IOP Conf. Series: Materials Science and Engineering **404** (2018) 012010 doi:10.1088/1757-899X/404/1/012010

Selection of Traceable Technology in Food Supply Chain

Mr Shahbaz Khan[1], Mr Mohd Imran Khan[1*], Dr Abid Haleem[2], Mr Mohd Shuaib[3]

[1]Research Scholar, Department of Mechanical Engineering Faculty of Engineering and Technology, Jamia Millia Islamia, New Delhi-110025, India

[2]Professor of Mechanical Engineering, Faculty of Engineering and Technology, Jamia Millia Islamia, New Delhi-110025, India,

[3] Assistant Professor, Mechanical Engineering, Delhi Technological University, Delhi

imrankhan@st.jmi.ac.in

Abstract Traceability is an essential tool to provide the product information throughout the Food Supply Chain (FSC), this help protecting the consumer welfare and in developing global competencies. Several technologies are available to implement the traceability system in FSC; these are barcoding, QR code, edible label, DNA- barcoding and paper-based systems. In this paper, we have tried to identify the significant factors towards the selection of the traceable technology within FSC through the literature review and supported by the expert opinion. These factor and sub-factors are prioritised using Analytic Hierarchy Process (AHP). The findings of this work suggest that product-related factors have the highest weight, and needs attention while selecting the traceable technology in FSC. This work may assist the practitioners in the selection of traceable technology for their FSC in an efficient manner.

Keywords: Analytic Hierarchy Process (AHP); Factors; Food supply chain (FSC); Traceability; Traceable technology

1. Introduction

Consumer concerns have increased towards the food safety, hygiene, and environment which has made the role of traceability important. Traceability is implemented not only to assure the consumer expectation but also to provide the effective management of product flow, increase the speed throughout the FSC [1]. Traceability systems are considered as the prerequisite for the food industry to explore the global market [2] as well as protecting the public health.

Olsen and Borit [3] define the traceability in a generic way as “The ability to access any or all information relating to that which is under consideration, throughout its entire lifecycle, using recorded identifications". In the context of food "all information" refer to the information related to ingredient origin, processing, logistics and retailing of the food products. The recoded information is stored and carried with the help of the “traceability information carriers” such as a barcode, RFID, edible label, DNA barcode and other advanced technologies. The term "tracing" and "tracking" is widely used in the literature of traceability. Tracing is a backward process where the origin is identified by history or records in the supply chain, and tracking is the forward process where consumers and supply chain partners are identified by location in the supply chain [4]. The traceability is the combination of the "tracing" and "tracking" of the product information in a backward and forward direction in the supply chain.

The implementation of traceability in the FSC gets strengthened with the adoption of technologies having the ability to track the product related information. Effective monitoring is the focus of the food industries which want low cost and easily applicable traceability technology. Thus, the selection of these traceable technologies is based on the several factors to provide product-related information to consumers. In this paper, the selection criteria of traceable technology are identified and ranked through the Multi-Criteria Decision Making (MCDM) techniques.

1.1 Need for the Study

The selection of the traceable technology is a difficult and complex task because of the several factors are involved. In the context of the food industry, it becomes more complicated because of the huge variation in the perception of the food consumers. Thus, in such situation, the selection of the traceable

technology for the food product is quite important for practitioners. Through this paper, we have tried to identify the factors and subfactors which are important in the selection of traceability technology is identified and prioritise to assist the practitioners.

1.2 Objective of the Research

The notable objectives of this research are:

- To identify the factors and sub-factors for the selection of traceable technology FSC
- To prioritise the factors and sub-factors for the selection of traceable technology in FSC
- To provide the managerial implications

1.3 Factors related to the selection of traceable technology in FSC

The factors which influence the selection of traceable technology are categorised and grouped namely: "product-related factor", "process related factor", "social factor" and "other factor". These factors are further divided into sub-factors and shown in figure 1.

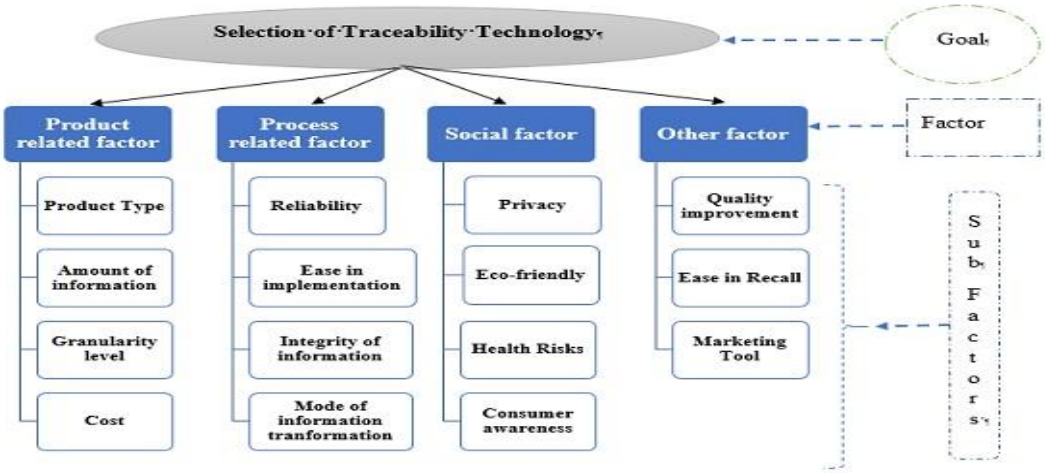

Figure 1: AHP hierarchical framework for the selection of traceable technology

2. Methodology

To accomplish the research objective, we have identified to use a suitable multi-criteria decision-making (MCDM) technique. Previous studies suggest that for prioritising the criteria/factors or factors some MCDM tools such as AHP [5], TOPSIS [6] and DEMATEL [7]. AHP seems to be a proper MCDM technique to provide the relative measurement or priorities by relative importance in this study. A group of five experts from academician and professionals gave their opinion through the AHP decision matrix. A brief about the AHP and process adopted are given below:

2.1Analytical Heretical Process (AHP)

AHP is a technique from the MCDM family and is extensively used in different applications such as supply chain, supplier selection, technology selection [8,9]. MCDM is used to rank or select a set of alternatives under usually independent, incommensurate or conflicting attributes [10]. In brief, the steps followed are given below:

Step 1: MCDM is structured as a hierarchy and decomposed into a hierarchy of interrelated decision elements. The hierarchical structure is used to arrange criteria/factors and sub-criteria/sub-factors.

Step 2: Here the pairwise comparisons between criteria and sub-criteria undertook using a nine-point ratio scale by experts (please see Table 1).

Table 1: Scales in pairwise comparisons

Definition	Equally important	Moderately important	Strongly important	Extremely important	Extremely more important	Intermediate values
Value	1	3	5	7	9	2,4,6,8

Step 3: The criteria are compared pair-wise according to their influence and based on the specified criteria in the higher level [11]. The weights are calculated from equation (1) as given below:

$$AW=\lambda_{max}W \quad (1)$$

In Equation 1; A is the priority matrix; W is weight, and λ_{max} is the maximum Eigenvalue of Matrix A

Step 4: The matrix A is checked for the consistency ratio (CR), this to be less than 0.10.

The consistency ratio is the ratio of consistency index (CI) and the random index number (RI). The CR and CI are defined as follows:

$$CI = \frac{\lambda max-1}{n-1} \quad (2) \quad CR= \frac{CI}{RI} \quad (3)$$

For the different count of criteria, it has a different value as is shown in Table 2.

Table 2: Random Index (RI)

N	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	.90	1.12	1.24	1.32	1.41	1.45

If CR is less than 0.10, the result can be acceptable, and matrix A is sufficient consistent. Otherwise, one has to return to step 1 and repeat the steps.

3. Results

In evaluating the relative importance of the factors to select the traceable technology AHP is used, here, a group of five experts from food manufacturing company and academician is formed. Experts inputs were collected and used in finalising the factors and sub-factors (Please see figure 1). After finalising the factors and sub-factors, expert's opinion is again used through Saaty scale to perform the pairwise comparison of factors and sub-factors. The pairwise comparison matrix for factors has been framed, and their relative weights are summarised in Table 3.

Table 3: Pair-wise comparison matrix for factors

	Product-related factor	Process-related factor	Social factor	Other factor	Weights	Rank
Product-related factor	1	2	2	4	0.435	1
Process-related factor	0.5	1	2	3	0.286	2
Social factor	0.5	0.5	1	2	0.182	3
Other factor	0.25	0.33.	0.50	1	0.097	4
Consistency Ratio (CR)=0.017						

The “product-related factor” having weight 0.435 is the most important factors for the selection of traceable technology for the FSC, followed by “process related factor” (0.286); “social factor” (0.182), and “other factor” (0.097). The pairwise comparison is performed for the subfactors and relative weights are calculated. These relative weights of sub-factors along with the global weight are shown in Table 4.

It is observed that the consistency ratio of pairwise comparison matrix of each factor and sub-factors is less than 0.1 in all the cases. Hence these matrices are highly consistent and acceptable. Table 4 also shows the relative rank and global rank of the sub-factors for the selection of traceable technology.

Table 4: Global Ranking of the factor and sub-factors to select the traceable technology in FSC

Factors	**Relative weight**	**Sub Factors**	**Relative weight**	**Relative rank**	**Global weight**	**Global rank**
Product-related factor	0.435	Product Type	0.274	2	0.11919	**3**
		Amount of information	0.086	4	0.03741	**10**
		Granularity level	0.178	3	0.07743	**5**
		Cost	0.462	1	0.20097	**1**
Process-related factor	0.286	Reliability	0.073	4	0.020878	**13**
		Ease in implementation	0.498	1	0.142428	**2**
		Integrity of information	0.172	3	0.049192	**9**
		Mode of information	0.258	2	0.073788	**6**
Social factor	0.182	Privacy	0.467	1	0.084994	**4**
		Eco-friendly	0.160	3	0.02912	**11**
		Health Risks	0.277	2	0.050414	**8**

		Consumer awareness	0.095	4	0.01729	**14**
Other factor	0.097	Quality improvement	0.297	2	0.028809	**12**
		Ease of Recall	0.54	1	0.05238	**7**
		Marketing Tool	0.163	3	0.015811	**15**

4. Discussion

Based on Table 4, the order of relative importance of the factors for selection of traceable technology for FSC as: 'Product-related factors' > 'Process related factors' > 'Social factors' > 'Other factors'. The order of relative importance of sub-factors is given in Table 4.

The 'product-related factors' are the most important factors for the selection of traceable technology in the FSC. This factor has four sub-factors namely: "product type", "amount of information", "granularity level" and "cost". The major sub-factors for the selection of traceable technology is the cost of the product having the highest weight. The second highest weight is the "product type" and the second major consideration for traceability technology selection. The product type refers to the perishability level, freshness, physical state of the product and their size. These aspects affect the selection of the traceable technology. Next important factors are the "Granularity level" after the "product type". The "granularity level" is defined as the *"...reflects the levels and size of the Identifiable unit, that are handled by the particular system*" [12]. The fine granularity level requires high cost and detailed information than the coarse granularity level. The last important sub-factors are "amount of information". The traceable information carrier limitations such as QR code having the capacity to contain more information than the barcode. Thus, these factors play an important role in the selection of traceable technology for the FSC.

The second important factor is the "Process related factor" which are having the weight 0.286. This factor has four sub-factors. In the context of this factor, most important sub-factor is the "Ease in implementation". Before implementing any technology, the organisation assesses the implementation issue. Similar to other technology, 'ease in implementation' is an important factor in the traceable technology selection. Next important sub-factor is the "mode of information" which refer to the "how information is processed (paper-based or digital)?". After the mode of information, the next important sub-factor is the "integrity of the information". The information integrity is an aspect of the food integrity which is protected through the traceability. Reliability of the traceable technology is the lowest relative weight to select the traceable technology for FSC.

The social factor is the next most important factor for the selection of traceable technology in FSC. This factor also has four sub-factors. "Privacy" is a most important factor for the traceability technology selection for the food product. The consumer's concern about their privacy and some traceable technology traces the product up to their fridge, and so the consumer loses their privacy [13]. Second important sub-factor is the "Health risk of the consumers". Some traceability carriers such as a barcode on fruits and fruits edible label are placed on the surface of the food product which is harmful to the health of the consumers [14]. Next important sub-factor is the "Eco-friendly". The traceable technology should be an eco-friendly and having the less effect on the environment. The advanced traceable technology is eco-friendly such as an elidable label. Selection of traceable technology also depends on the consumer awareness about the traceability of food product because the industries do not want to engage their resources in an environment where demand is very low [15].

Finally, the fourth important factor is "Other factor" which have the three sub-factors namely: 'Quality improvement'; 'ease in recall' and 'marketing tool'. The suitable traceable technology is utilised for the effective recall system especially in case of the food crisis. So, this sub-factor is most important sub-factor in this context. Second important sub-factor is the "quality improvement". Traceability technology is used for the purpose to improve the quality of the food product by effective monitoring the food throughout the supply chain. The next important sub-factor is the "marketing tool". The food companies provide the information about the food product through the traceability, and these systems are used as a marking tool.

5. Implications

This study provides the understanding of the factors and sub-factors for the selection of traceable technology in FSC. The significant implication of this research suggests for facilitating the managers and professionals of food industries; to select a suitable traceable technology for their respective supply chain. The finding of this work provides a direction to the decision maker of the specific FSC such as fruit, vegetables, and dairy supply chain in selecting the traceable technology.

6. Conclusions

The factor and sub-factor for the selection of traceable technology in FSC are identified through the literature survey and are supplicated by the expert's opinion. These factors played a significant role in the selection of the traceable technology for FSC. After achieving the four main factors and fifteen sub-factors, AHP is used for prioritising these factors and their associated sub-factors as per their relative importance and global importance. Finally, the finding of this work is presented, and the implications are provided.

References

1. Leat, P., Marr, P., & Ritchie, C. (1998). Quality assurance and traceability—the Scottish agri-food industry's quest for competitive advantage. Supply Chain Management, 3,115–117.
2. Khan, S., Haleem, A., Khan, M., Abidi, M., & Al-Ahmari, A. (2018). Implementing Traceability Systems in Specific Supply Chain Management (SCM) through Critical Success Factors (CSFs).*Sustainability*,10(2), 204.
3. Olsen, P., & Borit, M. (2013). How to define traceability. Trends in Food Science & Technology
4. Van Dorp, K. J. (2002). Tracking and tracing: A structure for development and contemporary practices. Logistics Information Management, 15(1), 24-33.
5. Luthra S, Garg D, Haleem, A (2013) Identifying and ranking of strategies to implement green supply chain management in Indian manufacturing industry using Analytical Hierarchy Process. Journal of Industrial Engineering and Management 6(4):
6. Kumar S, Singh B, Qadri MA, Kumar YVS, Haleem A (2013) A framework for comparative evaluation of lean performance of firms using fuzzy TOPSIS. International Journal of Productivity and Quality Management 11(4): 371-392
7. Kumar S, Luthra S, Haleem A, Mangla S.K, Garg D. (2015) Identification and Evaluation of Critical Factors to Technology Transfer Using AHP Approach. International Strategic Management Review 3 (1): 24–42
8. Subramanian N, Ramanathan R (2012) A review of applications of Analytic Hierarchy Process in operations management. International Journal of Production Economics 138 (2): 215–241
9. Kumar S, Luthra S, Haleem A (2015) Benchmarking supply chains by analyzing technology transfer critical barriers using AHP approach. Benchmarking: An International Journal 22(4)
10. Hwang CL, Yoon K (1981) Multiple attribute decision making: Methods and applications. A state of the art survey. New York: Springer-Verlag
11. Chrysochou, P., Chryssochoidis, G., & Kehagia, O. (2009). Traceability information carriers. The technology backgrounds and consumers' perceptions of the technological solutions. *Appetite,53*(3), 322-331. doi:10.1016/j.appet.2009.07.011
12. Bollen, A.F., Riden, C.P. & Cox, N.R. (2007). Agricultural supply system traceability, part I: Role of packing procedures and effects of fruit mixing. Biosystems Engineering, 98(4): 391-400
13. von Locquenghien, K. (2006). On the potential social impact of RFID-containing everyday objects. Science, Technology and Innovation Studies, 2, 57–78.
14. Khan, M. I., Khan, U., & Haleem, A. (2014). Corporate Social Responsibility: Modelling of Critical Factors using an Integrated ISM and Fuzzy-Micmac approach. International Journal of Global Business and Competitiveness, 9(1).
15. Haleem, A., & Khan, M. I. (2017). Towards successful adoption of Halal Logistics and its' implications for the stakeholders. British Food Journal, 119 (7).
16. Khan, S., Asjad, M., and Ahmad, A. (2015), "Review of Modern Optimization Techniques", International Journal of Engineering Research and Technology, 4(4).