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Stochastic Optimization of Supply Chain Risk Measures –a Methodology for Improving Supply Security of Subsidized Fuel Oil in Indonesia

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Abstract

Monte Carlo simulation-based methods for stochastic optimization of risk measures is required to solve complex problems in supply security of subsidized fuel oil in Indonesia. In order to overcome constraints in distribution of subsidized fuel in Indonesia, which has the fourth largest population in the world—more than 250,000,000 people with 66.5% of productive population, and has more than 17,000 islands with its population centered around the nation's capital only—it is necessary to have a measurable and integrated risk analysis with monitoring system for the purpose of supply security of subsidized fuel. In consideration of this complex issue, uncertainty and probability heavily affected this research. Therefore, this research did the Monte Carlo sampling-based stochastic simulation optimization with the state-of-the-art "FIRST" parameter combined with the Sensitivity Analysis to determine the priority of integrated risk mitigation handling so that the implication of the new model design from this research may give faster risk mitigation time. The results of the research identified innovative ideas of risk based audit on supply chain risk management and new FIRST (Fairness, Independence, Reliable, Sustainable, Transparent) parameters on risk measures. In addition to that, the integration of risk analysis confirmed the innovative level of priority on sensitivity analysis. Moreover, the findings showed that the new risk mitigation time was 60% faster than the original risk mitigation time.

Abstrak

Optimalisasi Stokastik Tindakan Pencegahan Resiko Rantai Suplai-Sebuah Metodologi untuk Meningkatkan Ketahanan Suplai Bahan Bakar Minyak Bersubsidi di Indonesia. Metode berdasarkan simulasi Monte Carlo untuk opimasi stokastik pada penilaian risiko diperlukan untuk menyelesaikan masalah kompleks di dalam jaminan ketersediaan bahan bakar bersubsidi di Indonesia. Untuk mengatasi kendala distribusi BBM bersubsidi di Indonesia yang memiliki populasi penduduk keempat terpadat di dunia (lebih dari 250.000.000 jiwa dengan 66,5% populasi masyarakat produktif, dan memiliki lebih dari 17.000 pulau dengan populasi penduduk yang terpusat hanya di wilayah ibukota Negara) diperlukan sistem pengawasan dan penanganan risiko yang terukur serta terintegrasi demi jaminan ketersediaan BBM bersubsidi. Dengan mempertimbangkan masalah kompleks tersebut, penelitian ini sangat dipengaruhi oleh ketidakpastian dan probabilitas. Oleh karena itu, penelitian ini menggunakan metode simulasi optimasi stokastik berdasarkan sampling Monte Carlo pada kerangka kerja analisis risiko dengan keterbaruan parameter “FIRST”, yang dikombinasi dengan Analisis Sensitifitas untuk menentukan prioritas penanganan mitigasi risiko yang terintegrasi agar implikasi dari rancangan model yang baru dari penelitian ini dapat memberikan waktu mitigasi yang lebih cepat. Hasil dari penelitian ini dapat mengidentifikasi ide-ide inovatif pada audit berdasarkan risiko pada manajemen risiko rantai pasok dan parameter FIRST (*Fairness, Independence, Reliable, Sustainable, Transparent*) dalam penilaian risiko. Selain itu, integrasi pada analisis risiko menghasilkan tingkatan prioritas pada analisis sensitivitas dengan temuan yang menunjukkan bahwa waktu mitigasi yang baru lebih cepat sebanyak 60% dari waktu mitigasi risiko dengan metode yang umum.

Keywords: Monte Carlo sampling, parameter FIRST, probabilistic, stochastic optimization, uncertainty

1. Introduction

The refined fuel oil is an important part of public life world-wide, as in Indonesia. Nearly all of humanity’s activities require energy one way or another, and they are powered by refined fuel oil; thus, it is a determining factor in driving the wheels of public economy. The classification of refined fuel oil users is as follows: electricity sector (14.51%), industry (19.01%), household (18.20%), with the energy demanding sector being the most dominant, i.e. transportation (48.29%) [1,2]. Given the importance of energy derived from refined fuel oil for the public, every employed citizen requires refined fuel oil for mobilization and daily activities.

Geopolitically, Indonesia has the fourth largest population in the world, with the total of 250,000,000 people. Of this population, the number of employed citizens is 66.5% or more than 163,000,000 people [3]. Furthermore, Indonesia consists mainly of seas with more than 17,000 islands. The population distribution is highly uneven because most of the population is centered around the nation's capital, Jakarta.

The definition of risk analysis variables in this research follows the guidelines of Commercial Distribution Area requirements, in accordance with the BPH Migas Regulation No. 10/P/BPHMigas/II/2016 i.e. by conside-ring the level of subsidized fuel oil requirement on sale, population density, distribution cost, and infrastructure availability. On the basis of such rationale and consideration, the definition of variables is calculated according to the existing Commercial Distribution Area division so that a risk analysis may be conducted in each area.

The Indonesian population currently still has a low per capita income, in average being US$268/month [3]. Meanwhile the average price of refined fuel oil in the world currently sits at US$2.46/gallon [4], and the amount of refined fuel oil required per month is less than 79.3 gallons or equal to US$195/month. Therefore, the Indonesian government must still help its people by providing particular types of refined fuel oil subsidies derived from the state budget. The particular types of refined fuel oil are gasoline with RON 88, diesel fuel with CN 48, and kerosene.

In answer to any opinion stating that refined fuel oil subsidies should be diverted to other sectors such as education, health, and infrastructure (as many of those are receiving subsidies from the upper class), we believe it may have negative impact because it means that the price of refined fuel oil will rise, resulting in increased price of staple commodities. Without a significant increase in national income, this would worsen the conditions in Indonesia, not only in the economic sector but also in the political, social, and security sectors. Therefore, the solution is not removing subsidies to overcome constraints in distribution of subsidized fuel oil in Indonesia, but by establishing a measurable and integrated risk control and handling system. The scheme for analyzing the risk of distribution of subsidized fuel oil in Indonesia is not yet integrated and measurable [5], as it is still restricted to each Commercial Distribution Area with the risk measurement described in the following scheme. Therefore, this research is highly critical. In addition to carrying the mission of helping millions of people in Indonesia and saving the nation's economic condition, it is also expected to be able to bring advantages to the educational world with its state-of-the-art contribution. For subsidized fuel oil in Indonesia, policies governing such matters already exist, but the implementation is perceived to be less than effective, so that such policies must always be updated. In consideration of the complex issue, uncertainty and probability heavily affected this research.

2. Methods

In order to conduct a risk analysis on the Supply Chain Risk Management of subsidized fuel oil, the value of risk (*R*) of an occurring event in the supply chain was dependent on the value of probability factor (*F*) and consequence factor (*C*). Thus, the research methods performed were the combined qualitative and quanti-tative methods. The supply chain of subsidized fuel oil has laws and regulations governing the implementing mechanism so that the measurement of probability (probable deviation event) may use the provisions of such laws as indicator variables (*Fj.n*) and (*Cm.n*). As for the consequence or impact factor in the event of deviation in the supply chain, the results of studies on the impact of deviation in the provision of subsidized fuel oil may be used.

The conditions for optimization of distribution of subsidized fuel oil in Indonesia are highly affected by uncertainty and probability [6-8]. On such basis, the method used in this research was the Stochastic Optimization with the basis of Monte Carlo sampling [9-11]. In addition, considering the extremely vast territory of Indonesia which results in an uneven national distribution of subsidized fuel oil, the imbalance between demand and availability so that the procurement sources consist of several parties, and imbalanced locations of source facilities across the territory, sensitivity analysis, analysis of deviance, and the measurement of rate of change were conducted [13].

The formulation for Stochastic Problem (SP) optimization is as follows [7]:

$$\min_{x \in X}\{g_0(x) := \mathbb{E}[G_0(x,\xi)] \leq 0, k = 1,2,\ldots,K\} \quad (1)$$

where G_k, $k = 0, 1, \ldots, K$ is the real value of function, $\boldsymbol{x}$ = decision vector, ξ = random vector, $K = 0$ → SP with the deterministic limit, and $K < \infty$ the stochastic limit. The optimization of subsidized fuel oil was performed using the 2-Stage Stochastic Linear Program, as post-risk mitigation, and it was necessary to view again a recourse variable in the form of time (*t*) and risk value change average (comparison between the initial risk and the post-mitigation risk).

In order to govern the availability and distribution of subsidized fuel oil in Indonesia, the government has provisions on Commercial Distribution Area division. The determining factors of Commercial Distribution Area are the level of subsidized fuel oil requirement/sale, population density, distribution cost and infrastructure availability. Currently the arranged distribution of subsidized fuel oil in Indonesia is divided into four Commercial Distribution Areas. Therefore, in the equation determining the total risk value, the risk value per Commercial Distribution Area (Rw) was obtained. Thus, $Rj = Rw$, and to perform the risk mitigation of all risks incurred in Indonesia it was necessary to formulate the priority level to find the highest and the lowest risk value in order to know the mitigation interest plan thereof [14,15].

The design of Analyis Model for the Supply Chain Risk Management of subsidized fuel oil in this research was made using the combined method of Monte Carlo sampling-based stochastic simulation optimization in the risk analysis framework with the state-of-the-art "FIRST" parameter, which is the abbreviation of Fairness, Independent, Reliable, Sustainable, Transparent, and the Multivariate Data Analysis steps. The methods performed were the Factor Analysis to make and identify correlated variables in one factor, the Multivariate Correlations to map all interconnected variables, and the Discriminant Analysis to identify and distribute independent variables and dependent variables. Moreover, in some random variables of the research, the Analysis of Deviance and Analysis of Sensitivity would be conducted to determine the priority of integrated risk mitigation handling [16] so that the implication of this research's new model design would give a faster mitigation time, which would definitely affect the distribution successfully assigned to all users of subsidized fuel oil entitled for the purpose of supply security.

3. Results and Discussion

Initial survey. Based on the initial observation on the condition and system of distribution of subsidized fuel oil in Indonesia—as can be seen in Figure 1—there were several considerations in a broad outline to be found: 1) inavailability of success parameter indicating the balance between the quota and realization so that efforts and supervision should be undertaken in order for all particular types of refined fuel oil to be balanced at the time of distribution, volume and user-consumer; 2) the difference in orientation (profit vs non profit) between the supply management and the supply facilities, so an integrated system was necessary; 3) uncollaborated laws between several related stakeholders, which could actually synergize with each other in supervising the system of distribution of subsidized fuel oil starting from the local, provincial, and national levels; 4) no standard and sustainable compliance audit system, meaning that supervision on the system of distribution of subsidized fuel oil in Indonesia was not measurable.

As supply security of refined fuel oil in Indonesia has the nature of being uncertain with high probability, the initial constraints and hypotheses were as follows: 1) reduce crude oil exports to prioritize domestic refined fuel oil production needs and demand, 2) increase crude oil supply to domestic production refineries, 3) reduce the volume of refined fuel oil imports to that the supply security of refined fuel oil for domestic needs is more certain, 4) upgrade the refineries on a periodical basis to increase the capacity of production and depot in the existing refineries and to increase the refined fuel oil quality standards so as to be more environmental friendly, 5) enhance supervision on distribution of refined fuel oil, starting from the refineries, distributors up to the user-consumers and improve the applicable policies on a continuing basis, and 6) improve an integrated and measurable distribution system and optimum risk mitigation time.

Infrastructure in Indonesia. The ability to produce and store refined fuel oil in Indonesia is very low and unsuitable for the population needs due to the lack of refineries. Therefore, Indonesia is currently importing refined fuel oil to meet its needs. Indonesia's refined fuel oil derives from oil processing at domestic refineries and direct imports in the form of refined fuel oil. This refined fuel oil importation activity is performed by the government due to the increasing consumption of refined fuel oil in Indonesia. In Indonesia there are eight oil refineries, i.e. Pangkalan Brandan, Dumai, Plaju, Balikpapan, Balongan, Cepu and Kasim with the processing capacity of 1,103 million barrels per day. The eight refineries are operated by Pertamina. Each refinery has different processing unit facilities and requires different specifications of crude oil input. Basic refinery process can be seen in Figure 2. Crude oil processed in Indonesian oil refineries derives from production of oil fields in Indonesia and imported crude oil. In addition to producing refined fuel oil, these refineries also produce other products, such as naphtha and asphalt.

Bivariate correlations. Based on the Commercial Distribution Area division requirements, five metric independent variables were defined. Of the five independent variables, the Dependent Variable of Sale Level (P), Population Density (G), Distribution Cost (R), and Infrastructure Availability (I) were formulated. Subsequently, each variable was formulated as the Priority Index (Pw, Gw, Rw, Iw). The average of Priority Index is Qw. The Priority Index shows that if the Dependent Variable has a high value, then the Priority Index is low, so that the Level of Priority (L) is high.

Innovative "FIRST" parameter. The distribution of subsidized refined fuel oil must be fair and appropriate for the public consumers in need, free of any conflict of interests in the procurement and distribution process, reliable, secure according to the needs, and any process and information relevant to the refined fuel oil subsidies

$$Q_{w.t}(\%)=\left[\left[\frac{\left(1-\left(\frac{P}{\Sigma P_t}\right)\right)x100\%}{t-1}\right]+\left[\frac{\left(1-\left(\frac{G}{\Sigma G_t}\right)\right)x100\%}{t-1}\right]+\left[\frac{\left(1-\left(\frac{R}{\Sigma R_t}\right)\right)x100\%}{t-1}\right]+\left[\frac{\left(1-\left(\frac{I}{\Sigma I_t}\right)\right)x100\%}{t-1}\right]\right]:4 \quad (2)$$

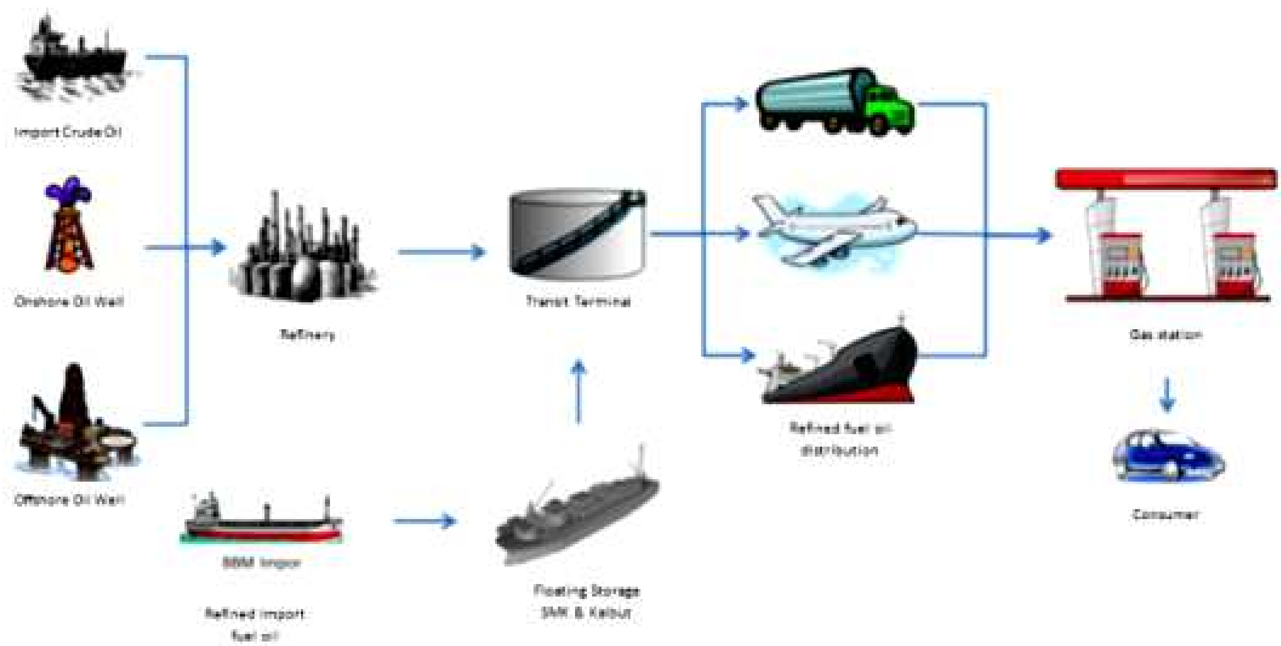

Figure 1. Fuel Supply Chain

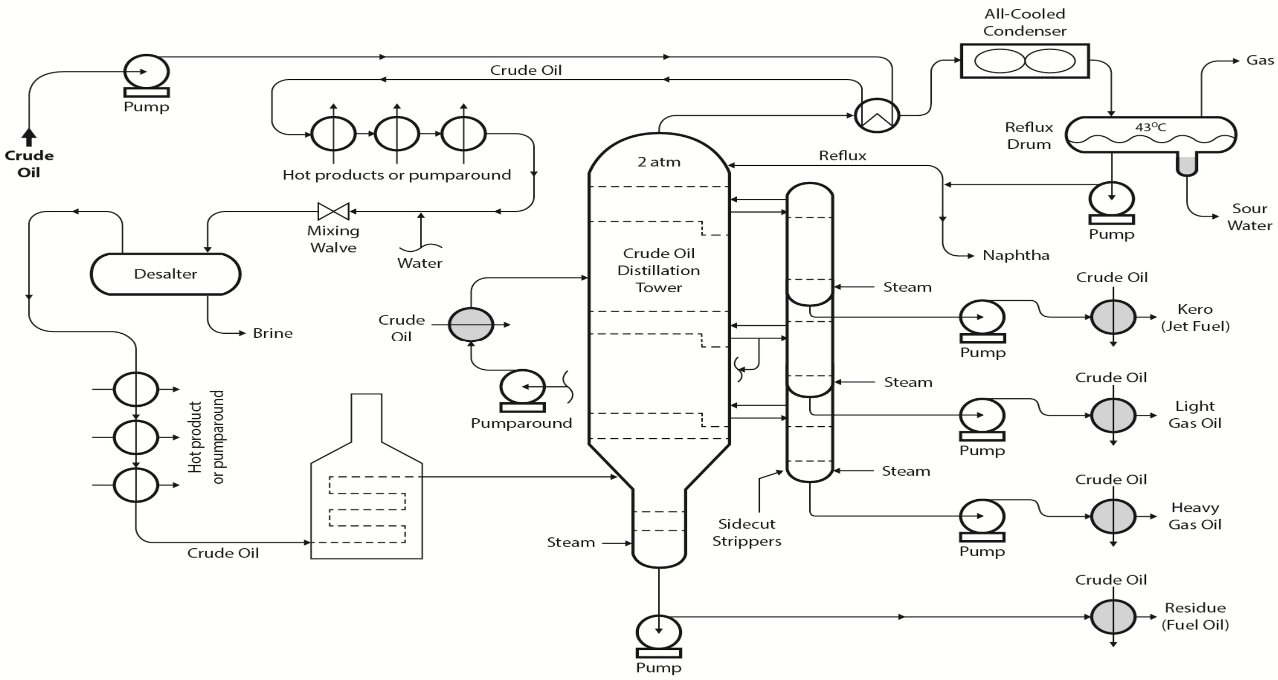

Figure 2. Basic Refinery Process

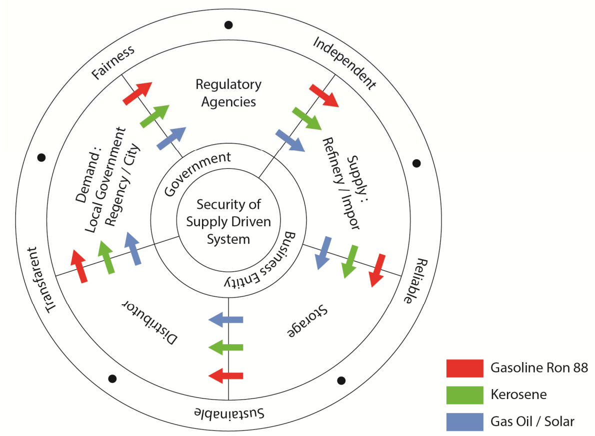

Figure 3. Innovative "FIRST" Parameter

must be publicized openly to create public awareness. In consideration of such rationale, the researcher created an idea of risk analysis and indicator concept to measure and supervise the distribution of particular types of refined fuel oil. The concept was called the "FIRST", which is the abbreviation of Fairness (F1), Independent (F2), Reliable (F3), Sustainable (F4) and Transparent (F5). Innovative "FIRST" parameter can be seen in Figure 3.

Risk value calculation variable. In order to calculate the Risk (R) value, the risk value forecast simulation was used. The method used to determine the value of each indicator variable (*Fj.n*) and (*Cm.n*) was by using the ordinal scale (1-5) [17] with the valuation mechanism using the Focus Group Discussion (FGD) concept because the value of entire indicator variable is non-metric. Based on the Multivariate Analysis, against each indicator variable the Factor Analysis was conducted, to be grouped and the Discriminant Analysis to define the independent variables and dependent variables. The calculation of risk value for each Probability Factor (*Fj*), each variable (*Fj.n*) was assumed to be in accordance with the data spread variance using the normal, triangular or uniform distribution chart [18]. The variable (*Cm.n*) was defined as continuous data, and the definition of calculation forecast (*Rj*) had the precision rate of 95% with the absolute unit of 0.05 [19]. The likelihood and Consequenses Variable can be seen in Table 1.

The Regression Equation used to calculate the Total Risk (*Rj*) in this research was based on the multivariate data as follows:

$$\frac{\sum R_j}{j} = \frac{\sum C_m \cdot \left(\frac{\sum (F_1 + F_2 + F_3 + F_4 + F_5)_n}{n}\right)}{m}$$

$$\sum R_j = \left[\frac{\sum C_m \cdot \left(\frac{\sum F_{jn}}{n}\right)}{m}\right]_j \qquad (3)$$

Simulation optimization. In order to perform the stochastic simulation optimization, the Monte Carlo sampling method was used. To determine the number of samples, the estimator efficiency calculation method was used [17]. The equation of correct estimator on an unknown quantity $\ell = \mathbb{E}\hat{\ell} = \mathbb{E}Z$ is represented below:

$$\hat{\ell} = \frac{1}{N}\sum_{i=1}^{N} Z_i \qquad (4)$$

where $Z_1, Z_2, \ldots Z_N$ is the independent replication of the random variable Z. $\hat{\ell}$ estimator hereinafter referred to as the Crude Monte Carlo (CMC) estimator. As a numeric example, the $\ell = 10^{-6}$value is assigned to estimate $\hat{\ell}$ accurately with the relative error of 0.01, the sample quantity is required

$$N \approx \frac{1}{\kappa^2 \ell} = 10^6 \qquad (5)$$

This reflects small probability limit via CMC by computation with the count of simulations being 10^6.

Crude Monte-Carlo Simulation Stage-1. In order to perform the simulation of risk value distribution in the supply chain risk management (SCRM) of subsidized fuel oil, the Monte Carlo method had to be implemented with a confidence rate of 85% and continuous decision and forecast of 95% precision rate with an absolute unit of 0.05. This distribution simulation must be performed as often as possible so that its accuracy is better guaranteed. Therefore, in this risk analysis, the simulation was performed for a total of 1,000,000 (one

Table 1. Likelihood & Consequences Variable

Independent Variable		Dependent Variable		
Indicator	n = number of indicator	Risk Value	Probability Factor	Consequences Factor
$F_{1.1} = x_1$ $F_{1.2} = x_2$ $F_{1.n} = x_n$	x_n = weights	$x = \frac{\sum F_{1.n}}{n} = F_1$	F_1= fairness	
$F_{2.1} = y_1$ $F_{2.2} = y_2$ $F_{2.n} = y_n$	y_n = weights	$y = \frac{\sum F_{2.n}}{n} = F_2$	F_2= Independent	
$F_{3.1} = z_1$ $F_{3.2} = z_2$ $F_{3.n} = z_n$	z_n = weights	$z = \frac{\sum F_{3.n}}{n} = F_3$	F_3= Reliable	
$F_{4.1} = u_1$ $F_{4.2} = u_2$ $F_{4.n} = u_n$	u_n = weights	$u = \frac{\sum F_{4.n}}{n} = F_4$	F_4= Sustainable	
$F_{5.1} = v_1$ $F_{5.2} = v_2$ $F_{5.n} = v_n$	v_n = weights	$v = \frac{\sum F_{5.n}}{n} = F_5$	F_5= Transparant	
$C_{1.1}=\alpha_1$ $C_{1.2}=\alpha_2$ $C_{1.n}=\alpha_n$	$\alpha_{n=}$ weights	$\alpha = \frac{\sum C_{1.n}}{n} = C_1$		C_1= Social
$C_{2.1}=\beta_1$ $C_{2.2}=\beta_2$ $C_{n.1}=\beta_n$	$\beta_{n=}$ weights	$\beta = \frac{\sum C_{2.n}}{n} = C_2$		C_2= Economic
$C_{3.1}=\mu_1$ $C_{3.2}=\mu_2$ $C_{3.n}=\mu_n$	$\mu_{n=}$ weights	$\mu = \frac{\sum C_{3.n}}{n} = C_3$		C_3= Keamanan
$C_{4.1}=\sigma_1$ $C_{4.2}=\sigma_2$ $C_{4.n}=\sigma_n$		$\sigma = \frac{\sum C_{4.n}}{n} = C_4$		C_4= Environement
$C_{5.1}=\tau_1$ $C_{5.2}=\tau_2$ $C_{5.n}=\tau_n$	$\tau_{n=}$ weights	$\tau = \frac{\sum C_{5.n}}{n} = C_5$		C_5= Politic

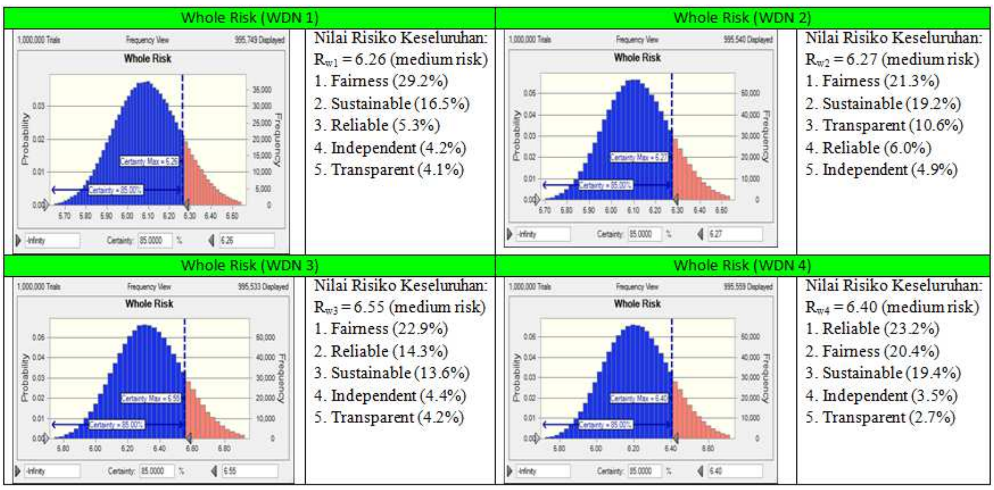

Figure 4. Risk Simulation on Stage 1

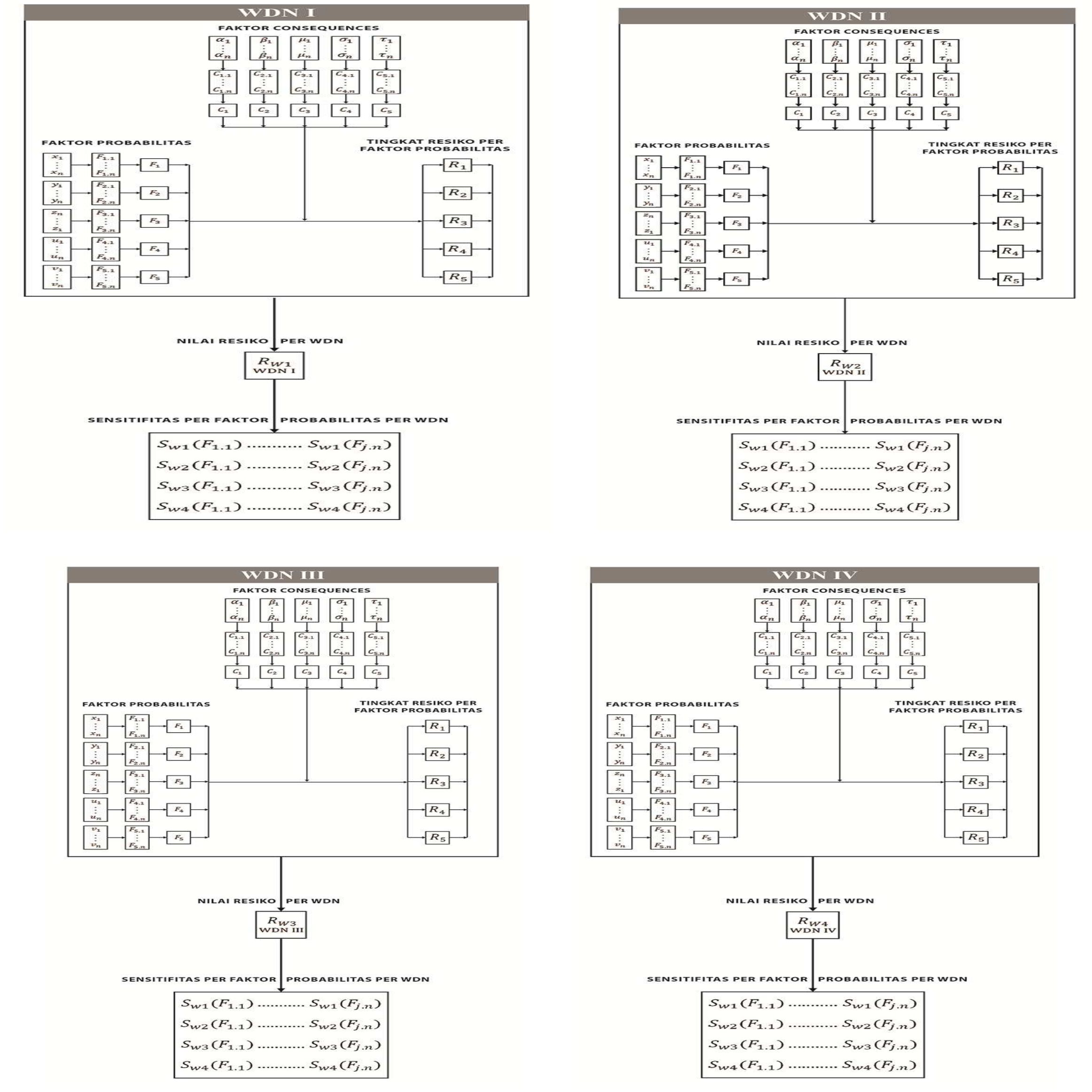

Figure 5. Initial Tree Scenario Stage 1

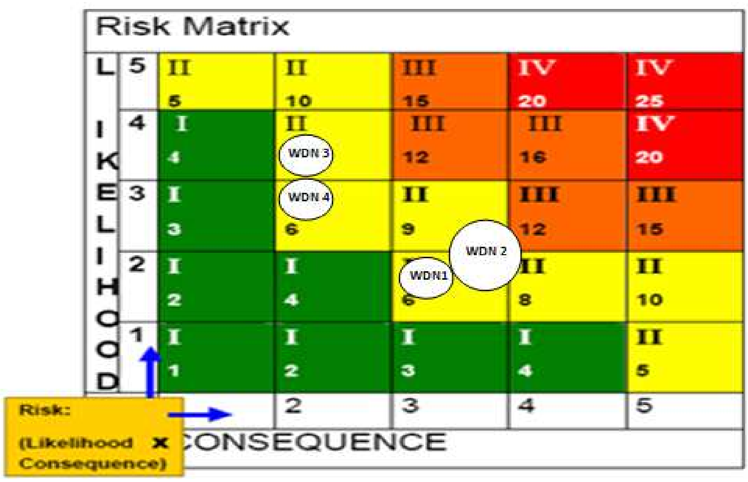

Figure 6. Risk Distribution Simulation Stage 1

Risk mitigation priority level. Affecting the determination of priority (*L*) and risk value to be mitigated was the risk value of each Commercial Distribution Area (*Rwt*), sensitivity level $S_{w.t\,(Fj.n)}\,(\%)$, and Priority Index value of each Commercial Distribution Area $Q_{w.t}\,(\%)$ formulated in the Level of Priority equation per Probability Factor. The amount of probability factor with high sensitivity percentage rate should be mitigated to reduce its risk value, therefore it was necessary to determine the priority of risk value to be immediately mitigated so that the risk value spread in each Commercial Distribution Area could be rated. Risk matrices during Stage 1 can be seen in Figure 6, which illustrates risk intermediate category.

$$L_{fj.n} = \sum L_{wt\,(Fj.n)} = \sum \frac{S_{w.t(Fj.n)}\,(\%)\ x\ R_{w.t}}{Q_{w.t}\,(\%)} \qquad (6)$$

Based on the formula to determine the priority level ($L_{fj.n}$), the percentage of priority of each probability factor risk value $L_{fj.n}\,(\%)$ to be mitigated could be obtained. Therefore, in accordance with the Supply Chain Risk Management (SCRM) principle [20, 21], the risk value may be prioritized for mitigation according to its priority level. The equation used to determine the percentage of priority level is as follows:

$$L_{fj.n}\,(\%) = \frac{(L_{fj.n})\ x\ 100\%}{\sum L_{fj.n}} \qquad (7)$$

Mitigation plan determination according to the priority level. After calculating the priority level of each probability factor of which risk value was quite high and should be mitigated. The priority level and risk value mapping can be obtained based on the equation of priority level with the variables of sensitivity value, area risk value, and priority index.

New integrated scenario tree. In order to design a new framework for the Supply Chain Risk Management of particular types of refined fuel oil in this research, the Multivariate Data Analysis method was performed. The method used was the Factor Analysis to perform and identify correlated variables in one factor and the Discriminant Analysis to identify and distribute the independent variables and dependent variables. Subsequently, the Multiple Regression Analysis was performed to validate the mathematical model equation formulated in the model for supply chain risk management of subsidized fuel oil. The new integrated tree scenario can be seen in Figure 8.

Measured rate of change. The rate of change of stochastic simulation optimization of the distribution of particular types of refined fuel oil in Indonesia could be measured using the following equation function:

$$F(x) = \frac{|r_{(n+1)} - r_n|}{r_{(n)}} \qquad (8)$$

Table 2. Level of Priority per Probability Factors

FIRST	No.	Probability Factors	Tingkat Prioritas (L)				L(fj)n	L(fj)(%)
			Rw1	Rw2	Rw3	Rw4		
Fairness	1	Determination of certain types of refined fuel oil volume allocation (Gasoline (RON 88), Gas Oil) per consumer	7.03	5.81			12.84	20
	2	High distribution cost as a result of the determination of trade distribution area on refined fuel foil			6.82	4.50	11.32	18
Independent	3	Control of supply, distribution, and transportation facility on Business Entity	1.10	1.34	1.31	0.77	4.43	7
Reliable	4	The distribution time quota for certain types of refined fuel oil for consumer	1.28	1.64	4.26	5.12	12.29	19
Sustainable	5	Realization of certain types of refined fuel oil distributor control to its consumer	3.97	5.23			9.21	14
	6	Lack of transportation and storage of certain types of refined fuel oil facility			4.05	4.28	8.33	13
Transparent	7	Socialization of economical vs subsidy price	0.99	2.89			3.88	6
	8	Socialization of monitoring and controlling for certain types of refined fuel oil			1.25	0.66	1.85	3

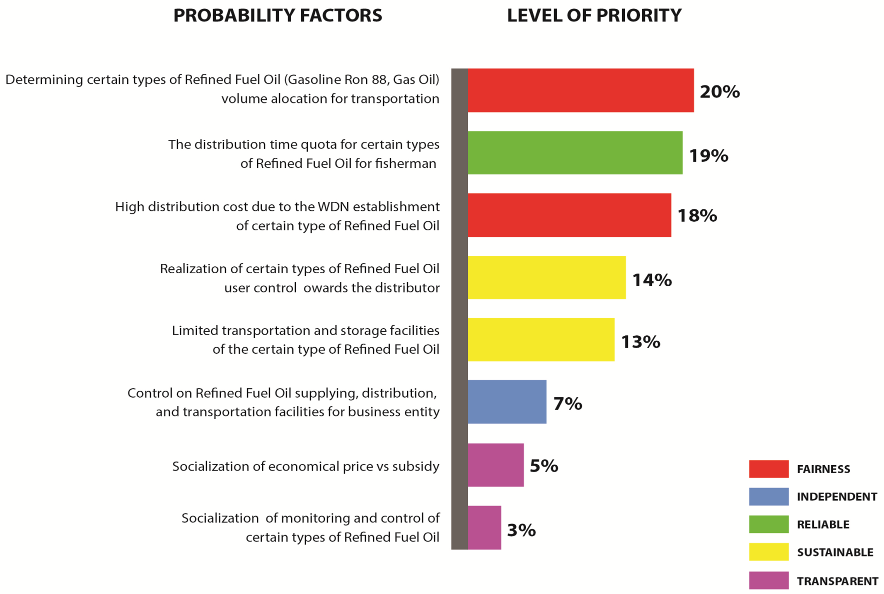

Figure 7. Level of Priority

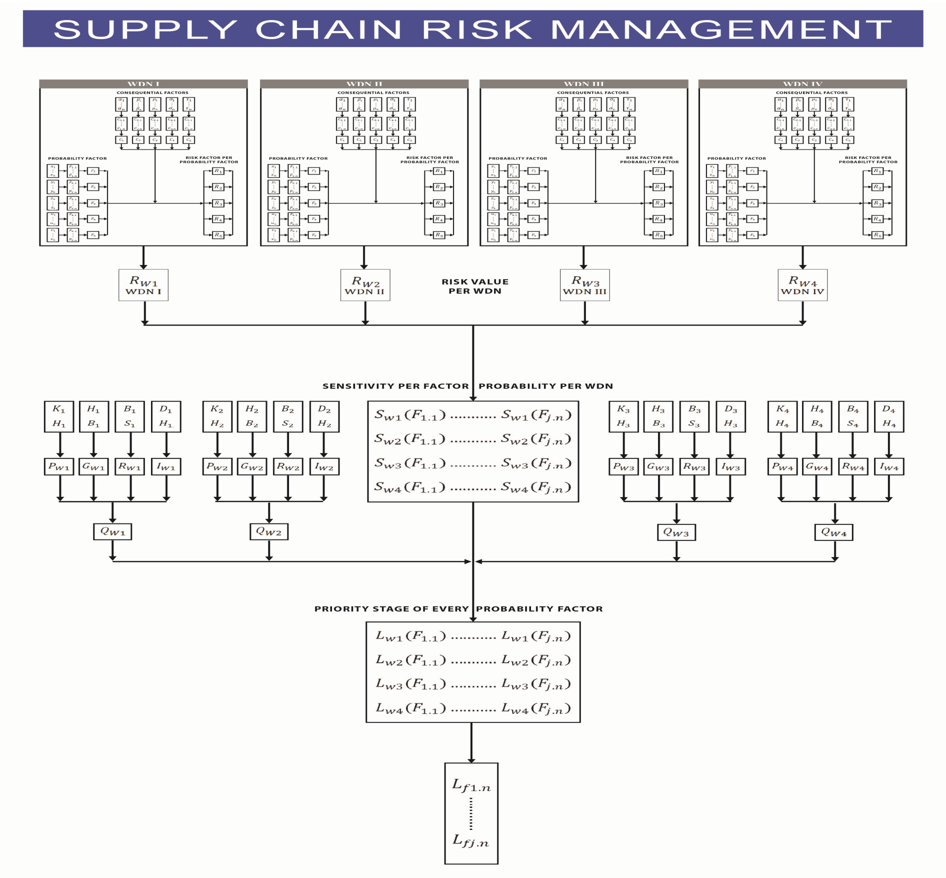

Figure 8. Final Tree Scenario

After performing the CMC simulation phase 2, we calculated the occurring rate of change after the mitigation. The results of rate of change obtained can be seen in Table 3.

Table 3. Rate of Change Result

Parameter	Stage 1	Stage 2	Rate of Change (%)
Whole Risk WDN 1	6.26	3.34	46.65
Whole Risk WDN 2	6.27	3.35	46.57
Whole Risk WDN 3	6.55	4.28	34.66
Whole Risk WDN 4	6.4	3.42	46.56

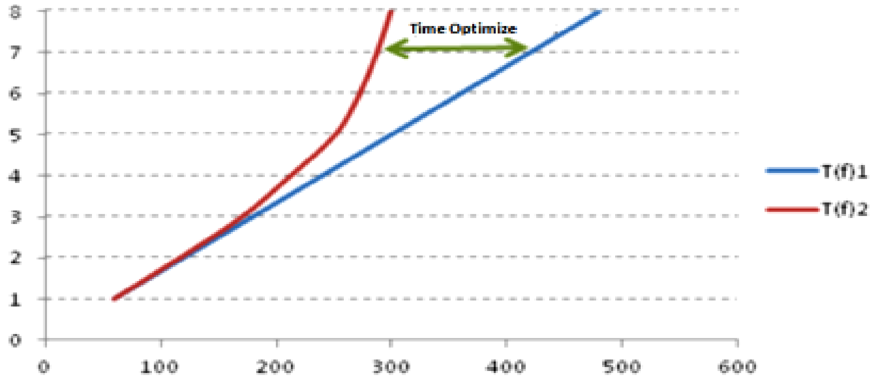

Figure 9. Conventional and Optimal Mitigation

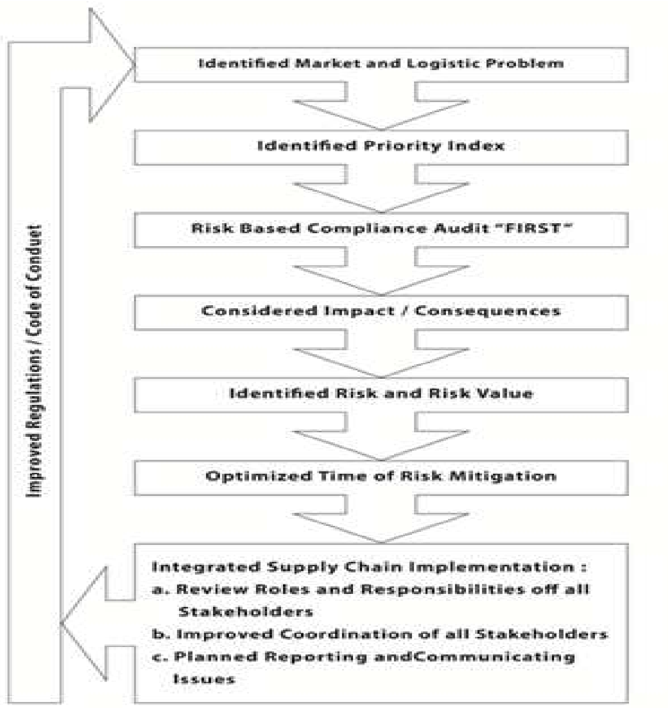

Figure 10. Cycles of Supply Security

Tabel 4. Innovative Ideas in FIRST Risk Analysis

Reference	Innovative Ideas
Mitigation based on Reports	Risk based Audit
Scattered Risk Analysis	Integrated Risk Analysis
No Parameters on Risk Analysis	FIRST Parameters
No level of Priority on Sensitivity Analysis	Level of Priority on Sensitivity Analysis
Slower Risk Mitigation Time	Faster Risk Mitigation Time

Recourse variable. The risk mitigation was only based on the risk value obtained through the simulation optimization with the Monte Carlo method in just one particular area, so that there was no determination of priority and mitigation time optimization that caused the mitigation to require a long time and to be unscheduled.

Example:
Time Function (T(f)1), *Estimated Time* (Et) = 2 months, *Variate* = % priority
T(f)1 = 1.0 (Et) + 1.0 (Et) + 1.0 (Et) + 1.0 (Et) + 1.0 (Et) + 1.0 (Et) + 1.0 (Et) + 1.0 (Et)
= 60 days+ 60 days + 60 days + 60 days + 60 days + 60 days + 60 days + 60 days
= 480 days
With this concept, the time required to perform the mitigation of all risks is 480 days.

Meanwhile, the risk mitigation we proposed could be performed simultaneously in several distribution areas by taking into consideration the area priority index used as a variable in priority determination. Given the existence of priority, a much better mitigation time optimization may be obtained.

Example:
Time function (T(f)2), Estimated Time (Et) = 3 months, Variate = % priority. In this function, the Et is targeted for the first risk mitigation, subsequently based on the variate of each risk variable.

T(f)2 = Et for 20% + 19% (Et) + 18% (Et) + 14% (Et) + 13% (Et) + 7% (Et) + 5% (Et) + 4% (Et)
= 60 days + 57 days + 54 days + 42 days + 39 days + 21 days + 15 days + 12 days = 300 days

New framework of supply security. Supply security of particular types of refined fuel oil in Indonesia may be measured on the basis of stochastic simulation optimization with an integrated supply chain system illustrated in Figure 10.

4. Conclusions

The Optimization Method is an extremely useful tool to be applied to various aspects of human life, either in academic scientific research, decision making in business, or decision making in any other project planning. In this research, the limitation imposed was based on the case of subsidized fuel oil distribution system divided into four Commercial Distribution Areas. However, future research may be conducted with whatever number of Commercial Distribution Area or area division required, not restricted to four areas only.

The focus of this research is the supply security of subsidized fuel oil in Indonesia, but with the same concept as this research, i.e. implementation of the FIRST parameter with the Monte Carlo sampling-based stochastic simulation optimization, it is also possible to implement the risk mitigation and risk analysis in other sectors, such as banking, stock market, amendments to policies and laws, marketing management for market penetration, and many more sectors.

The Commercial Distribution Area division, currently divided into four areas, is appropriate only if there is a comparison between the independent variables of total refinery capacity, total depot capacity, number of distributors and population in each Commercial Distribution Area as the ratio shown was balanced. However, in the Land Mass comparison, it was visible that the division was inappropriate because in the Commercial Distribution Area 3, the land mass was vast, i.e. 63% of the entire existing area, whilst the Land Mass of Commercial Distribution Area was only 7% with 59% population. Therefore, the Commercial Distribution Area division could not be seen only from the independent variable value but also the correlation amongst such variables by measuring the Dependent Variable ratio. The greater the Dependent Variable value in a Commercial Distribution Area, the lower the Priority Index average (*Qwt*) in the Commercial Distribution Area.

The types of data of the Priority Index value (*Qwt*), Risk Value (*Rwt*), and Priority Level ($L_{fj,n}$), were different (metric and non-metric), so each variable could not be compared directly proportional or otherwise inversely proportional. We can see that they have different paradigm but were strongly correlated.

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