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Animal Feed Business Risk Assessment Quantification COVID-19 and Supply Chains Disruptions Losses

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Abstract

The animal feed business is facing the risk of raw material grain shortage due to global supply chain disruption during the COVID-19 pandemic, the Russia and Ukraine conflict and recently global shipping disruption at the Red Sea. These situations cause high increases in raw material prices and animal feed cost of production. The feed mills business plant demand uncertainty and material shortage reduced plants' production capacity to 36% - 46%. The bounce back in animal feed consumer demand leads to more stress on supply chains and business sustainability. This study identifies and quantifies business risk due to low sale revenue and test subsidy program proposed for rebuilding plant capacity affected and caused by supply chain disruption. The study applied stochastic budgeting simulation method to evaluate risk and uncertain factors and calculate NPV probability distribution under different feed mill plant capacities generated by supply chain disruption pressures. Different feed mill plant capacities calculated and ranked across various risk aversion levels. The potential loss of COVID-19 and supply chain disruption of animal feed business and food security sustainability and the need to return the supply chain system to normal situation has not been quantified in a robust manner. Therefore, the stochastic budgeting simulation model performed to incorporate risk variables and draw NPV probability distributions to quantify COVID-19 and supply chain disruption effect on feed mill business under various risk preferences. The Government raw materials incentive strategies were evaluated for different coronavirus levels and ranked across absolute risk aversion coefficient levels. The study shows that raw material subsidy for feed mill business plants will reduce the expected loss probability due to COVID-19 and supply chain disruption challenges and increase NPV return above RO 2.00 million by 71%. The SERF analysis calculated certainty equivalent (CE) and risk premiums (RP) value to payoff for COVID-19 and supply chain disruption.

Keywords

Project Operation Efficiency, Dynamic Simulation Model, COVID-19, Supply Chain Disruption, Stochastic Efficiency with Respect to Function (SERF), Certainly Equivalent (CE), Risk Premiums (RP), Value at Risk (VaR)

1. Introduction

Animal feed industry plays a key role in providing poultry and animal feed to agri-business to achieve food security goals in the Sultanate of Oman. Most of the raw materials used to produce feed such as corn, soybean, wheat and wheat bran, premix and vitamins imported from outside and exposed to raw material availability, cost, and price uncertainties. Recently, the risk of raw material unavailability and price variability affected animal feed production processes and reduced business sale revenue and jeopardized feed business economic sustainability and country food security goals achievements.

The country's food security achievements during the year 2023, as per the Ministry of Agriculture Fisheries and Water Resources account for 88% for fresh milk, 61% poultry table eggs, 62% poultry meat and 44% for red meat. The total animal sector production increased from 148 thousand tons in 2011 to 437 thousand tons in 2022 with annual production growth of 9.4% compared to annual production growth of 8% for the agriculture sector, as per MAFWR 2022 [1]. Dairy and beef farming contribute 62.5% of the total animal sector production compared to 37.5% of poultry business farming. The above-mentioned figures show the essential role of the animal feed business sector in achieving food security goals and farming business growth sustainability.

The price of main raw materials ingredients such as corn and soybean increased by 36% since 2021 and created high pressure on animal feed business profitability, as per Ishag Kheiry in 2022 [2]. The impact of raw material shortage reduced production and sale revenue which increased fixed costs by 89% due to supply chain disruption. The animal feed main raw material price increased again by another 33% during the year 2023 and reduced raw material stock to a lower level and disturbed customer order fulfillment. Moreover, sales volume reduced revenue and created an inability to pay creditors and workers and to maintain workforce levels. The quicker companies respond to the COVID-19 pandemic, the more chance for company survival, argued Asare Andy *et al.* [3] in 2020. The Government imposed raw material subsidy programs for six months starting from the first of July 2022 and extended the program for another six months up to the end of June 2023 due to global grain prices rallying to 10 years high levels, COVID-19 epidemics, and global supply chain disruptions effects.

The Coronavirus COVID-19 pandemic which started in 2020 has a high association effect with global supply chain disruption and exposed risk and uncertainties to animal feed and agri-business economy activities. Animal feed raw materi-

als shortages and increase in international prices and shipment cost due to container crisis have created significant challenges and severe animal feed processing bottlenecks due to delay in raw materials imported arrivals and shortages in production and sale revenue sever reductions. The senior management had to struggle to respond to critical uncertainties factors to protect their employees, safeguard supply security, argued Saleheen, F. and Habib, M. in 2022 [4]. The impact of considerable risk of raw materials unavailability and vulnerability on animal feed business profitability and business continuity need to be investigated and measured.

The operation of an animal feed mill plant located in the southern part of the Sultanate of Oman at Salalah Region affected due to supply chain disruption. The factory produced 145,000 tons of animal and poultry feed in 2020 out of a total plant capacity of 160,000 tons per year. The feed mill plant production dropped to 121,833 tons in 2021 due to COVID-19 pandemic global lockdown and raw materials shortage and affected sale revenue and business profitability. The animal feed plant production capacity again reduced to 73,900 tons in year 2022 and created a server business loss due to internal and external factors of coronavirus COVID-19 pandemic and the effects associated with global supply chain disruptions. The COVID-19 out-break and global health crisis forced the Government to lock down social and economic activities. In 2024, Vincent Canwat [5] studied supply chain disruption effect on MSMEs performance and outline a reduction in good supply quantity, quality and orders lead times. He assessed resilient strategies of MSMEs enterprise responses adopted to overcome disruption challenges which varied according to business age, size, geographical location, and products industries.

The global supply chain disruption started in early 2020 and complete lockdown in most of the countries experienced by the first half of 2020 due to coronavirus spread over the world, as per Giroud Axle and Inge Ivarsson in 2020 [6]. The supply chain disruption picked up over courses of 2021 and interrupted business and industries operation processes. The supply chain disruption together with increasing raw material prices causes the cost of production to increase and affects business profitability. In 2020 Ivanov and Dolgui [7] and [8] examined available literature to conceptualize the effect of the coronavirus pandemic on supply chain disruption and recovery action needed to rebuild a sustainable supply chain. In 2021, Magableh G. M. [9] examined the impact of COVID-19 on supply chain disruptions and their associated challenges and trends. He formed a (SCC19) framework of supply chain and COVID-19 interrelationships and identified factors and approaches to help decision makers to improve and rebalance supply chain disruptions. In 2021, Saima and Mohammed [10] argued that, developing countries dependent on importing staple crops and grain will suffer from global food chain disruptions and trade protection policies due to COVID-19 outbreak and lead to great economic losses and could have serious negative consequences for food security. Agri-business has gone through many challenges and adapted

to changes in economic situations, technology, and resources availability, but uncertainty remains concerning the ability of Agri-business systems to adapt to COVID-19 pandemic and supply chain disruptions impact and fast resilience action to be taken to achieve food security goals.

Business risk analysis and management is a process which enables management to understand business risk and uncertainty to mitigate risks associated with a business continuity and failure. The risk and contingency plan and preventive risk budgeting are appropriate measures to prevent stock out as per Romana, F., Gestoso, C. and Gonzalez Fernandez, S. [11] recommendation in 2023. The proper risk analysis will increase the likelihood of successful business, cost control and the achievement of business performance objectives as per Lalani B. *et al.* [12]. In 2024, he formed a simulation cash flow model to calculate NPV for different future price scenarios to test trade off or synergy for coffee production systems profitability and sustainability. Simulation model risk analysis with a probabilistic approach gives the Managers and decision makers accurate future prediction information and a holistic understanding of business technical problems and working environment at initial stages and enable Managers to get appropriate solutions and business opportunities at the right time. Moreover, decision makers could understand the probability associated with business feasibility output metric *i.e.*, NPVs including extreme events and incorporate various levels of fixed and variable cost for various levels of production scenarios representing COVID-19 and supply chain disruptions business loss.

Animal feed business production risk model can be formed to examine and quantify uncertainty by including production inputs cost, production capacity level changes due to feed mill raw materials availability, annual revenue growth rate, sale revenue level and sale price. The annual discount cash flow used to generate present values and calculate NPV for each production level scenario incorporating risk of raw material availability due to COVID-19 and supply chain disruptions impact. The study quantified risk and uncertainty of animal feed business loss.

The difference between deterministic conventional business methodology analysis and simulation analysis is that the conventional analysis generates single points and ignores thousands of the results that may be considered in simulation model analysis. It also gives equal weight to each outcome and ignores the interdependence between inputs, and impact of different inputs to the outcome. Monte Carlo Simulation models were used in this study to quantify animal feed business risk, and uncertainty parameters affected by COVID-19 and supply chain disruption. The quantitative risk analysis will provide decision makers with a means of estimating the probability that the project NPV will fall below zero. The model will also help in improving the supply chain system and rebuild a sustainable system that can achieve project objectives simultaneously. In 2023, Taro Akiko used a quantitative and comprehensive analysis approach [13] to optimize sustainable farming practices and investigate relationships between climate resilience and rice

crop productivity factors. Partial and enterprise budget approaches are used by many researchers to calculate margin and net return from different business inputs level scenarios, as per Yubing Fan, *et al.* [14] in 2022. Four scenarios formed to cover basic operation capacity level for the year 2020 and three models to cover COVID-19 and supply chain disruption for the year 2021 to 2023. Risk parameters factors such as plant production level, first year sale revenue, variable cost including raw material price, fixed cost and annual demand growth rate are incorporated in above mentioned models.

The stochastic efficiency with respect to a function (SERF) approach used by many researchers as a tool to assess business model scenarios and rank alternatives risk efficiency (see [15]-[17]). In 2020, (SERF) analysis used by Ishag Kheiry [18] and in 2008, Richardson J. *et al.* [19] used (SERF) to compare and rank alternatives policies and scenario management preferences at different absolute risk aversion coefficients (ARAC). In 2022, Khakbazan, M. *et al.* [20] used SERF and certain equitant (CE) figures to rank different silage-based feed diet scenarios to obtain cattle breading efficiency for beef backgrounding streets. The Government raw material support programs are evaluated by calculating certainly equivalent (CE) and risk premium price (RP) over a range of absolute risk aversion coefficients (ARACs).

In 2015, Ishag Kheiry [21] used the Monte Carlo Simulation model for project appraisal alternative comparison. He argued that integrated analysis provided a range of outcomes that can reduce the risk of uncertainty and give more reliable results for business management. Additional information related to adaptive and robust policies applied to the management of water and aquatic ecosystems can be found in [22]-[27]. In 2006, the risk faced ethanol plant was assessed and quantified by obtaining NPV probability and cumulative distribution function (CDF) by Richardson J. *et al.* [28].

The objective of this article is to assess animal feed business risk and uncertainty due coronavirus challenges through analyzing operation performance viability of different production and key variable levels to quantify COVID-19 pandemic and supply chain disruptions impacts. The Government subsidy program to improve performance and achieve business sustainability in term of (NPVs) evaluated under future operation scenarios of key variables to quantify risk and uncertainty of coronavirus and supply chain disruptions. The study highlights the urgent need for policies that not only encourage animal feed business sustainable practices but also support local farmers' likelihood and achieve food security goals.

2. Materials and Methods

The feed mill business performance feasibility evaluation performed through estimating the future values of the projected business production data for 12 years. The assumption and parameters process with stochastic budgeting simulation. The historical data includes variable and fixed cost, production capacity, annual growth rate and sale revenue for five scenarios from 2020 to 2023 to represent

operation before and after pandemic and all data obtained from feed mill plants record data. The risk factors incorporated in analysis by the dynamic simulation model include variables and uncertainty data as a triangle range as (*i.e.*, minimum, most likely and maximum). The future plant production figure estimated by taken first year sale revenue multiplied by annual growth rate. Model scenarios represent by using available data for regular operation years before and during a specific situation crisis, *i.e.*, COVID-19 and supply chain disruption times. The outcome of the consequences predicted future profitability *i.e.*, Net Present Value (NPV) compared to each scenario over different decision makers risk averse level. The NPV used as financial criteria to reflect overall business return in today's value in (RO) Rial Omani. The conventional business model evaluation only generates a single value of NPV and does not consider risk and uncertainty variables of business such as inputs and outputs. As a result, dynamic simulation business models used in this study reflect a range of inputs and outputs to quantify business risk and uncertainty.

2.1. Model Structure and Data Collection

First, the feed mill business modeling process defined a number of uncertain inputs to describe the ordinary business operation parameters during the year 2020 and operation data reflecting COVID-19 in 2021 and supply chain disruption during the year 2022 and 2023 from animal feed plants. The model used to quantify coronavirus outbreak crisis loss.

The purpose of qualitative risk analysis in this study is to provide an important level of understanding risks exposed to the feed mill business. The data is collected from feed mill business plants and various sources to build stochastic budget models. The study modeled five scenarios according to the following key risk variables assumptions summarized as under:

1) Option 2020: Business basic operation data during the normal year 2020 (production, sale price, inputs costs).

2) Option 2021: Business operation data during COVID-19-year 2021 (production, sale price, inputs costs).

3) Option 2021 RS: Business operation data during COVID-19-year 2021 with raw material subsidy program (production, sale price, inputs costs).

4) Option 2022: Business operation data with severe impact of COVID-19 and supply chain disruptions in the year 2022 which include a drop in production level and increase in fixed and raw material costs due shipment rate increase.

5) Option 2023: Business operation data year 2023 including drop in production level, additional increase in variable cost due to international grain price increase and paying material in containers and not in bulk shipment.

6) Capital cost of feed mill project including revaluation of building and machinery irrespective of operation performance. Data collected from historical records (2020-2023) and modified by using triangular and normal distribution to estimate future value for 12 years.

The key variable risks related to feed mill plant operation performance during COVID-19, and supply chain disruption are identified and divided into six key variable risk according to decision makers. The project investors and Managers are not prepared to bear some of the risks related to feed mill operation factors. They think that the risk associated with COVID-19, and supply chain disruption are too high, and that if they bore the risks, they would not be able to recover their costs. The risks that the potential investors and managers are not prepared to bear during COVID-19, and supply chain disruption period (2020-2023) can be summarized as under:

- Production level reduction risk: The risk that not enough production will be produced from the project, or that there will be not enough production to recover the operation and investment cost of the project. The plant production for basic operation year 2020 was 145,126 tons and reduced to 121,833 tons for 2021 due to COVID-19 epidemic. The plant production level dropped by 49.08% and reached 73,900 tons in the year 2022 due to the severe supply chain disruption impact. The risk and uncertainty incorporated in the model with triangular distribution function.
- Variable cost increase risk: The risk of variable cost and raw material cost increase was due to raw material price increase and shipment rate increase due to the container crisis. The variable cost increased from RO 101 per ton in 2020 to RO 125 in the year 2021 and again increased to RO 143 per ton in 2022. The variable cost increase reflects COVID-19 and supply chain disruption impact which increase operation cost and reduce plant profit. The risk and uncertainty incorporated in the model with triangular distribution function.
- Fixed cost increase risk: due to plant production capacity decreased by 49.08%, the fixed cost per ton increased from RO 9.45 in 2020 to RO 12.60 and doubled to RO 26.00 in 2022. The risk and uncertainty incorporated in the model with triangular distribution function. Fixed costs include storage cost, maintenance cost, machineries depreciation and administration cost.
- The first-year revenue risk: The first-year sale revenue reduced sharply from RO 17,709,852 in basic year 2020 to RO 11,120,237 in 2022 and reflects COVID-19 and supply chain disruption regarding raw material availability and cash shortage. The risk and uncertainty of this variable are incorporated in the model with triangular distribution function and calculated by multiplying units sold by sale price per ton.
- Annual growth rate risk: Risk that there is not enough annual sales revenue growth for 12 years due to COVID-19 and Supply chain disruption impacts with respect to business growth and continuity. The risk and uncertainty of this variable is incorporated in the model with normal distribution function and calculated by mean and standard variation of the parameters.
- Capital cost increases risk: The capital cost of the project increases risk formed by using a triangular distribution function with an average RO 2,900,000 project capital cost. The project's capital cost was re-valuated and calculated by

valuation of all assets including machinery, building and raw material storage silos.

According to the net present value distribution, we can analyze the feasibility of the feed mill performance and the impact of COVID-19 and supply chain disruptions. From the NPV distribution characteristics, we can get some information such as NPV expectation positive value and probability of project sustainability and risk management alternatives. This can provide more comprehensive information than a single net present value calculated by conventional approach. The dynamic simulation method and approach obtain a range of NPV probability distribution features and animal feed business performance considering the COVID-19 and supply chain disruption impacts as a random variable which generates a certain NPV distribution.

The random variation characteristics of key factors such as the production level, price, variable and fixed cost and so on are not obvious. Therefore, sensitivity analysis was performed. Specifically, in the simulation, each of these factors are set as a different value respectively and then the probability distribution curve of NPV under different scenario is obtained, respectively. So that we could obtain project earn probability, loss probability and risk measures for different COVID-19 and supply chain disruption factors impact. In this way, we carried out a comprehensive analysis of the influencing factors affecting the NPV of the project, thus providing a reliable basis for rational decision making and relevant risk management strategies.

2.2. Model Net Present Value

The study calculated NPV and used it as an evaluation criterion for each model. The net cash flow, calculated by subtracting the variable and fixed cost from sale revenue, and figures discounted by 12% interest rate to obtain present value figures and the NPV of each scenario. The study obtained deterministic figures and generated stochastic inputs and outputs variables to calculate and range of probability of NPV values instead of having a single value of key output values (KOVs) for a conventional deterministic financial evaluation. The range of probability of NPV distribution shows the risk and uncertainty impact of COVID-19 and supply chain disruption. The NPV for each scenario obtained from the formula below.

$$\text{NPV} = \sum_{n=0}^{N} \frac{Bn - Cn}{(1+r)^n}$$

were,

Bn = present value of the benefit in year n (n = 0, 1, 2, …, n).

Cn = present value of the variable and fixed cost in year n (n = 0, 1, 2, …, n).

ci = the net cash flow in year n (n = 0, 1, 2, …, n), represented by operation income in this study.

n = the planning period which equals twenty years in the current analysis.

r = the discount rate.

2.3. Monte Carlo Simulation, COVID-19 and Supply Chain Disruption

Monte Carlo simulation model in this study designed to evaluate the variability or stochastic of the input variables during coronavirus outbreak. The model is used to incorporate uncertainty and estimate the effects of key variables such as production level, variable and fixed cost, sale revenue during coronavirus on the NPV of a given proposal. The process involves the identification and assessment of the main key variables affected by COVID-19 and supply chain disruptions. For each key variable, we fit a probability density function that best describes the range of uncertainty around the expected key variable value. For this purpose, the study used output and input variables data and operation recorded historical data.

The historical data for the period (2020 to 2023) were obtained and used to estimate variable distribution for each key variable in the model. The study used at Risk program 8.6 with five thousand iterations to estimate and generate outcome and NPV for each scenario representing regular basic year 2020 and COVID-19 effect operation year 2021 and supply chain disruption effect during year 2022 and 2023. The feed mill plant production capacity was affected by COVID-19 outbreak and a reduction of 16% is recorded from the basic operation year 2020. The risk of raw material availability and price increase impact on business performance were calculated through dynamic simulation model. The risk and uncertainty key variables such as variable and fixed cost, sale price and sale revenue were recorded and supply chain disruption impact on business profitability are estimated. The study formed Cumulative Distribution Function analysis (CDF) to rank risk management alternatives according to COVID-19 and supply chain disruptions.

During the year 2022 the global supply chain bottleneck resulted in significant animal feed raw materials and feed additives shortages and cost increase. The landed raw materials cost increased by 41.58% from the basic operation year 2020. COVID-19 Pandemic recovery actions such as vaccination, steady economic recovery and insatiable consumer demand could not tempered COVID-19 Market disruption effect. Moreover, transportation and logistics issues such as container high freight rate which increased three times since last year 2021 caused delay in raw material shipment and profit loss. The feed mill plant production capacity reduced to 73,900 tons *i.e.*, 49% of basic operation in the year 2020 and caused negative NPV figures.

Monte Carlo simulation model is currently regarded as a powerful technique and used for cash-flow analysis in the study to evaluate business performance. It is used to investigate COVID-19 and supply chain disruptions effects and cope with significant uncertainties variables effects complication. The more complex the project and the more risks and uncertainty variables are associated; the more valuable Monte Carlo simulation analysis will be.

2.4. Stochastic Efficiency with Respect to a Function, COVID-19 and Supply Chain Disruption

The study used stochastic efficiency with respect to a function (SERF) as an approach and tool to assess business performance scenarios during COVID-19 and supply chain disruption. The Simetar program used Monte Carlo simulation for 500 iterations to simulate NPV from input and output specific probability distribution. The model is used to calculate NPVs of different five business models and rank business performance scenarios and raw materials subsidy programs over a range of absolute risk aversion coefficients (ARAC). The models were run for 12 years for each business performance scenario to assess economic sustainability of different alternatives. The feed business performance failure measured in financial terms of getting negative NPVs. The business performance model also helps decision makers to understand feed manufacturing bottlenecks and business sustainability to meet consumer demand and food security goals with lower risk and uncertainty and future virus outbreak and supply chain disruptions. Decision makers need to make alternative plans and strategies to solve business bottleneck problems for all supply chain stages from raw material availability, skill labor shortage, truck drivers to final products transportation and logistics facilities.

The risk premium parameters used to measure minimum amount of money need to be paid to decision makers to justify a switch from business loss area to profit and compensate COVID-19 outbreak and extreme challenges of supply chain disruption. The Risk Premium RP calculated by subtracting Certainty Equivalent CE for less preferred performance alternatives from dominant basic feed mill operation year.

2.5. Cumulative Distribution Function, COVID-19 and Supply Chain Disruption

The cumulative distribution function (CDF) analysis is performed to calculate the probability range of operation performance profitability and break even for each operation level scenario under four plant production levels and different raw material variables and fixed cost. The cumulative distribution function (CDF) analysis is a more advanced tool to compare animal feed operation performance than first- and second-degree stochastic dominance analysis as cumulative distribution lines cross each other, and no clear operation performance is recorded and can be preferred.

3. Result and Discussion

3.1. Animal Feed Operation Model and Statistical Analysis

The stochastic simulation dynamic model performed to test five animal feed operation performance. The statistical analysis data in Table 1 shows a positive NPV for the basic year 2020 and Government raw materials subsidy program model for year 2021. The severe reduction in plant production capacity due to raw material shortage in 2022 and 2023 record a high negative NPV and insignificant risk asso-

ciated with investment return. The ranking criteria and method used in analysis were the Cumulative Distribution Function analysis (CDF) to rank feed mill operation before and during COVID-19 to investigate supply chain disruption impacts. The study used Stochastic Efficiency with Respect to Function (SERF) criteria to compare NPVs of five scenarios representing COVID-19 impact scenarios over a range of absolute risk aversion coefficients (ARACs). The ARAC represents a decision maker's degree of risk aversion for risk neutral with ARAC equal (0.000000) and moderate risk aversion equal (0.0000003) ARAC and extreme risk aversion with (0.0000007) ARAC.

Table 1. Statistical for feed mill performance model and raw material subsidy program.

Risk Model	Basic	COVID-19	COVID-19 RS	COVID-19 & SCD	COVID-19 & SCD
Model	Option 2020	Option 2021	Option 2021	Option 2022	Option 2023
Production/tons	145,126	121,833	121,833	73,900	82,366
NPV Mean	10,291,016	(6,371,690)	10,665,201	(9,484,093)	(29,972,992)
Std. Deviation	4,438,314	2,562,693	4,404,576	1,874,825	3,645,786
CV %	0.552	1.346	0.413	0.471	0.227
Skewness	0.569	0.371	0.590	0.341	(0.592)
Kurtosis	3.712	3.596	3.733	3.387	3.844
Exp. positive %	1.000	0.011	1.000	0.038	0.000

The high variable and fixed cost due to COVID-19 and supply chain disruption impact were the most sensitive factors ranked by Tornado analysis for business viability Model for years 2022 and 2023. Feed mill performance model 2023 indicates negative skewed distribution with long tail to left with skewness figure (0.592) and high kurtosis 3.844 which means frequent small gain and few large losses of business model. The high cost of raw material landed due to container crises were the main factors need to be controlled and reduced for business financial sustainability.

3.2. Cumulated Distribution Function Analysis (CDF) and Risk Efficiency

The study formed Cumulative Distribution Function analysis (CDF) to rank feed mill business risk models. Figure 1 below shows all operation models affected by COVID-19, and supply chain disruption have a negative NPV distribution range except operation model for the year 2020 before COVID-19 and supply chain challenges. The figures illustrate the government's raw material subsidy program by RO 20 per ton can compensate the coronavirus challenges impact and mitigate risk at downside level and achieve sustainable animal feed business performance and food security gools.

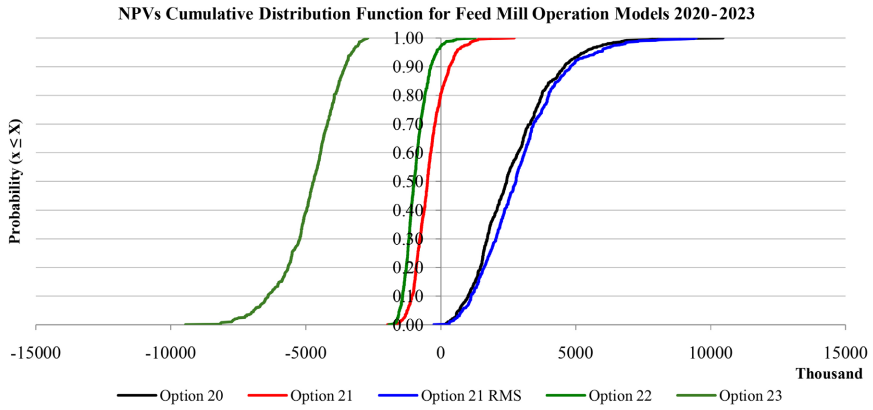

Figure 1. Cumulative Distribution Function analysis (CDF) to rank feed mill business risk models.

Due to CDF lines crossing each other in the graph we could not be able to rank animal feed operation performance model during coronavirus according to their financial sustainability by using first and second stochastic dominance with respect to function (SDRF), and accordingly we use Stochastic Efficiency with Respect to Function (SERF) criteria to quantify COVID-19 and supply chain disruption impact and obtain Certainty Equivalent CE values over a range of absolute risk aversion coefficients (ARACs).

3.3. Stochastic Efficiency with Respect to Function (SERF) and Certainty Equivalent CE

The study used Stochastic Efficiency with Respect to Function (SERF) criteria to compare NPVs of five scenarios representing COVID-19 and supply chain challenge impacts. The Simetar program used to perform (SERF) analysis and rank the risk-efficient of animal feed operation performance under coronavirus challenges and quantify the Government support program and risk management alternatives. Figure 2 showed only the basic model and Government raw material subsidy model are risk efficient and sustainable alternatives as their CE lines located above other lines represent COVID-19 impact performance lines.

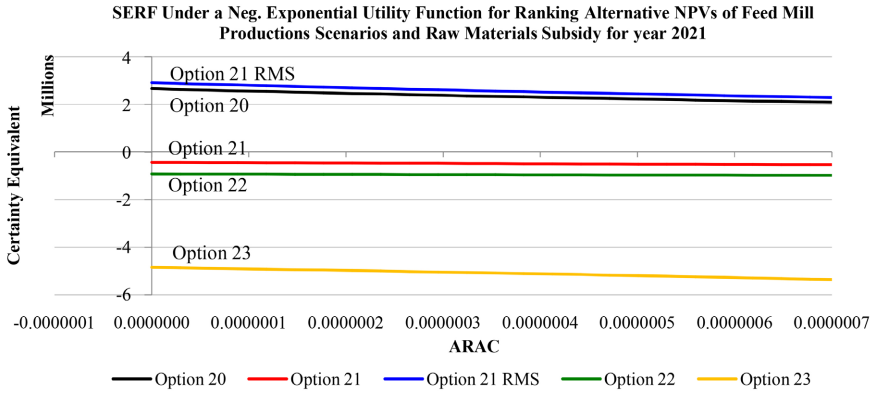

Figure 2. Stochastic Efficiency with Respect to Function (SERF) for NPVs scenarios representing COVID-19 and supply chain challenge impacts.

The SERF method used to calculate Certainty Equivalent CE values over a range of absolute risk aversion coefficients (ARACs). The ARAC represents a decision maker's degree of risk aversion. Decision makers are risk averse if ARAC > 0, risk neutral if ARAC = 0, and risk preferring if ARAC < 0. The ARAC values used in this analysis ranged from (0.0000001) represent risk neutral to (0.0000007) represent extreme risk averse. The higher CE alternative at the same level of ARAC is considered a best model alternative. Model (Option 21 RMS) which represent year 2021 with Government raw material subsidy obtained high CE values of RO 2,908,168 followed by Model (Option 20) which represent basic year before COVID-19 with a value of RO 2,656,749, and Model (Option 21) second year of COVID-19 with negative CE value of RO (432,690), and Model (Option 22) with negative CE of RO (926,796) and Model (Option 23) with NPV of RO (4,850,115) at risk neutral level, Figure 2. Stochastic Efficiency with Respect to Function (SERF) analysis showed that COVID-19 and supply chain disruption have a severe impact to animal feed business performance and only Government raw material subsidy of RO 20 per ton can be used as sustainable risk management to mitigate coronavirus and supply chain disruption challenges and impacts.

The high value of CE at the same level as ARAC indicates a preferred alternative and operation performance level. Absolute risk aversion coefficient (ARAC) values ranging from 0.000000 to 0.0000007 were used in the (SERF) analysis to calculate CE values for each animal feed operation level as indicated by Figure 2.

Table 2 below showed that (Option 20) model which represents animal feed operation before coronavirus is the only risk averse alternative for at all absolute risk aversion coefficient (ARAC). The range of risk aversion coefficients (ARAC) from 0.000000 which represent risk neutral to 0.0000007 which present strongly risk averse. Sustainable international raw material price and shipping rate increase plant operation capacity to 90.7% and increase CE value for all (ARAC). All other operation option models are not risk averse alternatives due to raw material shortage and container shipping rate increase due to COVID-19 and supply chain disruption challenges.

Table 2. Ranking coronavirus challenges NPV according to Basic Model by using Certainty Equivalent and Risk Premium measurement for all Absolute Risk Aversion Coefficient.

Variables	Model	CE			Risk Premium (Basic before COVID19)		
		Neutral	Moderate	Strong	Neutral	Moderate	Strong
		(0.000000)	(0.0000003)	(0.0000007)	(0.000000)	(0.0000003)	(0.0000007)
Option 20	Basic	2,656,749	2,354,241	2,080,719	-	-	-
Option 21	Miner	(432,690)	(484,765)	(540,437)	3,089,439	2,839,006	2,621,156
Option 22	Moderate	(926,796)	(956,323)	(988,362)	3,583,545	3,310,564	3,069,081
Option 23	Extreme	(4,850,115)	(5,063,648)	(5,367,522)	7,506,864	7,417,889	7,448,241
Option 21SRM	SRM	2,908,168	2,581,047	2,281,772	-	-	-

The NPV risk premiums RP calculated for each operation level and production scenarios by subtracting CE values of coronavirus and supply chain disruption operation models from Basic operation model CE values at given ARAC values. Risk premium is a measure of NPV return that is required by decision makers to compensate for being subjected to an increased level of COVID-19 and supply chain disruption risk such as (reduce in sale revenue or raw material availability and cost increase). The CE and risk premium figures for each operation scenario in the study calculated and summarized at Table 2. Risk premium for (Option 23) model has a high-risk premium RP due to severe supply chain disruption such as raw material vulnerability and price increase and container shipment crisis for all ARAC. The extent to which supply chain disruptions impact on animal feed business performance depends on their supply chain vulnerability and resilience and raw material imported from long distant South America countries and geopolitical situations in Russia and Ukraine which affect business operation performance. The unclear business resilience strategies and slow response during COVID-19 pandemic due to uncontrollable parameters and adoption of less effective measurement extended and exaggerated supply chain disruption effect to year 2021 and 2023. As a result, the raw material availability and business ability to restore operation capacity were the main challenges and required low raw material landed cost to compensate for sale revenue reduction risk and moved to Basic operation level before supply chain disruption challenges.

3.4. Probability Density Function and Risk Assessment of Supply Chain Disruption

The probability density function analysis performed to test NPV distribution shape and the tail end risk. Animal feed basic operation performance Model (Option 20) has higher positive NPV mean than other models representing COVID-19 and supply chain disruption challenges as per Figure 3. The first virus stage model (Option 21) represents the first year COVID-19 pandemic outbreak which needs emergency response to maintain and reshape the supply chain system. The second stage model (Option 22) represents a second year coronavirus outbreak with low standard deviation of 436,326 and low variation range between minimum and maximum figures compared to 582,500 SD for (Option 21) model. Model (Option 23) represents the third-year coronavirus outbreak with negative NPV and high standard deviation of 1,099,360 with a probability density function distribution skewed to left side and downside risk associated with loss. A downside risk management at this stage required urgent and careful attention and business strategies to recover the supply chain system and capture full value of opportunities and minimize supply chain disruption fat tail risk.

The government raw material subsidy program represented by Model (Option 21SRM) has a positive NPV with largest standard deviation of 1,524,446 with positive skewed distribution and upside profit opportunities. The business operation at this stage depends on business continuity strategies and Management.

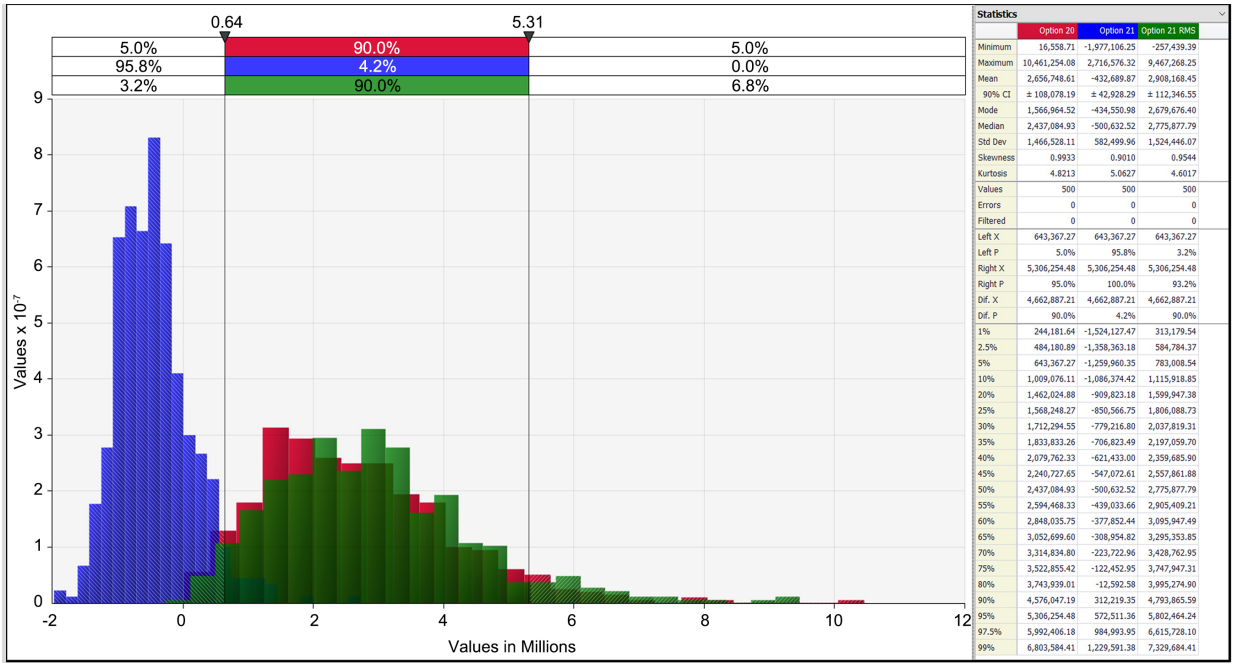

Figure 3. Probability Density Function (PDF) for NPVs scenarios before and after COVID-19 and supply chain challenge impacts.

needs to set policies, processes, and design plans to ensure that business can maintain critical operations level during a disruption. Business continuity policies, processes and plans are proactive measures that need to be put into place after supply chain disruption according to management's risk appetite and potential threats, to safeguard animal feed operations' brand reputation. Government subsidy program with a business continuity plan will mitigate risk and rebuild a reliable sustainable supply chain.

3.5. Stoplight Analysis and Supply Chain Disruption Impact Risk Efficiency

The Stoplight analysis is a useful tool to rank feed mill operation performance alternatives. The analysis compared animal feed operation for basic year and other year's operation affected by COVID-19 and supply chain disruptions challenges. The analysis relies on Cumulative Distribution Function CDF information and does not require decision maker risk preference and (ARAC) measurement. The advantage of Stoplight analysis is to calculate the probability of getting decision maker profit targets and business scenarios that fall below a lower target and exceed the upper limit target. It is a more visually appealing depiction of probabilistic information. Red color represents the probability of having negative NPV and business operation failure. The yellow represents the probability of NPV range from (0.00) to RO 2.00 million, whereas the green color represents probability of having NPV more than RO 2.00 million.

The Stoplight analysis uses stimulated NPV distribution data to calculate the probability of animal feed business operation sustainability during COVID-19 and supply chain disruption challenge. The analysis showed the percentage of

NPV of business operation viability exceeding an upper cutoff value of RO 2.00 million and being less than a lower cutoff value of RO (0.00) NPV. The percentage of NPV between upper and lower cutoff values calculated. Stoplight analysis performed to identify the probability of business sustainability of five operation models. Figure 4 shows that the animal feed business model (Option 20) for basic operation year will achieve an NPV of RO 2.00 million or more with a probability of 61% and 39% range between RO 0.0 and RO 2.00 million. The first-year coronavirus operation model (Option 21) will get negative NPV with a probability 81% and positive NPV below 2.00 million with a probability of 19%, whereas second year of coronavirus outbreak (Option 22) got negative NPV with a probability of 97% indicating business operation failure. The third-year coronavirus outbreak model (Option 23) represents a complete risk exposed and supply chain system non-resilient and management failure to cope with COVID-19 and supply chain disruption challenges. The Government raw material subsidy model (Option 21 SRM) will achieve a positive NPV more than RO 2.00 million with a probability of 71% and cope with risk of supply chain disruption challenges.

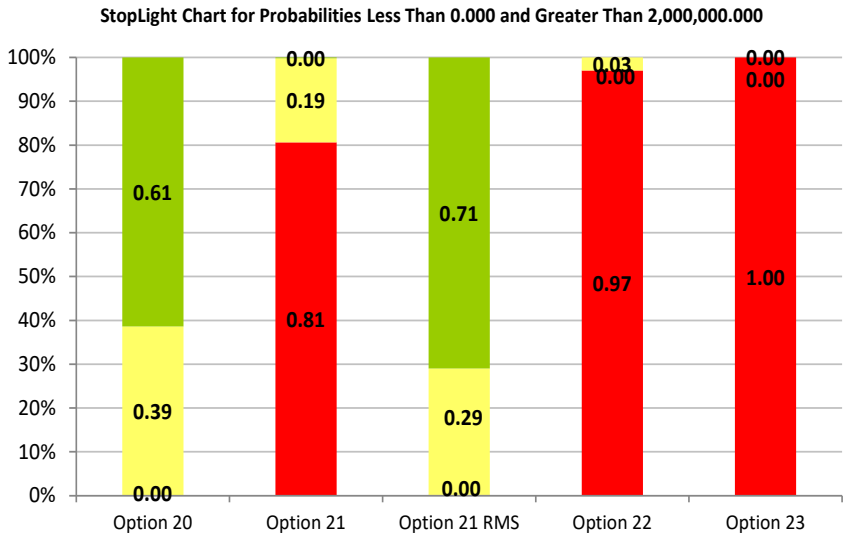

Figure 4. StopLight Chart for NPV Probability Less RO 0.000 and Greater RO 2,000,000 for Operation Models and COVID-19 and supply chain challenge impacts.

4. Results and Conclusion

The main task of this study is to investigate and quantify risk exposure to animal feed business operation due to coronavirus outbreak and identify risk management strategies efficiency and project viability and sustainability under COVID-19 and supply chain disruption. The study also identified sensitivity of the key variables such as raw material variable, production level and quantity risk and uncertainty of main key variables which effect NPV due to supply chain dis-ruption after coronavirus outbreak. The study utilizes information available regarding a specific current business environment and data record available to predict a potential future outcome and risk management strategies efficiency of an-

imal feed operation by using dynamic simulation analysis and methodology to incorporate risk and uncertainty of key variables.

The Stochastic Efficiency with Respect to Function (SERF) analysis used to rank feed mill operation risk-efficient and showed business unsustainability for all operations after coronavirus outbreak. The SERF method used to calculate Certainly Equivalent CE and risk premium RP values over a range of absolute risk aversion coefficients (ARACs) and indicate high loss for operation after supply chain disruption.

The probability density function (PDF) analysis performed to test NPV distribution shape and the tail end risk. Value at Risk (VaR) performed to calculate and quantify the risk of extended potential loss of animal feed operations. The VaR analysis showed that the expected NPV of animal feed operation before COVD-19 is RO 2,656,749, whereas the probability of realizing maximum NPV loss in a year would not exceed RO 640,000 at 95.8% confidence on the first year of coronavirus outbreak. The expected RO 0.00 return of NPV for second and third year of coronavirus outbreak is 97% and 100% respectively as illustrated by StopLight analysis. The recommended Government raw material support program and risk management alternatives have been examined in this study and showed a subsidy of RO 20 per ton can cope with COVID-19 and supply chain disruption challenges and achieve animal feed business sustainability. The approved Government raw material subsidy incentive dispersed delayed and impacted on cash availability to purchase material on time and had a severe accumulated impact on animal feed operation and business profitability.

In this article, we analyze risks caused by supplier disruptions by introducing concepts from probabilistic risk assessment (PRA), which is a widely employed methodology for the risk analysis of complex engineering systems. The analysis of the supply chain disruptions can help management to mitigate risks: for example, instead of relying on local measures such as safety stock or insurance, a company can introduce new supply contracts or backup risky suppliers and deal with regional suppliers who can provide material safety and fast.

The company needs to set policies and plans to ensure and maintain critical operational process during supply chain disruption. Operational risk management program needs to be imposed to help the company to reduce potential losses from poorly identified and emerging risks. Establishing an effective operational risk management program prepares a company to achieve its strategic objectives and assures business continuity despite unanticipated disruptions to operations. Business transformation models and business continuity strategies need to be implemented to safeguard operation and brand reputation according to investor risk appetite and potential business threats.

Competing Interests

The author declared that the research conducted in the absence of any commercial or financial and non-financial relationships that could be construed as a potential conflict of interest.

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