Augmented halal food traceability system: analysis and design using UML

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Abstract. Augmented halal food traceability is expanding the range of halal traceability in food supply chain where currently only available for tracing from the source of raw material to the industrial warehouse or inbound logistic. The halal traceability system must be developed in the integrated form that includes inbound and outbound logistics. The objective of this study was to develop a reliable initial model of integrated traceability system of halal food supply chain. The method was based on unified modeling language (UML) such as use case, sequence, and business process diagram. A goal programming model was formulated considering two objective functions which include (1) minimization of risk of halal traceability failures happened potentially during outbound logistics activities and (2) maximization of quality of halal product information. The result indicates the supply of material is the most important point to be considered in minimizing the risk of failure of halal food traceability system whereas no risk observed in manufacturing and distribution.

1. Introduction
In term of supply chain management, logistic activities are divided into two main activities, i.e., inbound and outbound logistics. Inbound logistics involves supply and receiving of raw material, processing, packaging and dispatching activities, while outbound logistics activities consist of distribution activities. Inbound and outbound logistics combine within the field of supply-chain management. Those activities of logistic are illustrated in Figure 1.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{logistic.png}
\caption{Logistic activities in food supply chain [1]}
\end{figure}

Halal traceability is one of critical success factors in halal supply chain management. Halal traceability means halal status should be maintained along the supply chain [2]. A fully integrated...
supply chain is needed to synchronize both inbound and outbound logistics in the halal traceability system to maintain product information and ensure the halal status from farm to fork. The traceability requires both forward and backward of product information (see Figure 2).

![Figure 2. The concept of traceability in the food supply chain [3]](image)

This study aims to identify and analyze the entities and the processes to develop halal food traceability system model by augmenting its system to cover the whole logistic activities through its supply chain. Based on the analysis, we design initial model to halal traceability system that encompasses inbound and outbound logistics. The model of this augmented halal food traceability system is expected to optimize the operational risk of the implementation of this system in food supply chain.

2. Methodology
The unified modeling language (UML) is used for analyzing and designing the model of this augmented halal food traceability system. As a methodology, standard diagrams of UML which relevant to this study are employed. They are use case, sequence and business process diagrams. Then the formulation for the risk of halal food traceability failure is analyzed by goal programming method. The step by step methodology is explained as follows.

2.1. Use case diagram
The step first of the system modeling is to identify the system’s entities and then analyze the functional requirements of the system using use case diagram. This use case diagram represents the main actors and use-cases together with their relationships in the supply chain [4]. This study shows general group of actors and use cases to make the initial model become simple and understandable.

2.2. Sequence diagram
A sequence diagram visualizes the different processes or objects that exist simultaneously and the messages exchanged between those objects. The Sequence diagram is designed based on use case diagram.

2.3. Business process diagram
Business process diagram describes a system at the highest level. Business process diagram facilitates the graphical display from the control of the data flow among processes at each level of building a system. Business process diagram is also used to analyze the flow process that will be developed.

2.4. Optimization of the halal food traceability system model
The augmented halal food traceability system model is formulated by goal programming. Goal programming is the branch of multi-criteria decision making [5]. For this model, the formulation is considering two objective functions which include (1) minimization of risk of halal food traceability
failures happened potentially during outbound logistics activities and (2) maximization of quality of halal food product information. The Goal programming model is given as below [5]:

\[ Z_{\min} = \sum_{k=1}^{m} (d_k^+ + d_k^-) \]  

(1)

The \(d_k^+\) and \(d_k^-\) are deviational variables that represent the level of achievement. It shows over and under achievement. Since goal programming for this study is the preeminent method where the level of importance of the variables is determined by the priority of the each variable [5].

\[ Z_{\min} = \sum_{k=1}^{m} P_k (d_k^+ + d_k^-) \]  

(2)

\[ Z_{\min} = P_1^*d_1^+ + P_1^-d_1^- + P_2^*d_2^+ + P_2^-d_2^- \]  

(3)

subject to:

\[ \sum_{i=1}^{n} C_{ki}X_i + d_k^- - d_k^+ = Y_k, \text{ for } k = 1, 2, \ldots, k \]  

(4)

\[ \sum_{i=1}^{n} a_{ij}X_i \leq or \geq t_j, \text{ for } i = 1, 2, \ldots, n \text{ and } j = 1, 2, \ldots, m \]  

(5)

\[ \forall d_k, \forall x_i \geq 0 \]  

(6)

\[ P_1 >>> P_2 >>> \ldots P_k \]  

(7)

where:

- \(k\) = the \(k^{th}\) objective functions \((k = 1, 2, \ldots, m)\)
- \(X_i\) = the \(i^{th}\) decision variable \((i = 1, 2, 3.. n)\)
- \(X_1\) = supplier
- \(X_2\) = manufacturer
- \(X_3\) = distributor/retailer. Because of distributor and retailer perform the same function, so in this study, we make it as just one variable to consider.
- \(C_{ki}\) = coefficient of \(X_i\) on the \(k^{th}\) objective function
- \(Y_k\) = objective function (goal constraints)
- \(a_{ij}\) = coefficient of constraint function
- \(t_j\) = the amount of resources
- \(P_k\) = the preemptive priority factors of the \(k\) goal
- \(P_1\) = the preemptive priority factor to the risk of halal food traceability system failure
- \(P_2\) = the preemptive priority factor to quality of halal food product information

3. Result and discussion

3.1. System entities and functional requirements

The augmented halal food traceability system was begun by identifying and analyzing system’s entities. The entities that construct the system are input, process, output, stakeholder, resources, role, missions and object, and other related components (see Figure 3). The primary actors of the supply chain consisting of the supplier, manufacturer, distributor, and retailer [6]. Furthermore the stakeholder (actors) of the system and the functional activities, including their relationship, are shown in Figure 4. Based on system’s entities and use case model was built the sequence diagram that
represents information exchange among the actors and their processes in food supply chain. This sequence diagram can show the material and information flow both (see Figure 5).

**Figure 3.** The entities of halal food traceability system

**Figure 4.** Use case diagram for halal food traceability system along logistic activities
3.2. Business process model
The model of halal food traceability system is developed by using business process diagram. Business process model describes one or more linked procedures or activities which aim to achieve overall system goals. The result of analysis and modeling of business processes for halal traceability system in food supply chain is illustrated in Figure 6.

![Business process model for halal food traceability system](image)

3.3. Simulation of the halal food traceability system model
The simulation has been done to the optimization problem in halal food traceability model. The data that used in this case is generated from the random number in excel and use the scale of 1-5 (attribute number). Since the goal programming operates by the variable number then we have to do the normalization of the data. The goal programming problem can be solved with solver in excel [7]. Based on data processing obtained and the equations at section 2.4, then the goal programming formulated as follows:

- \(0.47X_1 + 0.43X_2 + 0.50X_3 \leq 1\) risk of failures
- \(0.43X_1 + 0.40X_2 + 0.46X_3 \geq 0\) quality of product information
- \(X_1, X_2, X_3 \geq 0\)
\[ Z_{\text{min}} = P_1 \cdot d_1^* + 0 \cdot d_1^- + 0 \cdot d_2^* + P_2 \cdot d_2^- \quad \text{The objective function} \]

subject to:
\[
\begin{align*}
0.47X_1 + 0.43X_2 + 0.50X_3 - d_1^* + d_1^- &= 1 \\
0.43X_1 + 0.40X_2 + 0.46X_3 - d_2^* + d_2^- &= 0 \\
X_1, X_2, X_3, d_1^*, d_1^-, d_2^*, d_2^- &\geq 0
\end{align*}
\]

The solver result:
\[
Z = 0; X_1 = 2.13; X_2 = 0; X_3 = 0; d_1^* = 0; d_1^- = 0; d_2^* = 0.91; d_2^- = 0
\]

From the simulation, the risk of failure halal food traceability system model is minimum or zero when the deviation of quality of product information is 0.91 and the value of supplier \(X_1\) is 2.13. The result of simulation also shows that the \(X_2\) (manufacturer) and \(X_3\) (distributor/retailer) does not work on the optimization of the problem as the values are zero. It shows that the supply of halal material influences the achievement of the objective. The halal material is not only limited to the product ingredient itself but also the material used for the packaging. Based on sensitivity analysis, the coefficient of \(X_1\) (supplier) can be allowed to decrease. The optimal solution value will change as the objective function coefficient of \(X_1\) is changing whereas the coefficient of the \(X_2\) (manufacturer) and \(X_3\) (distributor/retailer) remain the same.

Even though the simulation result showed that the critical point of halal traceability system in food supply chain is in the supply of material, the risk of failure may occur in manufacturing and distribution processes. For instance, in the fermentation process, the manufacturer may produce the non-halal product. In the distribution process, besides of the halal assurance of halal of packaging material, it also needs to pay attention in the handling of the product. It may happen contamination and mix of halal product and non-halal product cause of the sharing facilities or mislabelled. In the context of halal assurance, there is no tolerance for the risk of failure. For that reason, all the processes in halal food supply chain must be considered to assure the halalness of a product. The actors in every phase take their own responsibilities to do the processes and produce the product that complies with the Shariah law and provide the information of product during the processes it does.

4. Conclusion
The results obtained that the main actors (stakeholder) of the system which is divided into supplier, manufacturer and distributor/retailer. Related to the actors, the main functions of the system are supplying of halal material, processing, and distribution of halal food product. The information flow follows the material flow. The control of document and communication among the actors become important factors for the product information to be traced and tracked.

The optimization result showed that the risk of failure of halal traceability system in the food supply chain depends on the beginning of the process. The complete and accurate information from the supplier can decrease the risk of system failure. The optimized condition is achieved when the halalness of supplying of material can be assured. However, it must be considered the risks of producing non-halal products in the production process, the non-halal packaging material used, and possibly being contamination in the distribution process.

For the future work, the stakeholders and decision makers have to further analyze the critical processes throughout the food supply chain. The identification of resources may influence the optimization of the system. It is also important to find the better decision for the integrated halal food traceability system by using actual data.

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