Inbound Multi-echelon Inventory Supply Network Model in Ethiopian Leather Industry: A Simulation Study

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Abstract. Leather processing companies are highly affected due to irregular availability of raw hide and skin by trends of globalization and dynamic behaviour of meat usage in Ethiopia. Maintaining optimal inventory stock in inbound multi-echelon supply networks is more complex in nature due to high fluctuation of raw materials availability. This paper presents a deterministic optimal procurement inventory policy among four designed inventory replenishment strategies in the tanning industries to avoid fluctuation raw materials. We proposed simulation model for these four different procurement strategies of raw materials in each inbound multi-echelon supply network. After running the trial simulation, a significant method of controlling the inventory level in the tanneries while keeping the operating performance in a reasonable level is achieved. The outputs are analyzed using ARENA simulation inventory stock information in every tier of the supply chain network. Finally simulated outputs of these strategies in each level are compared with performance using analytic hierarchy process (AHP) a multi-criteria decision model.

Keywords: Discrete event simulation · Multi-echelon inventory · Multi-criteria decision · Supply chain

1 Introduction

Ethiopia possesses one of the largest populations of livestock in Africa and 7^{th}–9^{th} in the world. Ethiopian hides and skins are having very good reputations in the international leather market for their unique natural substance of fitness, cleanness, and compactness of texture, thickness, flexibility and strength.

Acute shortage and poor quality of raw hides and skins are the major problems faced by Ethiopian tanning industries and force them to operate under capacity. According to Tolossa (2013) there are 22 tanneries operating in the country with annual tanning capacity of 2.2 million hides, 25.9 million sheep skins and 13.7 million goat skins. But the annual potential of purchase of these tanneries is 1.7 million hides, 7.7 million sheep skins and 8 million goat skins. This illustrates that the tanneries are utilizing only 77.3%, 29.7% and 58.4% of their tanning potential respectively due to the shortage of raw material. On the other side collecting hides and skins with

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acceptable quality grade is becoming a challenge due to poor husbandry, storage and transport mechanism.

The potential supply of hides and skins depend of the scale of meat production, not on the size of livestock population. Thus availability of hides and skins depends on the need of meat usage rate. In Ethiopia the raw hides and skins have very high fluctuation which depends on festivals and fasting periods. High volatility of raw hide and skin may considerably impact on the profit margin and production capacity of leather manufacturing industries.

In this research maintaining optimal inventory stock in inbound multi-echelon supply network is considered as an alternative solution for this dynamic market by taking one tanning industry as a case which is located in Addis Ababa, Ethiopia. Modelling and simulation of inbound multi-echelon supply network with four different scenarios on the inventory replenishment strategies using ARENA simulation software is proposed to address this issue. Etraja and Jayaprakash (2016) proposed Analytic Hierarchical Process (AHP), a multi criteria decision model is employed to evaluate the alternative results of the simulation model.

2 Literature Review

In this research, literature review has been conducted in three stages. First identification of list of journals published with more priority in simulation and modelling of supply chain methodology and then identification of most influenced operational performance criteria and finally identification of research gap & performance analysis on different aspects of supply chain with respect to case company problems.

Nearly more than thirty research articles have been reviewed in simulation of logistics and supply chain management with decision support system from various e-resources from 2001 to 2018.

2.1 SCM Network Operational Performance Indicators

Beamon (1998) classified performance measures of supply chain design and analysis into qualitative and quantitative categories. Agarwal and Shankar (2005) evaluated qualitative measures include customer satisfaction, flexibility, information and material flow integration, effective risk management and supplier performance. Quantitative measures include measures based on cost and measures based on customer responsiveness etc. These performance criteria are mainly depends on the supply chain network structure, its complexity and the product/service type that is flowing in the chain. Mobini et al. (2013), who reviewed simulation model for the design and analysis of wood pallet supply chain selects cost, energy consumption and carbon dioxide emission as the key performance indicators. Jansen et al. (2000) identified satisfaction of customer and lead time in their catering supply chain simulation model. Noche and Elhasia (2013) introduced strategies in cement industries, Carvalho et al. (2011), Li et al. (2010), Cannella and Ciancimino (2008) and Cigolini et al. (2013), proposed simulation supply network. Simic et al. (2015) proposed hybrid GA inbound network, Fengli et al. (2009) simulated bio-mass supply chain, Klimov and Merkuryev (2008) considered the resilience and reliability of the supply chain network when there is something that interrupts the chain and Datta and Christopher (2011) simulated uncertainty in supply chains.

We have identified eight different performance indicators of supply chain network with related to the Ethiopian leather context from the literature review. The identified supply chain performance evaluation criteria are quality of goods, lead time, operational cost, risk mitigation strategy, flexibility to survive uncertain environments, access to the required quantity, service level and inventory level.

During the article review process in addition to the eight supply chain performance indicators we prepared five other evaluation criteria to identify literature gap. These are number of sources of raw material or sub assembled items, variety of goods, number of echelons, resource constraint (whether the model is developed with limited or unlimited resource) and the type of simulation software used to model the supply chain. Wan et al. (2005) considered single source of input and single echelon. Nikolopoulov and Ierapetritov (2012) and Zhang and Zhang (2006) considered two source of input with two echelons. These assumptions are mostly unpractical in the global world in which companies extend their supply up to thousands of sources to survive in the market by mitigating risk factors and uncertainties in the supply. The number of the variety of inputs also significantly affects the performance of the chain. Most of the articles consider the variety of inputs as one or two which is also rare in real world. A supply chain also should have to react for limited resources which cannot be found when needed like hide and skin. The number of echelons/tiers is also directly related with the performance of supply chains.

2.2 Research Gap

From the review of SCM inbound logistic distribution network, Persson and Olhager (2002) has considered quality of good/service criteria and rest of the researchers neglected it. But in our case leather industry suffering with more second grade quality of raw hide and skin and significantly it affects the performance of leather production. Even though all the eight key performance indicators of the supply chain are necessary to measure the performance of Ethiopian leather industry, according to a survey conducted in the industry quantity, quality, cost and lead time and tanneries capacity utilization are identified in the order of seriousness by keeping in mind the uncertain environment in different scenarios.

The other basic element in supply chain network is the availability of the required raw material/resource in sufficient amount for production. Umeda and Zhang (2001), Jie and Cong (2009), Chan and Prakash (2011), Mishra and Chan (2011), Wan and Zhao (2009), Patil et al. (2011) and Persson and Olhager (2002) consider inventory level criteria. Nikolopoulov and Ierapetritov (2012) and Mobini et al. (2013) considered limitation of resources in the supply chain network. In this research work source of raw materials is limited.

No research articles were found to interlink between the supply quantity and the inventory level for perishable goods. In this case, we made an attempt with case Ethiopian leather company, simulation study of interlink supply quality and inventory in supply chain with either fresh or salted hides and skins are considered. The unsalted fresh hides and skins should never been stored for more than a single day and fifteen days on average after salt is applied.

Even though there are millions of hide and skin producers, thousands of small collectors and hundreds of hide and skin traders, the tanneries are suffering from shortage of raw hide and skin. None of the researches indicate seasonal and dynamic supply of raw materials like the Ethiopian hide and skin. In addition no research addresses the by-product nature of supplied goods and lacks integration with the original product. To overcome these limitations and other challenges there should be a balance between the amount of on hand inventory and the quantity of the raw material received per unit time by considering the daily demand of the tanneries while keeping the limitation of the resource (not found in the required quantity when required) under consideration.

This research is basically focuses on handling this situation by developing a validated simulation model with the help of Arena software and testing different scenarios/experiments to see the operating performance of the tanneries with a reasonable amount of raw hides and skins in their stocks. This is done by developing four scenarios by varying the time between consecutive orders and the quantity of shipment per unit order.

2.3 Supply Chain Network Problem Associate with Case Company

This study focused four echelon supply chain in which two nodes in two of the echelons in Addis Ababa (capital of Ethiopia) and regional small traders of hides and skins, Dire Hide and Skin Procurement and Collection Centre (DHSPCC), regional big suppliers and the case company. The general framework of the supply chain under study is depicted in Fig. 1 below. Dire Hide and Skin Procurement and Collection Center (DHSPCC) received raw hide and skins from small producers located in Addis Ababa, some other regional small traders and Addis Ababa municipality abattoir by participating on a bid which is held monthly. DHSPCC then send shipment of 1000 sheep skins/order to the tannery after receiving order.

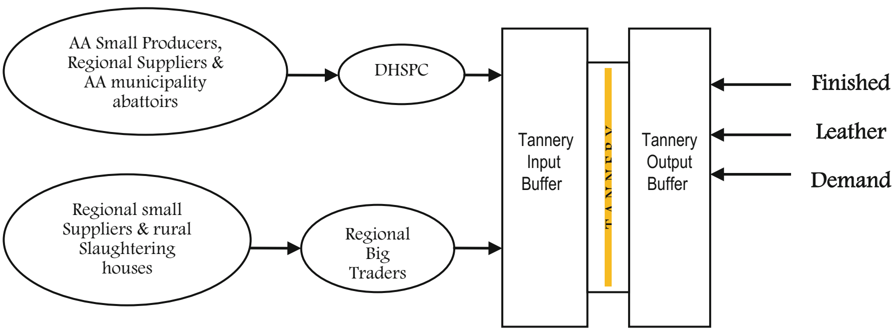

Fig. 1. General framework of the supply chain under study

The Regional Big Suppliers (RBS) of Dire tannery are a lot which are distributed all over the country. Some of the major suppliers come from Sellalie, Jimma, Gojam and Wollo regions in Ethiopia. These regional big traders will receive collected skins and hides from the small ones and rural slaughtering houses on daily basis without quantity restriction. Those regional big suppliers of hide and skin will ship a full truck load of 4000 sheep skins on average after receiving order from the tannery if and only if they have inventory on hand. If the inventory level of the RBS is less than the economic order quantity (EOQ) of the tannery the order will wait until the stock is replenished.

The case company, Tannery have strived to fulfil their daily demand with first grade quality of raw hides and skins to operate with its full installed capacity. If there is any difference in the supply of first quality the case company would be forced to operate with second grade quality or partial/under capacity or stop production/starved.

3 Simulation of Inbound Supply Chain Network

Discrete event system simulation and modelling methodology accommodate more realistic characteristic study in different supply chain environments, like stochastic, dynamic, and distributed environments and allow the supply chain decision makers can make quick decisions related to various critical conditions. In this study we divided the case company supply network model in to eight different logically interlinked sub-models from various suppliers, distribution, case company warehouse, work-in-process inventory, finished goods inventory and finally simulate these sub models distribution with real data for a year. The simulation is done in varying the time between consecutive orders and the amount of skins required by the tannery.

One year daily data is collected for the case company supply chain and provided in the developed simulation model to conduct experiment. The developed sub-models in the main research are inventory management segment for regional small suppliers, Addis Ababa suppliers, Addis Ababa – DHSPCC suppliers, regional big suppliers, DHSPCC, Inventory replenishment control strategy of the tannery and production inventory management of work-in-process tannery. The latter is indicated in Fig. 2 below.

The sub-model as shown in Fig. 2, work-in-process inventory simulate the tannery inventory management and production control segment manages raw-material consumption and finished goods production by keeping track of a circulating control entity that modulates the suspension and resumption of production.

A control entity is created in every day production process skin demand and determines the quantity of demand in the assign module production batch sizes. These values are “5e+003 + EXPO (505)” for full production batch size and “2.5e +003 + EXPO(253)” for partial production.

Then the entity will lead to four Decide modules to check the quantity of both grades of skins available on hand and determine the capacity utilization of the tannery. First check the level of first grade skin inventory in the input buffer of the tannery is greater or equal to the full production batch size and if not check second graded skin inventory. The tannery gives first priority to run the company to full production capacity with either first or second grade of skins. Second check the level of inventory fulfils minimum requirement for partial production for both quality grade skins. Finally

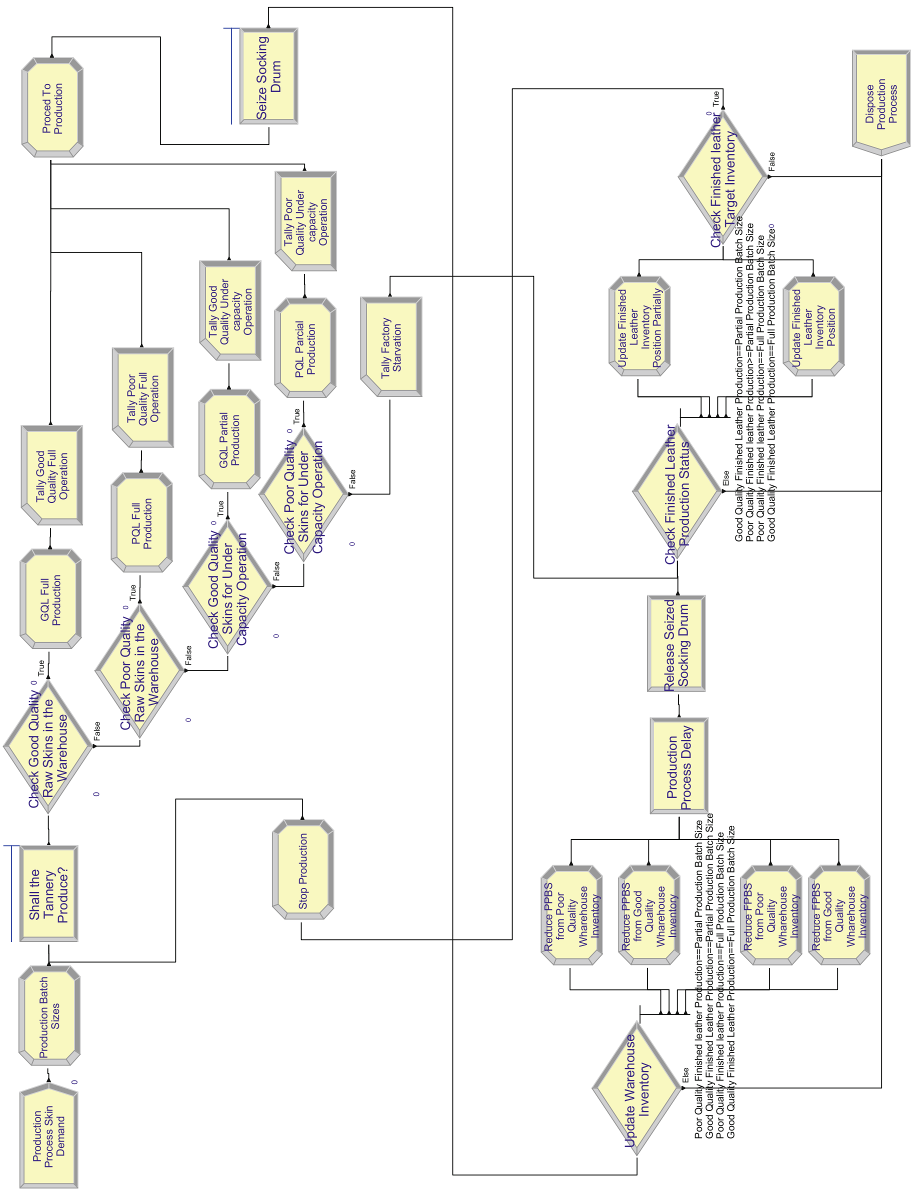

Fig. 2. Production inventory management of work-in-process tannery

the tannery faces with more scarcity of the raw material and inventory level reduced less than partial production then factory will be starved.

Another sub-model developed is finished goods inventory. For this case study it is taken as the daily demand of the finished product exceeds the daily production. At the same time the finished leather target stock is assumed to be 100,000 to abandon production termination due to excess finished product stock.

After validating the conceptual framework by company experts, the simulation model is verified by comparing the simulation result with the real performance of the supply chain.

4 Result and Discussion

The basic performance measurement criteria for this system under study is the factory status of tanning operation (four operations and a starvation) and the daily average and maximum inventory available in each suppliers and tannery warehouse stock. As described earlier the more time the skins are stored the less quality of skins. The five status of tanning operation are the primary measurement criteria for the performance of the supply chain system under study are:

- The number of days that the tannery processes first grade quality skins with full capacity.
- The number of days that the tannery processes second grade quality skins with full capacity.
- The number of days that the tannery processes first grade quality skins with under installed capacity.
- The number of days that the tannery processes second grade quality skins with under installed capacity.
- The number of days that the tannery is fully starved.

These conditions are varied based on the availability of the raw material on hand. These all are measured in days out of the operating 365 days (one year simulation).

The other output of the simulation that is used as the performance measurement criteria for the supply chain system under study is the average and maximum value of on hand inventory under stock in each echelons. These are

- The average and maximum skins inventory in DHSPCC stock
- The average and maximum skins inventory in RBS stock
- The average and maximum skins inventory in tannery warehouse stock.

This is selected because of the skins quality deterioration when stocked for more than fifteen days as well as to know and share information between echelons regarding the inventory status in each suppliers and customers. Based on this regard below are the four basic scenarios and cases under each scenario to be tested and the analyzed output of the simulation model. These four different strategically developed scenarios are

- Place the order with fixed time interval and fixed quantity of hide and skin
- Place the order with fixed time interval and variable quantity of hide and skin

- Place the order with variable time interval and fixed quantity of hide and skin
- Place the order with variable time interval and variable quantity of hide and skin.

This order placement is done by the tannery for its immediate suppliers. The simulation result of all developed scenario are listed in Table 1 below.

Table 1. Criteria comparison with various scenarios

Scenario	Number of days factory running				
	Full capacity with first grade quality	Full capacity with second grade quality	Under capacity with first grade quality	Under capacity with second grade quality	Factory starved
S-1	117	2	159	26	46
S-2	261	14	65	6	4
S-3	323	19	8	0	0
S-4	297	17	33	2	1

5 Optimal Inventory Decision Using AHP Method

After the completion of simulation results, each scenario has different working days with different levels of production capacities. Consider these mixed combination simulation results to evaluate optimal inventory level scenario using multi-criteria decision model. Multi-criteria decision using AHP model problem has three element parts. First level: to improve the production capacity of leather plant without shortage and surplus of inventory of raw hide and skin. Second level: selection of important criteria which influences the first level. These are

- Full capacity with first grade quality of raw material (FCFQ).
- Full capacity with second grade quality of raw material (FCSQ).
- Partial capacity with first grade quality of raw material (PCFQ).
- Partial capacity with second grade quality of raw material (PCSQ).
- Factory starved (FS).

Third level: contains the options of finalize the alternatives of this problem. The alternatives are fired the Inventory order to Factory warehouse, DHSPCC and RBS in the following scenario.

- Fixed time and fixed economic order quantity (FTFQ).
- Fixed time and variable economic order quantity (FTVQ).
- Variable time and fixed economic order quantity (VTFQ).
- Variable time and variable economic order quantity (VTVQ).

In a final step after weighing and scoring, the option scores are combined with the criterion weights to calculate an overall score for each option. Then evaluate all the options satisfy the criteria based on weightage according to the relative importance of the criteria. This is done by simple weighted summation. Finally, after judgments have

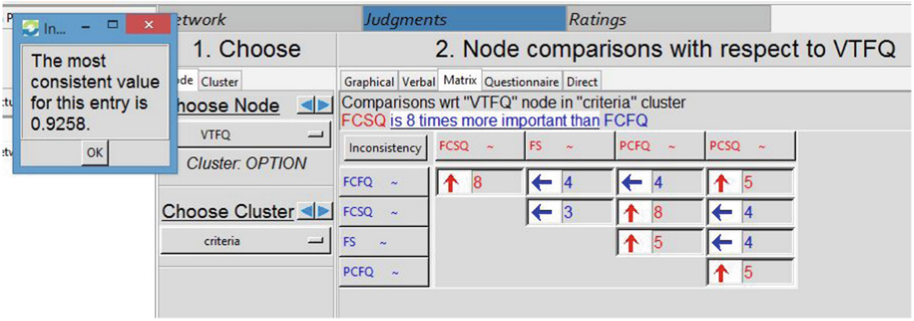

Fig. 3. Multi-criteria decisions for order placed with variable time and fixed quaintly

been made on the impact of all the elements and priorities have been computed for the hierarchy as a whole. Order placed with variable time and fixed quantity has arrived maximum consist value of 0.9258 as shown in Fig. 3.

Therefore, by observing all those parameters the tannery decision makers are able to make decisions based on the tested results so that they are able to make decisions based on facts rather than assumptions. Based on the executed data it can be simply observed that scenario 3 is found the better strategy for replenishing the tannery raw material warehouse.

6 Conclusion

Among the evaluation schemas identified for the article revision a big ignorance has been found for the two basic parameters that has an immense point while modelling and simulation. These evaluation parameters are the quality of goods in and out in the supply chain and the availability of the resources in the supply chain while the Ethiopian leather industries, particularly the tanneries are suffering from the shortage of raw material (hides and skins) as well as its quality problem.

This study paved the way to create a balance between the two conflicting objectives of tanning industries while keeping the operating performance of the tannery to the optimum level. After developing a four echelon verified simulation model four different scenarios (Inventory Replenishment Strategies) are designed by varying the time between two consecutive orders and the quantity of shipment per unit order. These scenarios are tested in the model for one year simulation run time with three replications to evaluate the tannery operating performance and the amount of on-hand inventory accumulated. But the simulation result has given mixed composition of full and partial number of tannery working days with both first grade and second grade quality raw skins. So we adapted AHP multi criteria decision method to rank these strategies. Hence, scenario three (Placing order to the suppliers with variable time interval and fixed quantity of skins in a shipment) result in the best operating performance of the tannery by keeping both capacity utilization and amount of raw material inventory in a reasonable quantity. Therefore, tanneries and other related sectors have a possibility to make decisions based on facts rather than assumptions in such uncertain environment.

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