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A sensitivity analysis of stochastic programming for reverse logistic of herbs agro-industry: a case study of herbs logistic in Indonesia

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Abstract. This paper analyses the sensitivity of reverse logistic formulation of herbs agro-industry based on fuzzy stochastic mixed integer linear programming. A case study from real world problem of herbs logistic in Indonesia is provided in order to respond stochastic challenges in the reverse logistic system. For implementation purpose of this current progress, some related historical and hypothetical data were deployed. The model was then used to test how far this fuzzy quantitative modelling is capable to solve the problem within available data ranges with consideration on possibility in each data occurrence. A GRG non-linear was used as model solution to solve the fuzzy stochastic modelling with implementation using Excel solver. The fuzzy quantitative modelling result with a case study in herbs logistic in Indonesia is concluded with verification and validation on current model formulation for decision making purposes in herbs reverse logistic.

Keywords: Herbs agroindustry, herbs logistic, reverse logistic, sensitivity analysis, stochastic programming

1. Introduction

In current business environment, where the level of competition is getting more competitive with limited natural resources, customer attention to environmental issues is getting higher. The increase of business adaptation challenges into competitive markets, and the increasing of stringent regulatory and regulatory controls, all play a central role to win a competition in the global market. This has caused most companies to turn to the closed loop supply chain (CLSC) design which facilitates increased economic benefits and minimizes environmental impacts through the use of waste products left over from production and consumption. The reverse logistic is a logistic flow that includes the flow of the returns to the supply source, namely the reverse supply chain that occurs repeatedly forming a closed cycle flow [1].

A reliable stochastic fuzzy programming model / robust fuzzy stochastic programming (RFSP) is a reverse logistic network design model with complex uncertainty factors, which includes two sources of uncertainty for most parameters, thus requiring a strengthening of the model to produce reliable decisions. Reliable decisions can facilitate better in terms of the average value and variability of the

objective function. RFSP facilitates two types of variability called scenario variability and possibilistic variability. Theories likely to be used to select solutions in uncertainty problems and the RFSP approach can provide more benefits like determining the location of the plant so that the lowest annual costs are obtained [2].

The growing complexity of the supply chain has demanded more effective supply chain management. For this reason, supply chain collaboration is an effective solution. Many industries have been involved in various forms of supply chain collaboration to maintain their existence in an increasingly fierce business competition environment. Through supply chain collaboration, including the flow of raw materials to end products for consumers, market share can be maintained and even increased. Supply chain coordination ensures better supply chain performance through optimization in terms of costs, quantity discounts, timely offers, repurchase policies, quantity flexibility, order size and total purchase commitment [3]. Collaboration can also be applied in terms of managing human errors in quality inspection and improving the quality of production. Models that can be used for appropriate investment decision making include relations management in terms of strategic and operational policy setting, product design, process design, and employee training [4].

A contract is an agreement between two parties in a formal bond. Supply chain contracts are one of the Supply Chain Managements (SCM) in the form of effective instruments to achieve conflicting goals between members of the supply chain and to motivate all members to be part of the overall supply chain [5]. Supply chain contracts ensure the provision of appropriate incentives so that each supply chain actor acts as it should, and causes both benefits and risks to be borne by both parties. Adaptive contracting is a system of contracts based on an adaptive system so as to provide more objective contract guarantees [6].

Herbal agroindustry is defined as an activity that utilizes agricultural products in the form of plants or plants that have more use or value in medicine as raw materials, design and provide equipment and services for these activities. Herbs are one of the commodities that have strategic opportunities and competitiveness. Herbal agroindustry has become a tangible manifestation of popular economy proven to be resistant to the global economic crisis. In 2017 the domestic herbal industry grew by 10% from the previous year. Currently in Indonesia there are 986 herbal industries consisting of 102 Traditional Medicines Industry (IOT), and the rest including Traditional Medicines Small Businesses (UKOT) spread across Java. The herbal industry is able to absorb 15 million workers. Herbs are also one of the industries that will drive the national economy in the future. There are 3 types of herbal products including: Herbal Medicine, Standardized Herbal Medicine (OHT) and phytopharmaca.

Demand for domestic herbal medicine has increased with a growth in market share that is better than the growth rate of the pharmaceutical industry. The existence of a trend back to nature has resulted in people increasingly aware of the importance of using natural ingredients for health. The community increasingly understands the advantages of using traditional medicines, including: cheaper prices, easier to obtain products, and minimal side effects. However, the herbal industry business players still face obstacles in creating quality products, highly competitive and market oriented. The second obstacle is the problem of access to capital in herbal medicine businesses, especially, traditional herbal medicine business; development of medicinal raw materials for medicinal plants and efficient processing, as well as constraints related to regulations and laboratory testing procedures. The previous related researches were proposed by [7] A multi-stage stochastic program for the sustainable design of biofuel supply chain networks under biomass supply uncertainty and disruption risk: A real-life case study, [8] for A Multi-stage Stochastic Programming for Lot-sizing and Scheduling under Demand Uncertainty, [9] for a two-stage stochastic optimization model for reverse logistics network design under dynamic suppliers' locations, [10] From a literature review to a multi-perspective framework and [11] for Meta-heuristics for reverse logistics: a literature review and perspectives. Those researches only focus on general logistic cases, and they need a model development for herb logistic implementation.

The rest of this paper is constructed according to standard operation research and mathematics modelling [12] as follow: First we explain problem definition of stochastic reverse logistic system in

herbs industry. Second, this paper presents formulations for stochastic mixed integer linear programming. Third, we present the scenario using fuzzy stochastic programming to answer the uncertainty challenges in reverse logistic system. Implementation and a case study are presented in the next section. Then we give results and discussion and present the conclusion of this research.

2. Problem description

Reverse logistics is for all operations related to the reuse of products and materials. It is "the process of moving goods from their typical final destination for the purpose of capturing value, or proper disposal. Remanufacturing and refurbishing activities may also be included in the definition of reverse logistics. When a manufacturer's product normally moves through the supply chain network, it is to reach the distributor or customer. Any process or management after the delivery of the product involves reverse logistics. If the product is defective, the customer would return the product. The manufacturing firm would then have to organize shipping of the defective product, testing the product, dismantling, repairing, recycling or disposing the product. The product would travel in reverse through the supply chain network in order to retain any use from the defective product. The logistics for such matters is reverse logistics. In herbs agro-industry figure 1 shows how reverse logistic operates.
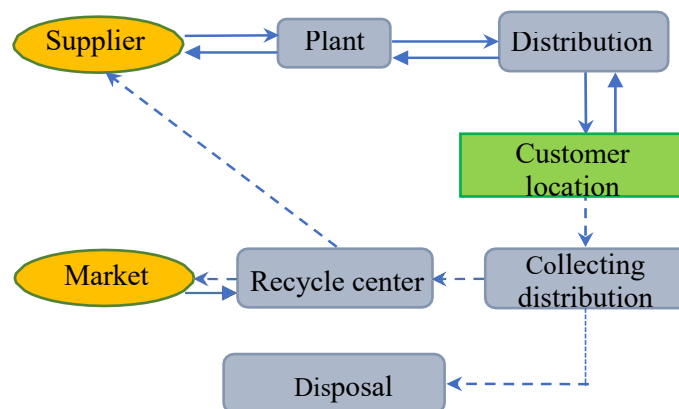

Figure 1. Reverse logistic illustration in herbs agro-industry.

Reverse logistics in the herbs agro-industry generally consists of suppliers supplying raw materials to processing plants, distributing products to consumers, re-collecting waste from consumer waste to be recycled, supplying back to factories to remanufacturing or selling it on the market. Collection of waste that cannot be reused can be processed so that it is suitable for disposal into the environment. Based on figure 3, the index needed to design reverse logistics consists of location, component, type of technology, type of herbal product, time period, scenario and flow of goods in the logistics. Location index consists of supplier location, potential plant location, potential distribution center location, consumer location, potential collection center location, potential location of the recycling center, potential location of the disposal center. Based on this, the indexes considered for optimization models in this study are as follows.

Table 1. List of Index for the model.

Index	Explanation	Index	Explanation
i	Supplier location	h	Collection center potential location
c	Material	r	Recycle center potential location
j	Plant potential location	m	Disposal center potential location
k	Distribution center potential location	e	Recycle technology
l	Customer location	t	Period
p	Herb product type	s	Scenario

In the following table show a list of required parameters for the model.

Table 2. List of parameters.

Parameters	Explanation	Parameters	Explanation
f_j	Factory investment costs j.	c_{ic}	Maximum supplier capacity i for components / materials c.
f_k	Investment center distribution costs k.	c_j	Maximum capacity of the factory j.
f_h	Investment costs for collection center h.	c_k	Maximum distribution center capacity k.
f_{re}	Investment costs for recycling centers r, technology e.	c_h	Maximum capacity of collection center h.
f_m	Investment cost of disposal center m.	c_{cre}	Maximum capacity of recycling center r with technology e, for material c.
t_{jkts}	Transportation costs per product unit from factory j to distribution center k in period t, scenario s.	c_m	Maximum disposal center capacity m.
t_{klts}	Transportation costs per product unit from distribution center k to consumer location l in period t, scenario s.	τ_l	Product return ratio from consumer location l.
t_{hrts}	Transportation costs per unit of used product from collection center h to recycling center r in period t, scenario s.	o^r	Percentage of return products that can be recycled.
t_{rjts}	Material transportation costs in kg from distribution center k to consumer location l in period t, scenario s.	o^{ur}	Percentage of return products that cannot be recycled.
t_{hmts}	Transportation costs per unit of product that cannot be recycled from the collection center h to the disposal center m in period t, scenario s.	W_c	Material proportion c in kg on products that can be recycled.
pp_{cits}	Material purchase costs c in kg from supplier i in period t, scenario s.	W_h	Weight per unit of product that cannot be recycled in kg.
po_{lts}	Cost of buying used products from the location of consumers l in period t, scenario s.	π_l	Penalty costs per unit of unmet demand for consumers l.
mc_{jts}	Production costs per unit of product at factory j, period t, scenario s.	p_s	Probability of occurrence of scenario s.
cc_{lhts}	Collection costs per unit of used product from consumer location l to collection center h in period t, scenario s.	rc_{crets}	Recycling costs per unit of material c in kg at the recycling center j with technology e, period t, scenario s.

While the decision variables that want to be obtained from the results of the optimization of the closed cycle supply chain design are shown in table 3.

Table 3. Decision variables.

Variables	Explanation	Variables	Explanation
X_{cijts}	Amount of material c which is transported from supplier i to factory j in period t, scenario s.	U_{crets}	Amount of material sales c produced from recycling center r with e technology in period t, scenario s.
X_{jkts}	The number of products produced at the factory j and sent to the distribution center k in period t, scenario s.	V_{hmts}	The number of return products that cannot be recycled are transported from the consumer location l to disposal m in period t, scenario s.
X_{klts}	Number of products sent from distribution center k to consumer l in period t, scenario s.	Inv_{kst}	The final inventory of products at the distribution center k, period t, scenario s.
Y_{lhts}	Number of used products sent from consumer location l to center of collection h in period t, scenario s.	M_j	1 if the factory is built on location j, 0 if otherwise.
Y_{hrets}	Number of used products sent from collection center h to recycling center r with e technology in period t, scenario s.	D_k	1 if the distribution center is built on location k, 0 if otherwise.
U_{crjets}	The amount of material production c with e technology is transported from the recycling center r to factory j in period t, scenario s.	C_h	1 if the collection center is built on location h, 0 if otherwise.
P_m	1 if the disposal center is built on location m, 0 if otherwise.	R_{rt}	1 if the recycling center is built on location r, 0 if otherwise.

The assumption used in this modelling is:
- Each factory can be built to process any product.
- The composition portion for the same type of product is considered identical / identical (most producers have their own formulations for their products even though the type of product is the same as other producers' products).
- There is no definition of the type of warehouse for a particular product. The distribution center is assumed to hold all types of products in the supply chain.
- The results of the sale of material recycling processing materials are used to buy raw materials for product waste from consumers.
- Waste material collected from consumers is assumed to be a package of waste products.
- Transportation costs from consumers to the waste collection center are assumed to be a unit with the cost of collection.
- Storage costs for each type of product are assumed to be the same.

3. Problem formulation

In our reverse supply chain problem formulation, We used and modified formulation proposed by [3]. The objective of the herbs industry reverse logistic design optimization is to minimize infrastructure development investment costs which are defined as the sum between the total facility development investment costs (FC) and the multiplication of opportunities for a scenario to occur so as to produce manufacturing and recycling costs raw materials and waste products to be recycled (PC), collection costs (CC), transportation costs (TC), holding costs (HC). These objectives are formulated as follows.

$$\min z = FC + \sum_s^S P_s(MRC_s + PC_s + CC_s + TC_s + HC_s) \qquad (1)$$

The investment costs for the construction of supply chain infrastructure (FC) are defined as the sum between: the total cost of building a product factory p in each regional alternative j, the total cost of constructing a distribution center in each alternative area k, the total cost of constructing a collection center each regional alternative h, the total cost of building a recycling center in each regional alternative r using technological alternatives e, and the total cost of building a disposal center on location alternatives m.

$$FC = \sum_{j}^{J}\sum_{p}^{P} F_{jp}M_{jp} + \sum_{k}^{K} F_k D_k + \sum_{k}^{K} f_h C_h + \sum_{r}^{R}\sum_{e}^{E} f_{re}R_{re} \sum_{m}^{M} f_m P_m \qquad (2)$$

Manufacturing and recycling costs (MRC) are defined as the sum between the total production costs of p products in factories built in area j, period t, s scenario for type p products and distributed to distribution centers k with total recycled costs being material c at the recycling center r with technology e period to t that will be sent to supplier *i* for scenarios.

$$MRC_s = \sum_{j}^{J}\sum_{t}^{T}\sum_{p}^{P}(MC_{jtps}\sum_{k}^{K} X_{jtpks}) + \sum_{c}^{C}\sum_{r}^{R}\sum_{e}^{E}\sum_{t}^{T}(rc_{crets}\sum_{i}^{I} U_{cretis}) \qquad (3)$$

The cost of purchasing raw materials and products to be recycled (PC) is defined as the sum between the total cost of purchasing raw materials *c* from supplier *i* to factory j for product p at period t for each scenario s with the total cost of purchasing waste products to be processed from consumer l in period t to scenario s and will be transported to collection center h. this formulation will be reduced by the amount of material c sold in the recycled market with e technology in period t for each scenario.

$$PC_s = \sum_{c}^{C}\sum_{i}^{I}\sum_{t}^{T}\sum_{p}^{P}\sum_{j}^{J} pp_{citps}X_{citpjs} + \sum_{i}^{I}\sum_{h}^{H}\sum_{t}^{T} po_{its}Y_{ihts} - \sum_{c}^{C}\sum_{r}^{R}\sum_{e}^{E}\sum_{t}^{T} sp_{cts}U_{crets} \; \forall s \qquad (4)$$

Collection costs (CC) are defined as the total cost of collecting waste products that will be recycled or disposed from consumers l which will be transported to the collection center to h in period t for each scenario to s.

$$CC_s = \sum_{i}^{I}\sum_{h}^{H}\sum_{t}^{T} cc_{ihts}Y_{ihts} \; \forall s \qquad (5)$$

Holding costs (HC) are defined as storage costs for each unit of product stored at the distribution center to k period t for each scenario to s.

$$HC_s = \sum_{k}^{K}\sum_{t}^{T} hc_{kts}Inv_{kts} \; \forall s \qquad (6)$$

Transportation costs (TC) are defined as the sum between the total transportation costs from the factory j to the distribution center k for p products in the period t for each scenario s, the total cost of transporting p products from the distribution center to consumers, transportation costs from the collection center to the center recycling, total transportation costs from the raw material processing center to suppliers, as well as product transportation costs that cannot be recycled from the collection center to the waste disposal center.

$$TC_s = \sum_{j}^{J}\sum_{k}^{K}\sum_{t}^{T}\sum_{p}^{P} t_{jktps}X_{jktps} + \sum_{k}^{K}\sum_{l}^{L}\sum_{t}^{T}\sum_{p}^{P} t_{kltps}X_{kltps} + \sum_{h}^{H}\sum_{r}^{R}\sum_{t}^{T} t_{hrts}Y_{hrts}$$
$$+ \sum_{c}^{C}\sum_{r}^{R}\sum_{i}^{I}\sum_{e}^{E}\sum_{t}^{T} t_{rits}U_{criets} + \sum_{h}^{H}\sum_{m}^{M}\sum_{t}^{T} t_{hmts}V_{hmts} \; \forall s \qquad (7)$$

The constraints for the function of these objectives consist of Hard and Soft Constraint, The hard constrains is constraint of the balance of material flow at the production center / factory in area j for product p which will be sent to the distribution center k in period t for each scenario s must be the

same as the amount of material from supplier to factory plus the amount of raw material derived from waste treatment.

$$\sum_k^K ca_c X_{pjkts} = \sum_i^I X_{cijtps} + \sum_r^R \sum_e^E \sum_t^T U_{crjets} \quad \forall j, t, s \tag{8}$$

Constraints for each period, the number of flows entering the distribution center of all processing plants and inventory residues from the previous period are equivalent to the amount of outflow from the distribution center and inventory residue from the current period[13].

$$Inv_{ks(t-1)} + \sum_j^J X_{jkts} = Inv_{kts} + \sum_l^L X_{klts} \quad \forall k, t, s \tag{9}$$

Constraint to ensure demand from consumers can be fulfilled contains hard and soft constraints. The hard constraints are

$$\sum_k^K X_{klts} \geq d_{lts} \quad, \quad \forall l, t, s \tag{10}$$

Constraints of relationship between consumer demand and the flow of waste products flowed from consumers to the waste collection center.

$$\sum_h^H Y_{lhts} \leq \tau_l d_{lts} \quad, \quad \forall l, t, s \tag{11}$$

The constraint for ensuring the amount of waste products entering the recycling center is equivalent to the amount of waste products (which can be recycled) that enter the collection center. The soft constraints are

$$\sum_h^H \sum_r^R \sum_e^E \sum_t^T Y_{hrets} = \sum_l^L \sum_h^H o^r Y_{lhts} \quad, \quad \forall t, s \tag{12}$$

Constraint to ensure that every material and in each period, material flowing from each recycling center to the market or supplier of raw materials for herbal production does not exceed the incoming material from products that can be recycled at the recycling center.

$$\sum_h^H W_c Y_{hrets} \geq \sum_j^J U_{crjets} + U_{crets} \quad, \quad \forall c, r, e, t, s \tag{13}$$

Constraint to ensure that the number of waste products entering the final disposal center is equivalent to the amount of waste (which cannot be recycled) entering the collection center.

$$\sum_m^M V_{hmts} = \sum_k^K Wh. o^{ur} Y_{lhts} \quad \forall m, t, s \tag{14}$$

The soft constraints are a constraint of capacity for supply, distribution, production, distribution, collection, recycling, final disposal respectively are as follows

$$\sum_j^J X_{cijts} \leq c_{ic} \quad \forall i, t, c, s \tag{15}$$

$$\sum_k^K X_{jkts} \leq c_j M_j \quad \forall j, t, s \tag{16}$$

$$\sum_{l}^{L} X_{klts} \leq c_k D_k \quad \forall k,t,s \tag{17}$$

$$\sum_{l}^{L} Y_{lhts} \leq c_h C_h \quad \forall h,t,s \tag{18}$$

$$\sum_{j}^{J} U_{crjets} + U_{crets} \leq c_{cre} R_{re} \quad \forall c,r,e,t,s \tag{19}$$

$$\sum_{h}^{H} V_{hmts} \leq c_m P_m \quad , \qquad \forall m,t,s \tag{20}$$

Constraint to ensure that only one technology can be allocated for recycling waste treatment at each potential development location.

$$\sum_{e}^{E} R_{re} \leq 1, \quad \forall r \tag{21}$$

For non-negative constraint, integer and binary variables, the following constraints were applied.

$$X_{jks}, X_{kls}, Y_{lhs}, Y_{hrs}, Inv_{kts}, X_{ijts}, U_{crjets}, U_{crets}, V_{hmts} \in \mathbb{N}$$
$$M_j, D_k, C_h, R_{re}, S_m \in \{0,1\} \tag{22}$$

4. Fuzzy stochastic programming

Fuzzy stochastic Optimization deals with situations where fuzziness and randomness co-occur in an optimization setting. We follow the concept of fuzzy stochastic programming proposed by [3] as Left-Right (LR) fuzzy number

$$M_*(\tilde{A}) = 2 \int_0^1 \rho(\inf \tilde{A}_\rho) d\rho \tag{23}$$

$$M^*(\tilde{A}) = 2 \int_0^1 \rho(\sup \tilde{A}_\rho) d\rho \tag{24}$$

where $\inf \tilde{A}_\rho$ and $\sup \tilde{A}_\rho$ show the left and right extreme points of the ρ-level cut of $\tilde{A}$ for $\rho \in [0, 1]$, respectively. By the definition, the lower and upper possibilistic means are respectively expressed as

$$M_*(\tilde{A}) = \underline{a} - \alpha/3, \tag{25}$$

$$M^*(\tilde{A}) = \bar{a} + \beta/3. \tag{26}$$

5. Model solution

To solve the single objective DMILP, we use GRG [4] that stands for "Generalized Reduced Gradient". In its most basic form, this solver method looks at the gradient or slope of the objective function as the input values (or decision variables) change and determines that it has reached an optimum solution when the partial derivatives equal zero. GRG Nonlinear is the fastest solving method to solve linear and non-linear condition. That speed comes with a compromise though. The downside is that the solution you obtain with this algorithm is highly dependent on the initial conditions and may not be the global optimum solution.

Implementation and case study in herbs reverse logistic in Indonesia we use a case study in a herbs Industry in Indonesia with an index illustrated in table 4.

Table 4. Index used in a case study in Indonesian herbs reverse logistic.

Index	Explanation	Index	Explanation
i	3 ($i1,i2,i3$)	r	3 ($r1,r2,r3$)
c	3 ($c1,c2,c3$)	m	3 ($m1,m2,m3$)
j	3 ($j1,j2,j3$)	e	2 ($e1,e2$)
k	3 ($j1,j2,j3$)	t	2 ($t1,t2$)
l	3 ($l1,l2,l3$)	s	2 ($s1,s2$)
h	3 ($h1,h2,h3$)	p	3 ($p1,p2,p3$)

The scenarios are defined according to alternative-alternative index above. And we implement the algorithm to solve the DMILP formulation using excel Solver.

6. Sensitivity analysis

To answer uncertainty challenges, this research does a sensitivity analysis to check the flexibility and robustness of the model. The sensitivity analysis is implemented by using Solver excel and change the value of uncertainty variable according to the 2 scenario aspects. There are economic aspect and season aspect. The result is tabulated in table 5.

Table 5. The results of implementation using excel Solver are illustrated as follow.

Result	Value sensitivity analysis 1	Value sensitivity analysis 2
Total cost of scenario 1 period 1	Rp 11 495 340 500	Rp 11 372 61 025
Total cost of scenario 2 periode 2	Rp 11 737 242 530	Rp 11 754 245 631
Supplier location	2	3
Material	2	2
Plant potential location	1	1
Distribution center potential location	2	2
Customer location	3	3
Collection center potential location	2	2
Recycle center potential location	2	2
Disposal center potential location	2	2
Recycle technology	1	1
Herb product type	3	3

As shown above, the mathematics modelling that are solving and implementation using excel software with a case study in Herb reverse logistic in Indonesia give result that can be used for decision making process. According to the results, the proposed model already gives good and reasonable value following the objective function and constraints. The robustness from sensitivity analysis is figured as follow figure 2.
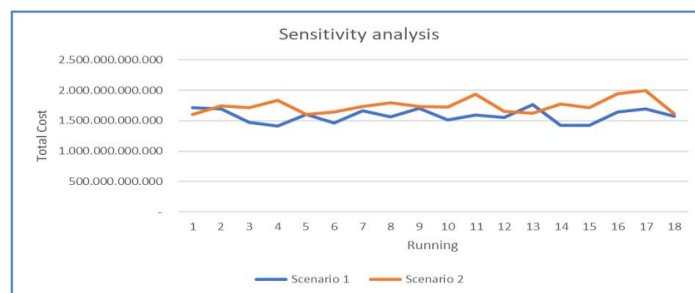

Figure 2. Sensitivity analysis.

We suggest an herbs company to pay attention to the uncertainty variable like raw material and cost, and to hard constraints.

7. Conclusion

This paper analyses and designs a reverse logistic of herbs agro-industrial based on fuzzy stochastic mixed integer linear programming with a case study of herbs logistic in Indonesia in order to respond stochastic challenges in the reverse logistic system. A case study of herbs logistic in Indonesia was used as an implementation and to test the fuzzy quantitative modelling. A GRG non-linear was used as model solution to solve the fuzzy stochastic modelling with implementation using Excel solver. The fuzzy quantitative modelling result with a case study in herbs logistic in Indonesia shows verified and validate result for stochastic quantitative-based condition for decision making purposes in herbs reverse logistic. To reduce risk in uncertainty: reverse logistic in herbs industry, we suggest future research for a development of contract model for future research. The contract model can develop reward and penalty according to quality of the herbs products.

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