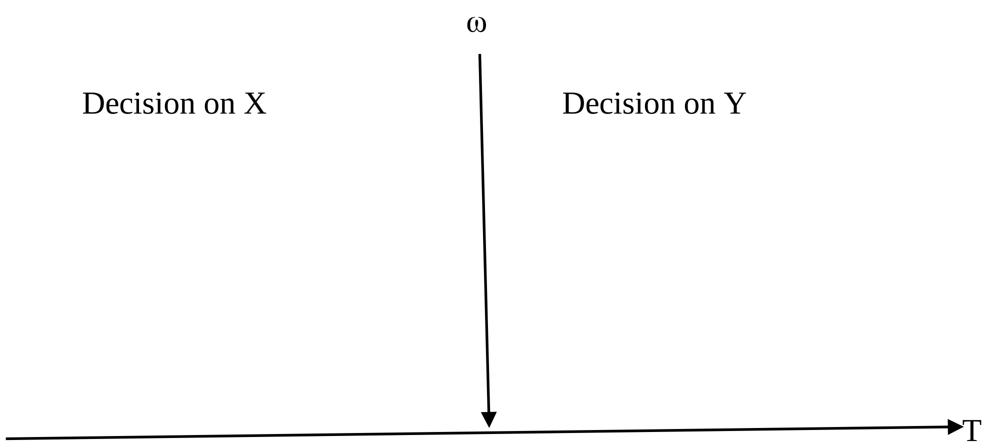

Figure 2.3 Realization of the uncertain variable ω which influences the decision on y.

Figure 2.3 above illustrates the realization of the uncertain variable ω which influences the decision on y. In stochastic programming uncertain variables represent all possible outcomes, based on the fundamental assumption that the probability distribution of the uncertain variables is either known or can be estimated. Both the uncertain variables and their probability distributions from the basis of how uncertainty in possible future realization are constructed. Therefore, the stochastic method is most efficient when the future can be described by discrete distribution. If data is continuous, it has to be discretized to possible outcomes, thus in most cases simplifying reality making the model less accurate.

The current study will use the stochastic model to develop a fish production processing model for Lake Harvest. Before describing the linear models that will be used in this study it is important that important terms used in linear programming be defined, to include: decision variable, objective function and constraints.

Decision variables: The decision variables are the variables which decide an organization's output. They represent the ultimate solution in solving any problem, consequently firstly need arises to identify the decision variables. The decision variables determine how much raw material is to be allocated to each product combination. This, we branded processing allocation within the restrictions of the available machine time, raw materials and other constraints including restrictions concerning cliental orders and sales contracts. Each processing allocation contains different blend of products in the fresh and frozen production.

Objective function: is defined as the objective of making a decisions, in this context the aim is to develop an optimization to aid production managers at Lake Harvest to plan how best to allocate resources to produce Maximum Net Profit, hence optimization model becomes the objective function.

Constraints: These are the restrictions or limitations on the decision variables. They usually limit the value of the decision variables. Hence, the required raw material constraint depends on the yield of each processing allocation and available raw material each day. Constraints enable production managers to decide the minimum production on products and according to customer orders or sales contracts. Constraints are used to allow the possibility to ensure some amount of raw materials to be allocated for processing to either fresh or frozen production.

This section introduced theory of uncertainties in the production process planning. Two models: the deterministic model and stochastic model are key in resolving uncertainties in production planning. There are many different types of linear have developed, however, the current study will only discuss the mathematical model and Autoregressive models which will be employed to develop a linear model for Lake Harvest.

2.5 Models of Production Planning Process

2.5.1 Mathematical model

The mathematical model is a linear programming model where decisions on anticipating the amount of raw materials to be allocated in the production of various products and product combination are decided by decision variables in a process known as processing allocation determined by constraints such as available machine time, raw material customer orders and sales contracts. The processing can have different combinations of fresh and frozen fish, the model aiding production decisions on short term bases, while formulating long terms production decisions. The model is articulated as a decision helper for one-day production planning with an extension to be discussed later. The development of a model like this is a replication process that ends when the model is weighed to be close enough to describe and explain the process observed. It has to remain practical and tractable in the process. Constant visits to the processing plant were made during the process of model construction. This was done to observe bona fide situations and also the collection of data and information about the processing. However, information about the modifications the model has undergone is not known for confidentiality purposes and protection of company intellectual rights.

Table 4.3, 4.4 and 4.5 are summaries of the indices of the model, decision variables and the standardized regression co-efficient or data of the mathematical model and the meanings of each.

Table 2.1. Indices used in the mathematical model

Indices	Definition
F	Raw material, species and size, here cod size 2.5rkg to 7.5 rkg. (f=1)

P	Processing allocation, each first or fillet is produced to give a certain product combination according to the reverse bill of material RBOM (p=1,…30)
W	Work centre, machine bottle necks in the processing line (w=1,…4)
K	Products, division of the fish into products (ku1,…47)

The development of the mathematical model is an iterative process, which involved repeated visits to the processing plant, observing and recording actual data and information about the fish processing. The source of data for this model was from Icelandic fisheries.

Table 2.2 Decision variables used in the mathematical model.

Decision Variable	Definition	Unit
X_{fp}	Raw material f allocated to processing allocation	(pkg)

Table 2.3. Coefficients or data used in the mathematical model.

Coefficient	Definition	Unit
Input $_f$	The amount of available raw materials of species and size f available for processing	(rkg)
c_{fp}	Net Profit Contribution of processing allocation p from raw material f	[kr/pkg]
M_w	Available machine time in work centre	[min/day]
M_{fw}	Required machine minutes for raw materials f in work centre	[min/rkg]
Demand$_k$	Demand for product k in the fresh and frozen production	[pkg]

$SCONTR_k$	Minimum production for product k according to sales contracts in the salted production	[pkg]
$RBOM_{fpk}$	The proportion of raw material f processed as processing allocation p that produces product k	[%]
Y_{fp}	Yield (kg product/ kg raw material) of raw material f in processing allocation p	[pkg/rkg]
RawS	Raw material forced to be allocated to salted production	[rkg]
RawF	Raw material forced to be allocated to salted production. rkg RawF Raw material forced to be allocated to fresh and frozen production	[rkg]

Computation of Net Profit

Net Profit Contribution of each processing allocation was formulated by Jensson & Maack in 1997. They assumed that Net Profit Contribution for daily production plan for product is determined by the difference between sales prize and only a few variables: production cost, case packaging and estimated inventory. Labour and raw materials cost were excluded from the variable cost in daily production planning as the raw material has already been bought (sunk cost) and permanent employees will always be paid irrespective of the type of product mix produced. .

The major objective of the Mathematical Model of production fish processing planning is to maximize Net Profit Contribution by examining the optimal production plan for particular day. The formula below illustrates or describes how Jensson & Maack (1997) calculated the daily Net Profit Contribution.

$$\mathbf{Max} \sum_f C_{fp} X_{fp}$$

The capacity to produce by the processing plant(s) dependents on machine time and the raw material ordered.

Firstly, machine time is the constraint, four machines being considered as bottlenecks in salted production it is advent freezer and a feeding machine, while in fresh and frozen production the a single FlexXicut machine and a Gyro freezer are adequate tools to optimize profits. The second challenge is raw material influenced by two factors mainly on the yield of each processing allocation and the available raw material and depends on the yield of each allocation being processed.

Equation (2) : $\sum_f \sum_y m_{fw} x_{fp} \leq \sum Mw$

The second challenge is the required raw material to optimum daily Net Profit and depends on yield of each processing allocation and the supply of available raw material on daily basis.

Equation (3) : $\sum_f X_{fp}/Y_{fp} \leq Inputf$

The fourth and fifth equation enable managers to resolve constraints by enabling production managers to make minimum decisions while maximizing production based on spot orders and sales contracts orders quantities.

Equation (4) : $\sum_f \sum^{11}_{p=1} RBOM_{fpk} X_{fp} \geq Demand$

Equation (5) : $\sum_f \sum^{30}_{p=12} RBOM_{fpk} X_{fp} \geq Scontrk$

Finally, both least constraints 6 and 7 allow some amount of raw material to be processed be allocated for processing as either salted or fresh, and frozen production.

Equation (6) : $\sum_f \sum^{11}_{p=1} X_{fp}/Y_{fp} \geq RawF$

Equation (7) : $\sum_f \sum^{30}_{p=12} X_{fp}/Y_{fp} \geq RawS$

Where $X_{fp} \geq 0$

Implementation

For the implementation of the model MPL modelling language (MPL Modelling System. (n.d.)) and solved with the CLPEX solver. Excel was used as data base linked to MPL and solution output was displayed in both MPL and Excel. The database contains data or information about each of the products and their prizes, raw material yield, packaging cost and estimated inventory cost. The model consisted of 30 variables and 54 constraints.

The composition of daily input data is: available raw material (Inputf), processing allocation of raw material to salted production or fresh and frozen production, RawS and RawF, market restrictions for some products, Demandk and Scontrk supply of certain products and exchange rate update.

2.5.2 Forecasting (Autoregressive models)

The salmon industry is characterized by large seasonal variations, e.g. with regards to water temperatures and price variations due to variations in the supply. Because of this, the authors will further explain models that handles seasonality in another way than e.g. exponential smoothing. Even if one can adjust models such as exponential smoothing to incorporate seasonality in the data by using seasonal factors for each sample, this is considered a weaker approach to get the best prognosis. Autoregressive integrated moving average models (ARIMA) on the other side aims to describe autocorrelations in the data (Hyndman and Athanasopoulos, 2015).

2.5.2.1 Autoregressive integrated moving average (ARIMA) models

Stationary process can be represented either in an autoregressive form or in a moving average form. Both of these formulations contain a high number of variables that needs to be estimated, which is a problem that arise in either representation. Even for a finite-order autoregressive model or finite-order moving average model a high-order model is needed to get a good approximation. The high number of parameters will in general reduce the efficiency of the estimation. This can be improved by combining the AR-model and MA-model into a useful mixed autoregressive moving average process (ARMA).

The process one wants to forecast is often non-stationary, and to account for nonstationary one often uses what is called the generalization of the ARMA-model. The generalization of the ARMA-model is expressed as an ARIMA. The ARIMA-model reduces the non-stationary time series to a stationary time series by taking a proper degree of differencing (Wei, 2006). The ARIMA-model, equation in the equation below, consist of the autoregressive representation, a differencing part, and the moving average representation.

$$Z0_t = c+\varphi_1 Z0_{t-1} +\cdots+\varphi_p Z0_{t-p} +\psi_1\varepsilon_{t-1} +\cdots+\psi_q\varepsilon_{t-q} +\varepsilon_t$$

Where: $Z0_t$ is the differenced series, $Z0_t = Z_t - Z_{t-1}$. This is called an ARIMA (p,d,q) model, where p is the order of the autoregressive part, d is the degree of first differencing involved and q is the order of the moving average part.

2.6 Case studies

2.6.1 Iceland industries

This section presents the results of the case study which was conducted to see the feasibility of the mathematical model, with regards to usability of optimization and sensitivity analysis in the production management of a fish processing facility. The presented model provided answers to and would be beneficial for the production manager to get quick estimate:

- Which processing allocation should the company produce today to maximize Net Profit Contribution?
- When is it desirable for the company to increase capacity and what should they be willing to pay for it?
- Is it advisable to work overtime?
- What is the desirable price for the company to buy additional raw material from the market?
- How much higher price would the company have to require in order to produce a certain product or processing allocation?

Questions such as these are among the many questions production managers have to ask themselves every day. These questions were answered by the case study presented.

Method

During the test different input conditions were inputted, reactions analysed and adjustments to the model made on need basis. The model was tested and validated using input conditions based on a real time typical processing data from production managers from the company understudy.

Analysis

As highlighted before, the company in which the mathematical model is vertically integrated producing a variety of fish products from its biomass: The products include salted, fresh and frozen. As mentioned before, the W material in the study was represented one fish species, cod, in the same size category, f=1, company is vertically integrated producing variety of fish products; salted, fresh and frozen. The w material in this case study is assumed to be one fish species, cod, in the same size category, f=1, allocated to few possible processing allocations during one day planning period. The objective is to maximize the Net Profit Contribution for one-day planning period. In this case study the model was allowed to run unrestricted, with 90 tonnes of raw material resulting in the model yielding Net Profit Contribution of around 39 million ISK (1 EURO=118,8 mbl.is 12 des 2016). Allocating, 55 tons to processing allocation 3 in the fresh and frozen production and 35 tons to processing allocation 1 in the salted production.

The case study was conducted based on input conditions tested determined by production managers of the company.

Our case study is based on the input conditions tested with the production mangers of the company under study. Decisions were made to allocate 90 tonnes, 22.2% of the available raw material, to salted fish production. Some restrictions were put in place on the processing day and these included; orders requesting products 1, 3, 5 and 17 of fresh and frozen production and the sales contracts for salted production, products 31, 37 and 40. The Net Profit Contribution in this trial decreased from the previous example, and returned appropriately 37 million ISK.

An analysis of the results of the model using sensitivity report revealed indicated that two of the machine constraints, the FleXicut and the Gyro Freezer, were tight along with the raw material constraint. Table 2 provided answers with regards to whether it is advisable to work overtime, increasing one additional machine per minute or raw material (rkg) is added to their capacity. In this particular example, the Net Profit Contribution would increase by 2.163 ISK or 2.867 ISK if one extra minute is added to either the FleXicut or Gyro freezer capacity.

The capacity of the machine constraints since labour cost is not taken into account when calculating the Net Profit Contribution. Therefore, if the company decides to work overtime for one hour they need to be willing to pay labour cost that is less than 129.780 ISK for the hour. The shadow price for the raw material constraint, 421 ISK, in gives the desirable price for the company to buy one extra kilo of raw material.

2.6.2 Salmon Industry

2.6.2.1 Production and inventory planning

Once harvested and slaughtered, the salmon producer must decide how to utilize the slaughtered fish. Fish could either be sold as fresh or frozen HOG salmon, or be processed further into value added products (VAP). As much of the processing is performed at separate facilities, the volume sent to processing and the volume sent directly to the market must be decided upon, meaning that the production decision and the logistical decisions are intertwined.

As discussed, there are limited options in the timing of harvest. When prices are low, another alternative is then to harvest and slaughter the fish, and then freezing it in hopes of better prices in the future. As the stock of frozen fish is less dependent on immediate effects of changes in the livestock, there is improved storage flexibility in keeping stocks of frozen fish. As such, frozen fish can provide a buffer for stochastic movements in the livestock (Oglend, 2010)

Although the margins for VAP are generally lower than for fresh HOG salmon (Marine Harvest, 2014b), the prices for VAP are also generally somewhat less volatile, as discussed in Section 3.4. Combined with the lower degradation rate of such products, this makes production of VAP interesting, as it offers the producer more flexibility in terms of when to sell. After processing, the processed products can either be sent directly to customer, or be stored in inventory for a certain amount of time related to the product’s durability. If prices are expected to rise in the future, it may be beneficial to postpone the sale as long as the expected price increase covers the inventory costs. Conversely, when the prices are high, the salmon producer may find it beneficial to empty or significantly reduce its inventories.

Oglend and Sikveland (2008) argue that the availability of inventories helps smooth prices, and that the utilization of inventories today comes at a trade-off of lower inventories tomorrow such that the option of smoothing prices in the future has decreased. As such, the product-mix can be used as a means to make the company less influenced by the spot price volatility. This flexibility may give more robust production plans, which are especially interesting for risk averse producers, as they tend to favour more stable profits over higher expected profits. Another argument for producing to stock is to do so in anticipation of the predictable seasonal patterns of demand discussed in Section3.4. As a side note it is worth mentioning that severe quality downgrades may increase the allocation to processed products (Aandahl, 2015).

Note that production decisions are restricted by transportation capacities and by the capacities at processing plants, as well as the inventory capacities.

2.6.2.2 Sales allocation

For a salmon producer there are several different ways to interact with customers in the global market. In the problem studied in this study, the transactions modelled are categorized as either spot transactions or contract transactions.

2.6.2.3 Spot transactions

Spot transactions are short term contracts agreed upon either the week prior to invoicing or in the week of invoicing. Although salmon producers can be considered price-takers in the short run, the salmon producer must decide what volumes to sell when. As prices differ in different market, another important aspect of the decision is in which markets to sell the products. Due to the imperfections in the market price correlations, efficient market allocation can potentially have an positive impact on the company’s revenue, even though these decisions must be made under uncertainty. The ability to react fast to price changes in a market could give the salmon producer a significant advent age. Note that the market allocation is not a purely financial decision, but is restricted by transportation capacities.

Furthermore, the salmon producer must decide how much fresh HOG salmon to purchase in the spot market at any given time. Often, purchases are used as a mean to fulfil contract obligations when the internal supply is insufficient to cover the contracted volume. Spot purchases also occur in cases where the current spot price makes it more economical for the producer to purchase HOG salmon rather than using internal supply as raw material in the secondary processing. This may either be due to considerations regarding return on feed or to avoid high transportation costs from internal production sites to the processing facilities.

2.6.2.4 Long term contract transactions

Entering contracts is used mainly as a means to mitigate the risks associated with price, volume or both, as well as to achieve predictability in future sales (Larsen and Asche, 2011).

2.6.2.5 Decisions

The predictability allows for better production planning and capacity utilization. Conversely, the downside of signing contracts is that because most contracts specifies a volume, the producer might have problems in keeping his contract obligations in case of poor growth. Furthermore, if large shares of the value chain capacity is tied up in contracts, this leaves less flexibility when problems or profitable opportunities arise or disruptions in the value chain occur. Situations where the producerfindsitchallengingtodelivercanleadtocontractre-negotiations, often resulting in less favourable pricing agreements. In using contracts where the price is fixed, there is also a risk of selling at a price lower than the spot price, thus missing out on extra revenue. Which contracts to enter is arguably one of the most important decisions facing a salmon producer. The decision is two-faceted:

1. The producer must decide what proportion of total production should be tied up in contracts.

2. The producer must decide what types of contracts to aim for in negotiations.

As discussed in earlier the industry operates with several different types of contracts, differing both in how price and volume are established, and the frequency of the deliveries and the time horizon of the agreement. Additionally, the producer should consider the network aspect of the contracts, e.g. how many customers he wants to engage contracts with, meaning if he wants to opt for fewer high-volume contracts, many low-volume contracts or something in-between.

The problem studied in this thesis includes three different contract types. They are all based on fixed volume agreements, but differ in how the price is established, and thereby in how they affect risk profile and predictability. Fixed price contracts give full predictability in terms of income, but you risk missing out on income if spot price rises during the contract period. Adjustable price contracts expose the firm to the spot market volatility, thus giving less predictability. In using such contracts you will not be forced to sell at a price significantly lower than the spot price, but conversely the opportunity to sell at a price significantly higher than the spot price is lost as well. Partially adjustable price contracts, which is the last contract type included, give some predictability and lower price risk than the adjustable price contracts.

2.6.2.6 Logistics

The salmon producer has to continuously make a large number of decisions regarding logistics. All of the decisions previously discussed set the frame for, and are at the same time restricted by the logistics decisions. For example, harvest and slaughter decisions decide what volume of fish must be transported from a farm to a nearby slaughtering facility with the use of a well boat. Furthermore, spot sales and contract volumes dictate which volume of a specified product that must arrive in each market at any given time.

The producer normally hire transport capacity from an external logistics provider. It is common for the provider to specify a minimum price the producer must pay for a specified time period regardless of how much of their services are used. Thus, to minimize costs the producer should seek to always use at least the amount of capacity corresponding to this minimum price.

The agreement could also specify an upper limit to the capacity that can be provided. If this capacity is surpassed, the producer would have to turn to the market and negotiate an agreement with an additional logistics provider. Due to increased transaction costs and a high probability of having to pay a premium price when conducting last minute negotiations, the producer have to weigh the benefit of the additional capacity against the added cost.

Deciding upon which transportation mode to use depends upon several factors:

The chosen transportation mode must be feasible across the distance. For example, ship freight is not possible between two inland locations. The chosen transport at mode(s) must bring the product to the market in time before it is degraded. Thus, in most cases the number of eligible transportation modes is limited due to long transportation time. Cost considerations. The cheapest choices are generally ship freight or transportation by trucks, whereas air freight is significantly more costly. Consequently, there will be a trade-off between transportation costs and how fast the product must be delivered, which depends on how fast the product deteriorates. Therefore, air freight might be necessary to get the product to its destination fast enough, even though it is the more expensive option.

2.7 Chapter Summary

This chapter discussed the different linear models that researchers have come up with to aid production managers in the production process planning in the fish industry. It has been observed that there are two types of linear models: the deterministic model and stochastic model. The programming model and autoregression models were discussed in detail as they are relevant to needs of this study. Two case studies were also presented: Iceland fish production planning model which used the linear programming model to help production managers to allocate fish for maximum profitability and the Salmon model which employed auto regression in this regards. Both models were found to have increased net profits of the organizations than before they were implemented. Consequently, basing on the reviewed literature it can be assumed that if Lake Harvest develops its own model its fortunes might increase, as decisions to allocate resources for optimum profits due to uncertainties will be will be overcome by the model. The next chapter will deal with the research methodology that will be employed to come up with a model for fish production planning processing at Lake Harvest.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

This chapter presents the methodology of the study. This involves data collection and analysis techniques. The chapter presents the research approach adopted, design and the formulation of the Linear Programming model that was used to model the maximisation of profit contribution for the Lake Harvest. An explanation of the variables based on the constraints on the fish processing planning is also provided.

3.1 Research method

This study is quantitative and as such it uses research methods dealing with numbers and anything that is measurable in a systematic manner of investigation of phenomena. Quantitative approach emphasizes the measurement and analysis of data in a numerical form to give precise description. Also called the scientific method, has been considered as the traditional mode of inquiry in both research and evaluation (Mugenda, 2008). Quantitative approach is adopted for this study because it places emphasis on methodology, procedure and statistical measures to make predictions and optimise resources allocation. The advantage of a quantitative method is that it becomes possible to assess patterns and trends, and help in the allocation of resources when there are competing ends to limited resources.

3.2 Research approach

Saunders et al. (2016) identified two research approaches, the deductive approach and the inductive approach. The current study was deductive in nature, an approach often referred to as deductive reasoning. Wilson (2010) highlighted that a deductive approach is concerned with the development of a hypothesis (or hypotheses) drawing from already existing theory, and then designing a research strategy to test the hypothesis. The deductive process entails reasoning from the particular to the general. This form of reasoning involves deducting conclusions from premises or propositions.

Deductive approach was desirable as the study commenced with an expected pattern which was then tested against observations. The aim was to ascertain the allocation of resources in a product mix which may yield better returns, in terms of Net profit Contribution. Deductive studies seeks to explore already known theory or phenomenon, they test such theory to find out if the theory holds in the given circumstances. Consequently, deductive reasoning closely follows the path of logic whereby a theory is identified which is then analysed to generate a new hypothesis. The generated standpoint is then tested against research observations with the intention to confirm or reject the hypothesis (Snieder and Larner, 2009). The deductive approach is especially appropriate for the current study given that the focus is on the application of the LP model to optimise resources allocation in a product mix. Various studies have proved positive results from the use of LP model in optimisation on the use of scarce resources. Basing on prior study findings, the study sought to apply the same LP model on the case of the Lake Harvest company in its fish process planning procedures.

3.3 Research Design

A research design pertains to the way in which a chosen research method is applied when answering the research questions. It has been described as a 'blueprint' which details the tasks to be accomplished and how this is done (Sekaran & Bougie, 2010). The research design outlines major aspects including: research method; the collection of sample; and procedures and research instruments.

The researcher adopted a case study design, using Lake Harvest as a case study. A case study is defined as an empirical inquiry that investigates a contemporary phenomenon (the case) in depth and within its real-world context (Yin 2014). The researcher deemed it the most approriate design in light of the scope of the research and the type of research questions to be answered. Yin (2014) also posited a case study as an all-encompassing method capable of embracing different epistemological orientations.

Thus, the researcher took one single unit to study and has also taken one situation, which is the issue of copyright compliance. This enabled the researcher to undertake a comprehensive study (Kothari 2004; Taylor 2006). Eisenhardt (1989) as quoted in Ngulube (2015) states that case study research assists in providing a description of phenomenon as well as testing or generating theory. Case study places more emphasis on the full analysis of a limited number of events or conditions and their interrelations (Kothari 2004; Biggam 2011).

The main purpose of the study was to establish the optimisation of resources allocation in a product mix which enhances Net Profit Contribution at the Lake Harvest. This involved an in-depth study of the scenario to obtain rich data of specific instances by using methods of probing like interviews (Krishnaswamy 2006). The objectives of the study centre around issues of what factors were constraining the company from reaching desirable profit targets. Thus, the research made a complete study of this social unit covering all facets by understanding complex factors that are operative within the study area.

3.4 Study setting

In Zimbabwe Lake Harvest, is the largest tilapia producer in Africa for domestic consumption, regional exports to countries such as Zambia, South Africa, Malawi and Botswana among others also it exports to European Union bloc of countries. Since its inception in 1997 the company has experienced tremendous growth in harvest volumes. For example from 2 500 tonnes whole fish produced in 2010 to 11 500 tonnes whole fish equivalence in 2013 and about 8 000 tonnes to date. The company processes fillets, frozen whole round, frozen gutted and fresh whole round tilapia. However, despite the notable growth and worldwide consumer at its disposal, Lake Harvest does not have a planning model at its plant. The fishing industry features a fast paced and ever changing environment where in recent years development of high-tech equipment have occurred in the processing sector resulting in a wider range of product possibility as well as increasing production capacity. Significant changes have occurred in fish processing where advanced machines and software are now used to control everything from sorting raw material to packaging the final raw material. Customers of fish can place an order and expect its delivery at the end of the day. This fast pace requires fast decisions; therefore the need for decision production planning tools (models) to aid production managers in making prompt decisions is inevitable.

3.5 Data Collection

Data collection is the systematic way of gathering data which is relevant to the research objectives, purpose or questions (Burns and Grove, 2001). Data was collected through both quantitative methods. A data collection sheet was used to request for information for analysis from Lake Harvest management. A copy of the data collection sheet is included in this document as Appendix

1. Information was compiled on a monthly basis, after which average figures were computed and these were used in the LP model.

3.6 Data Analysis

Cooper and Schindler (2011) notes that data analysis includes interpreting findings from the research in the light of the research questions, and determining if the results are consistent with the research hypotheses as well as the views of prior authors and researchers. A linear programming model was developed, to analyse the data obtained, using the LINGO software.

3.6.1 Linear programming model

Linear programming, may be referred to as linear optimization, and it is concerned with finding efficient solutions to systems defined by multiple linear equalities and inequalities. It is a type of optimization technique which helps to economically allocate 'scarce' resources to several competing activities on the basis of a given criterion of optimality. Basic assumptions of the linear programming model includes that of linearity and additivity. Linearity (or Proportionality) is an assumption that all relationships in the LP model are linear. In terms of Additivity, it is assumed that the value of the objective function for the given values of decision variables is equal to the sum of the contributions (profit or cost) earned from each decision variable and the total sum of resources used, must be equal to the sum of the resources used by each decision variable.

General Formulation of a Linear Program

The following notations are essential to consider when formulating the general linear programming model.

m: number of constraints

n: number of variables

x_j: decision variables

a_{ij}: coefficients of variable $\boldsymbol{j}$ in constraint $\boldsymbol{i}$

b_i:right-hand-side coefficients for constraints

c_i: objective function coefficients of the variable

A: matrix (with m rows and n columns) of the coefficients of the variables in the constraints.

The LP model is **Maximization:**

$$Max \sum_{j=1}^{n} c_j x_j$$

$$s.t \sum_{j=1}^{n} a_{ij} x_j \ \le \ b_i \, , \forall_i = 1, \dots \dots, m \ (constraints)$$

$$x_j \ \ge 0$$

Considering z as representing profit maximisation, the function z is known as the Objective Function. It is a linear combination of the variables (x_1,x_2,...,x_n) with the general form:

$z = c_1x_1+c_2x_2+\cdots+c_nx_n$ where each c is a constant.

The linear constraints can be either equality constraints or inequality constraints, and take the general form

$$a_1x_1 \ + \ a_2x_2 \ + \cdots \ + a_nx_n \begin{Bmatrix} \le \\ = \\ \ge \end{Bmatrix} = b$$

where a and b are constants.

A feasible solution is any combination of the variables (x_1,x_2,...,x_n) that satisfies the constraints, and the set of these n-tuples is known as the feasible region. A problem which has no solution which satisfies all of the constraints is infeasible.

The full form of the general linear programming problem is as follows

Maximize $c_1x_1 + c_2x_2 + \dots + c_nx_n = z$

Subject to $a11x1 + a12x2 + ... + a1nxn \leq b1$

$a21x1 + a22x2 + ... + a2nxn \leq b2$

...

$am1x1 + am2x2 + ... + amnxn \leq bm$

$x_i \geq 0 \; i \in 0,1,...,n \;\; b_i \geq 0 \; i \in 0,1,...,m$

The general linear programming problem is also commonly written in matrix form

$z = c^T x,\ Ax \leq b,\ x_i \geq 0,\ b_i \geq 0$

$$c = \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_n \end{bmatrix}, x = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix}, A = \begin{bmatrix} A_{11} & A_{12} & \cdots & A_{1n} \\ A_{21} & A_{21} & \cdots & A_{2n} \\ \vdots & \vdots & & \vdots \\ A_{m1} & A_{m1} & \cdots & A_{mn} \end{bmatrix}$$

There are several important properties of LP models which should be considered, in relation to whether a solution exists as long as the feasible region is bounded. It is important to note that the feasible region is said to be ‘bounded’ if there exists a number M such that $|x_i| \leq M$ holds for every feasible point $(x_1,x_2,...,x_n)$ and each $i = 1,2,...,n$.

1. If the set of linear constraints defines bounded feasible region, then there exists a point in that region that maximizes the objective function and a point that minimizes the objective function.

2. If a maximum occurs in the feasible region, it must be a vertex point of the feasible region.

3. If a minimum occurs in the feasible region, it must be a vertex point of the feasible region.

The Simplex Algorithm

The simplex method helps to solve LP problems developed by George Dantzig in 1947. It is based on that LP problems that have a solution must have an optimal solution corresponding to a corner of the feasible region. However, it is possible that there may be multiple or alternative optimal solutions. Simplex usually starts at the corner representing non activity, that is, a solution when no activity has taken place. It moves to the nearby corner that best improves the solution. The process is repeated continuously, making the greatest possible improvement each time. When no more improvements can be made, the most attractive corner corresponding to the optimal solution has been found.

General Simplex Formulation

In general, the simplex algorithm is a method for solving linear programs in the following form,

Maximize $c_1x_1 + \cdots + c_nx_n$

subject to the constraints

$$a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n \leq b_1$$

$$a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n \leq b_2$$

$$\vdots$$

$$a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n \leq b_m$$

$$x_1, x_2, \cdots, x_n \geq 0$$

The constraints

$$a_{i1}x_1 + a_{i2}x_2 + \cdots + a_{in}x_n \leq b_i$$

can be written as

$$a_{i1}x_1 + a_{i2}x_2 + \cdots + a_{in}x_n + x_{n+i} = b_i$$

where $x_{n+i} \geq 0$ is a slack variable.

The new variables x_{n+i}, would be assigned zero cost coefficients in the objective function, i.e.

$c_{n+i} = 0$.

In matrix notations, the standard form of a linear programming problem be represented by an $m \times n$ matrix

$$\mathbf{A} = \begin{pmatrix} a_{11} a_{12} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} a_{m2} & \cdots & a_{mn} \end{pmatrix}$$

together with an *n*-vector of $\boldsymbol{C} = (c_1, \cdots, c_n)$ "costs"and an *m*-vector of "right-hand sides"$\boldsymbol{b} =$

$(b_1, \cdots, b_m)$. The variables can also be grouped into an *n*-vector:

$$\boldsymbol{X} = (x_1, \cdots, x_n, x_{n+i})$$

Then the entire linear program can be written as follows:

$$Maximize \boldsymbol{C}^T \boldsymbol{X}$$

$$subject\ to\ \ \mathbf{AX} = \mathbf{b}$$

$$\mathbf{X} \geq \mathbf{0}$$

Presolving the LP problem

The presolving procedure as a critical part of problem solving process using linear programming. **Presolving** is a procedure performed on LP problems prior to the application of the model onto an LP solver. This was performed in order to reduce the size of the LP problem through the elimination of redundant constraints and variables. It helped to identify possible infeasibility and unboundedness of the problem.

The computational complexity of the LP solver depends on the number of constraints and variables in the LP problem. As such, it was necessary to check for the redundant constraints and variables in the current LP problem. These were eliminated before sending the problem to the LP solver, LINGO, in this case to reduce the size of the problem. The associated reduction in the size of the LP problem resulted in a decline in the time taken by the LP solver to solve the problem.

Also, the presolving step was performed to assess on any possible infeasibility and unboundedness conditions of the LP problem. Upon finding that there were no incidences of infeasibility and unboundedness conditions of the problem, the LP solving process was continued. It was however acknowledged that despite the robustness of the process, no presolving technique may guarantee detection of all infeasible and unbounded problems.

3.7. Ethical considerations

The participants who participated in the study were guaranteed that their responses were to be used for the purpose of the research only and with strict confidentiality by the researcher, and they signed the consent form that is attached herein. Permission to do the research was granted by the company with strict understanding that the source documents used in the research were not be attached to the research for purposes of confidentiality and keeping them as intellectual property of the company.

3.8 Chapter Summary

The chapter presented the methodology of the study. A quantitative research method has been adopted, based on deductive reasoning. The linear programming model was found appropriate for this study. The next chapter focuses on presenting the findings of the study gathered using methods outlined in this chapter. Data presentation and analysis in the next chapter is informed by the data analysis techniques discussed in this chapter.

CHAPTER FOUR

4.0 Introduction

This chapter presents the data collection and Analysis, the formulation of the linear programming model, results of the maximisation model and a comparison of the two models.

4.1 Data Collection and Analysis

The data was obtained from the operations data obtained from the company's internal reports availed by management. Analysis was done using the linear programming (LP) model. LP is a renowned tool for the purposes of optimisation when faced with resource constraints, yet profits are to be maximised. Two LP models were developed, to address Objective One and Objective Two. Several assumptions were made, which are common when formulating LP models. First is that of linearity of variables. The expression to be optimized and the inequalities are assumed to be linear functions of the variables. Second, it was assumed that prices are fixed, for the period under consideration, and possible returns were fixed.

The aim of this study was to develop a Net Profit Contribution maximisation model that can be used as a decision tool to aid production managers in determining how best to allocate materials for fish processing, allocate labour hours, meeting customer demand while also preventing inventory build-up.

4.2. Formulation of LP Model

The model for the maximisation of profit contribution for the four products was developed from the following information in Table 4.1

Table 4.1: Data for the LP model

Item	Constraints	Product type				Total available
		Fish fillets	Frozen whole round	Fresh whole round	Frozen whole gutted	
		A	B	C	D	
1	Labour hours available (hours)	3	2	5	2.5	55hrs/week
2	Materials cost	1	1	1	1.50	26
3	Production capacity (in units)	1	1	3	1	300
4	Storage capacity (in units)	5	2	4	6	57 tonnes
5	Storage cost (per fish)	$0.04	$0.04	$0.04	$0.04	$10 000
6	Overtime possible (hrs/fish)	1	1	2	4	42.5
7	Overtime possible ($/hr)	1	1	-	1	$11 000
8	Maximum demand (in units)	100	120	70	60	
Objective function	NP contribution	$2.00	$1.00	$1.5	$1.20	

For ease of computations, the products were represented by letters of the alphabet as follows:

A= Fish fillets

B = Frozen whole round

C = Fresh whole round

D = Frozen whole gutted

The Net profit contribution maximisation linear programming model can be written as follows:

Objective Function: Max = 2.0 * A + 1.0 *B +1.5 *C + 1.2 * D; [Net profit Contribution]

Constraint 1: 3 * A + 2 * B + 5 * C + 2.5 * D <= 55;

Constraint 2: 2 * A + B + C + 1.5 * D <= 26;

Constraint 3: A + B + 3 * C + D <= 300;

Constraint 4: 5*A + 2 * B + 4 * C + 6 * D <= 57;

Constraint 5: 0.04 * A + 0.04 * B + 0.04 * C + 0.04 * D <= 10000;

Constraint 6: A + B + 2*C + 4*D <= 42.5;

Constraint 7: 1*A + 1*B + 0*C + 1*D <= 11000;

Constraint 8: A <= 100;

B <= 120;

C <= 70;

D <= 60;

4.3. Result of the Maximization Model

Table 4.2 Model 1 - Processing allocation that maximizes the Net Profit Contribution

Global optimal solution found.	
Objective value:	264.1667
Infeasibilities:	0.000000
Total solver iterations:	4
Elapsed runtime seconds:	3.77

Model Class:	LP	
Total variables:	4	
Nonlinear variables:	0	
Integer variables:	0	
Total constraints:	12	
Nonlinear constraints:	0	
Total nonzeros:	35	
Nonlinear nonzeros:	0	
Variable	Value	Reduced Cost
A	3.333333	0.000000
B	18.50000	0.000000
C	0.8333333	0.000000
D	0.000000	12.16667
Row	Slack or Surplus	Dual Price
1	264.1667	1.000000
2	3.833333	0.000000
3	0.000000	5.000000
4	275.6667	0.000000
5	0.000000	1.666667

	6	9999.093	0.000000
	7	0.000000	1.666667
	8	10978.17	0.000000
	9	96.66667	0.000000
	10	101.5000	0.000000
	11	69.16667	0.000000
	12	60.00000	0.000000

Fish fillets	Frozen whole round	Fresh whole round	Frozen whole gutted
A	**B**	**C**	**D**

Optimal product mix

Using LINGO, the optimal solution is as follows: Product A (Fish fillets) = 3.33 tonnes, Product B (Frozen whole round) = 18.50 tonnes, Product C (Fresh whole round) = 0.83 tonnes and Product D (Frozen whole gutted) = 0.00 tonnes, which yields an Objective value of $264.17. The results suggests channelling more resources for the processing of Product type B and none for product type D.

Reduced costs

With the exception of Product D, all other product types had no reduced cost. Reduced cost is

Product type D had a reduced cost of 12.67

Dual prices

Dual prices were found on the following rows, row 1, row 3, row 5 and row 7 for the constraints as follows: Labour hours [DP=1.00]; Storage cost [DP=1.67] and Overtime cost [DP=1.67].

The results suggests that a change in Labour hours will result in an associated improvement of the objective value by 1.00 units. Increasing labour hours, at the standard rate may result in an improvement in the objective value. However, labour hours are in line with Collective bargaining Agreements, hence may not be easily altered without serious repercussions to company operations.

A change in storage costs will result in an associated improvement of the objective value by 1.67 units. Effective management of storage costs is key, as this constitutes a significant proportion of the company's overheads. It is necessary for the company to effectively manage costs by reducing overstocking of raw materials, work in progress and even finished products.

A change in overtime cost will result in an associated improvement of the objective value by 1.67 units. Effective management of overtime costs is essential. Overtime is often paid at a rate higher than the standard rate. As such, it is important that the company strive to ensure all production is done within the standard normal working hours to avoid engaging in overtime to meet customer demand.

4.4. Model 2 – Optimisation without working overtime with production capacity available

Table 4.3: shows the Net Profit Contribution maximisation model in the absence of overtime

Global optimal solution found.	
Objective value:	268.0000
Infeasibilities:	0.000000
Total solver iterations:	3
Elapsed runtime seconds:	0.08
Model Class:	LP
Total variables:	4
Nonlinear variables:	0

Integer variables:	0	
Total constraints:	10	
Nonlinear constraints:	0	
Total nonzeros:	28	
Nonlinear nonzeros:	0	
Variable	Value	Reduced Cost
A	1.800000	0.000000
B	20.80000	0.000000
C	1.600000	0.000000
D	0.000000	5.500000
Row	Slack or Surplus	Dual Price
1	268.0000	1.000000
2	0.000000	1.000000
3	0.000000	6.000000
4	272.6000	0.000000
5	0.000000	1.000000
6	9999.032	0.000000
7	98.20000	0.000000
8	99.20000	0.000000
9	68.40000	0.000000
10	60.00000	0.000000

Optimal product mix

Using LINGO, the optimal solution is as follows: Product A ()= 1.80 tonnes, Product B = 20.80 tonnes, Product C = 1.60 tonnes and Product D = 0.00 tonnes, which yields an Objective value of $268.00. The results suggests channelling more resources for the processing of Product type B and none for product type D.

Reduced costs

With the exception of Product D, all other product types had no reduced cost. Reduced cost is

Product type D had a reduced cost of 5.50

Dual prices

Dual prices were found on the following rows, row 1, row 2, row 3 and row 5 for the constraints as follows: Labour hours [DP=1.00]; Materials [DP=1.00], Production capacity[DP=6.00] and Storage cost [DP=1.67].

The results suggests that a change in Labour hours will result in an associated improvement of the objective value by 1.00 units. Increasing labour hours, at the standard rate may result in an improvement in the objective value. However, labour hours are in line with Collective bargaining Agreements, hence may not be easily altered without serious repercussions to company operations.

A change in materials quantity will result in an associated improvement of the objective value by 1.00 units. Increasing materials quantity available is likely to result in an improvement in the objective value. However, there is need for consideration of other factors such as storage costs, as more materials may imply an increase in the need for more space to store the materials and additional goods produced.

A change in production capacity will result in an associated improvement of the objective value by 6.00 units. It is essential that production capacity be improved so that an objective value also increase. This may require procurement of additional equipment, or replacing obsolete equipment with modern state of the art equipment with improved production capacity. While considering this initiative, management should also be aware of associated impact on stock piling. As such, there should a balance between increasing production capacity and the need to avoid high storage costs.

4.5. Comparison of the two models.

The result show that the company stands to realise a high objective value when there is no overtime (Model 2). This indicates that the costs associated with overtime are not offset with the associated benefit. As such, in financial terms, it is advisable that the company do away with overtime. However, management also should consider other factors such as the need to continue providing products which could be forgone by discontinuing overtime. When overtime is avoided, model 2, more of product type B is produced and less of product type A. as such, the need to keep the customers loyal to product type A may compel management to continue with overtime, however at the expense of a declining objective value.

4.6. Chapter four summery

This chapter presented the data collection and Analysis, the formulation of the linear programming model, results of the maximisation model and a comparison of the two models.

CHAPTER FIVE

5.0 Introduction

This chapter presents the research conclusion and recommendation inferred from the research findings.

5.1 Conclusion and Recommendation

The results of the study indicate that a Net Profit Contribution maximisation model can be used effectively as a decision tool to aid production managers in determining how best to allocate materials for fish processing, allocate labour hours, meeting customer demand while also preventing inventory build-up.

From the data that was obtained from the operations of the company's internal reports availed by management. The Analysis which was done using the linear programming (LP) model indicated that the optimisation when used even in the face of resource constraints can still be used to maximise profits. Two LP models were developed, to determine the processing allocation that maximises Net profit contribution and examine if it was profitable to use overtime with the available production capacity. Several assumptions were made, which are common when formulating LP models. First is that of linearity of variables. The expression to be optimized and the inequalities are assumed to be linear functions of the variables. Second, it was assumed that prices are fixed, for the period under consideration, and possible returns were fixed. The study has demonstrated that variations in input result in different gross revenue. It is recommended that effective management of storage costs is key, as this constitutes a significant proportion of the company's overheads. It is necessary for the company to effectively manage costs by reducing overstocking of raw materials, work in progress and even finished products.

Managers also need to consider management of overtime costs as it is very essential. Overtime is often paid at a rate higher than the standard rate, as such, it is important that the company strives to ensure all production is done within the standard normal working hours to avoid engaging in overtime to meet customer demand. Increasing labour hours, at the standard rate may result in an improvement in the objective value. However, labour hours are in line with Collective bargaining Agreements, hence may not be easily altered without serious repercussions to company operations.

More so it is essential that production capacity be improved so that an objective value also increase. This may require procurement of additional equipment, or replacing obsolete equipment with modern state of the art equipment with improved production capacity in order for profit maximisation to be realised.

5.2 Chapter five summery

This chapter presented the research conclusions and recommendations inferred from the research findings.

References

Aandahl, F.G., 2015. Fred G. Aandahl Biographical Records.

Bakhrankova, K., Midthun, K.T. and Uggen, K.T., 2014. Stochastic optimization of operational production planning for fisheries. *Fisheries research*, *157*, pp.147-153.

Bendall, B., Ives, M.J., Edmonds, N.J. and Maxwell, D.L., (2012). Street lighting disrupts the diel migratory pattern of wild Atlantic salmon, Salmo salar L., smolts leaving their natal stream. *Aquaculture*, *330*, pp.74-81

Birge, J.R. and Louveaux, F., (2011). *Introduction to stochastic programming*. Springer Science & Business Media. Biggam, J. (2011). *Succeeding with your master's dissertation: a step-by-step handbook.* Berkshire: University Press.

Burns, N. & Groove, SK. (2001). *Understanding nursing research.* Philadelphia: W.B. Saunders.

Buzby, J.C. and Hyman, J., (2012). Total and per capita value of food loss in the United States. *Food policy*, *37*(5), pp.561-570.

Cooper, D. & Schindler, P. (2011). *Business Research Methods* 8th ed. New Dehli: Tata McGraw-Hill.

Gudmundsdottir, K., Lord, C.J. and Ashworth, A., (2007). The proteasome is involved in determining differential utilization of double-strand break repair pathways. *Oncogene*, *26*(54), pp.7601-7606.

Gunn, E.A., Millar, H.H. and Newbold, S.M., (1991). Planning harvesting and marketing activities for integrated fishing firms under an enterprise allocation scheme. *European Journal of Operational Research*, *55*(2), pp.243-259.

Hu, W., Li, Y., Srihari, V. and Yemeni, R., Oracle International Corp, (2013). *High-performance log-based processing*. U.S. Patent 8,566,326.

Hyndman, R.J. and Athanasopoulos, G., (2015). 8.9 Seasonal ARIMA models. *Forecasting: principles and practice. oTexts*.

Jensson, P. and Maack, P.K., (1997). The Practical use of duality in product mix optimization. *Yearbook VFÍ/TFÍ*, pp.237-246.

Jensson, P., (1988). Daily production planning in fish processing firms. *European Journal of Operational Research*, *36*(3), pp.410-415.

Kaut, M., Vladimirou, H., Wallace, S.W. and Zenios, S.A., (2007). Stability analysis of portfolio management with conditional value-at-risk. *Quantitative Finance*, *7*(4), pp.397-409.

Kontali Analyse, A.S., (2014). Systemizing the world of Aquaculture and Fisheries.

Kothari, CR. (2004). *Research methodology: methods and techniques*. New Delhi: New Age International.

Krishnaswamy, KN. (2006). *Management research methodology: integration of principles, methods and techniques*. New Delhi: Pearson

Larsen, B.D., Petersen, J.S., Meier, E., Kjolbye, A.L., Jorgensen, N.R., Neilsen, M.S., Holstein-Rathlou, N.H., Martins, J.B. and Jensen, P.H., Zealand Pharma AS, (2009). *Medical uses of intercellular communication facilitating compounds*. U.S. Patent 7,585,839.

Margeirsson, S., Hrafnkelsson, B., Jónsson, G.R., Jensson, P. and Arason, S., (2010). Decision making in the cod industry based on recording and analysis of value chain data. *Journal of food engineering*, *99*(2), pp.151-158.

Margeirsson, B. and Arason, S., (2008). Temperature monitoring and CFD modelling of a cold storage. In *Proceedings of the 4th International Workshop on Cold Chain Management, University of Bonn, Bonn*.

Margeirsson, S., Jonsson, G.R., Arason, S. and Thorkelsson, G., (2007). Influencing factors on yield, gaping, bruises and nematodes in cod (Gadus morhua) fillets. *Journal of food engineering*, *80*(2), pp.503-508.

Mathiesen, Árni M. "The state of world fisheries and aquaculture 2012." (2015).

Mikalsen, B. and Vassdal, T., (1981). A short term production planning model in fish processing. In *Applied operations research in fishing* (pp. 223-232). Springer, Boston, MA.

Moffitt, C.M. and Cajas-Cano, L., (2014). Blue Growth: The 2014 FAO State of the World Fisheries and Aquaculture. *Fisheries*, *39*(11), pp.552-553.

Mudhunguyo, C., (2017). Formal employment in Zimbabwe: outlook of the next decade (2017-2026). *Journal of Public Administration and Development Alternatives (JPADA)*, *2*(2), pp.47-59.

Mugenda, O. M. (2008). *Research Methods, Quantitative and Qualitative Approaches. Nairobi, Kenya: African Centre for Technological Studies*. Approaches. Nairobi, Kenya: African Centre for Technological Studies.

Neubert, M.G., (2003). Marine reserves and optimal harvesting. *Ecology Letters*, *6*(9), pp.843-849.

Ngulube, P. (2015). Trends in Research Methodological Procedures Used in Knowledge Management Studies. *African Journal of Library, Archives and Information Science* 25 (2): 125-143.

Ólafsson, R.P., Emmelkamp, P.M., Gunnarsdóttir, E.R., Snæbjörnsson, T., Ólason, D.T. and Kristjánsson, Á., (2013). Suppressing disgust related thoughts and performance on a subsequent behavioural avoidance task: implications for OCD. *Behaviour research and therapy*, *51*(3), pp.152-160.

Øglend, A., (2010). An analysis of commodity price dynamics with focus on the price of salmon.

Ólafsson, E., Johnstone, R.W. and Ndaro, S.G., (1995). Effects of intensive seaweed farming on the meiobenthos in a tropical lagoon. *Journal of Experimental Marine Biology and Ecology*, *191*(1), pp.101-117.

Porter, M.E., (1985). Value chain. *The Value Chain and Competitive advantage: creating and sustaining superior performance*.

Randhawa, S.U. and Bjarnason, E.T., (1995). A decision aid for coordinating fishing and fish processing. *European journal of operational research*, *81*(1), pp.62-75.

Saunders, M., Lewis, P. and Thornhill, A. (2016). *Research Methods for Business Students* (7th Ed.). Harlow, Essex: Pearson Education Ltd.

Sekaran, U. & Bougie, R. (2010). *Research methods for business: A skill building approach.* Chichester: John Willey & Sons Ltd.

Snieder, R. & Larner, K. (2009). *The Art of Being a Scientist: A Guide for Graduate Students and their Mentors*. Cambridge: Cambridge University Press.

Taylor, B. (2006). *Research Methodology: a guide for researchers in management and social sciences.* New Delhi: PHI Learning.

Vormedal, I., (2017). Corporate Strategies in Environmental Governance: Marine harvest and regulatory change for sustainable aquaculture. *Environmental Policy and Governance*, *27*(1), pp.45-58.

Wilson, J. (2010). *Essentials of business research: a guide to doing your research project*. London: SAGE Publication.

Yin RK. (2014). *Case study research design and methods*. 2nd ed. Applied Social Research Methods Series. SAGE Publications.