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# IOT-enabled Quality Management Process Innovation and Analytics in China's Dairy Industry: A Data Flow Modeling Perspective

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**Abstract:** Since the "melamine" incident was reported in China, China's dairy industry attracts more and more attention, leading some scholars to conduct research on quality management and safety monitoring issues of China's dairy industry. The technology of the Internet of Things (IOT) is viewed as one of the best ways to solve the safety problems of China's dairy industry by supporting the development of dairy traceability systems. This paper firstly analyses the current situation of China's dairy industry supply chain to get at the root of the problem. We then propose an IOT-enabled quality management framework which is an innovation mode of quality management in China's dairy industry supply chain. To further highlight the important role of IOT technology, we employ a business process modeling approach based on data flow perspective to describe this innovation management mode. The artifacts we design, especially the matrix of dairy products and process information, can help the practitioners to efficiently monitor the quality information of dairy products.

**Keywords:** dairy industry, quality management, the Internet of Things, data flow

## 1. INTRODUCTION

Dairy production and processing sectors are often dispersed in different regions at different times which make the supply chain complex. Organizations, participating companies, and other more processing sectors were included in the chain. Because of a deficiency in overall control of the operational processes, the products data and business information cannot transmit effectively<sup>[1], [2]</sup>. As a result, it is hard to guarantee the quality and safety of dairy products. Consumers and managers can hardly find out the dairy source and processing information from the final link of the dairy chain and dairy products events occur from time to time.

In recent years, the flow of information has attracted more and more attention<sup>[3]</sup>. In this paper, we propose an IOT-enabled quality management framework to solve problems like poor flow of information, unreasonable data supervision in dairy industry<sup>[4]-[6]</sup>. Firstly, we establish a unified data platform, using RFID, GPS and other technologies. We then apply the IOT-enabled quality management framework to the quality safety management of dairy products industry by building a dairy industry quality management information system, which monitors the whole process management information. The IOT-enabled quality management framework could close existing loopholes in dairy industry operation process effectively<sup>[7]</sup>.

The key quality management problems in dairy industry are unscientific supervision, uncontrollable data, and confused business process<sup>[8]</sup>. We will make a visual information flow in the dairy industry by modeling the IOT-enabled quality management framework from the data flow perspective. Finally, we summarize the information traceability under the IOT-enabled quality management framework.

## 2. IOT-ENABLED QUALITY MANAGEMENT FRAMEWORK: AN INNOVATION MODE

Throughout the dairy supply chain process, From cow breeding, raw milk purchasing, transportation, dairy production, dairy processing to products selling, Accurate data recording, reasonable file storage, timely information sharing are the key of quality supervision of dairy products. IOT technology can ensure the core perfectly. IOT is viewed as one of the best ways to solve the safety problems of China's dairy industry by

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supporting the development of dairy traceability systems. We propose an IOT-enabled quality management framework which is an innovation mode of quality management in China’s dairy industry supply chain. We firstly establish a unified data platform to ensure data precise, information consistent. Then we build dairy quality management information system to manage all processes information of the supply chain holistically. The system is equipped with RFID technology, GPS navigation and positioning technology<sup>[9]</sup>. We employ a business process modeling approach based on data flow view to describe the innovation management mode.<sup>[10]</sup>

The core of quality management of the dairy industry is the quality of raw milk and dairy products. Quality controls of raw milk include supervision of milk yield, milk prices, milk quality and fresh milk flow regulation, related to the management of cows, dairy farmers, milk station, milk vehicle and enterprise business. Quality supervision of dairy products includes equipment, technology, materials, operations, warehouse management, involving raw milk inspection, production management, warehouse management, transportation management, dealer management and other services, illustrated in Figure 1. Combined with the specific business process, we design the dairy industry quality management information system platform of IOT, as illustrated in figure 2. The key points of Dairy industry quality management information system of raw milk quality supervision are quality and quantity. System should strictly control the balance between the two:

- (1) Quantity: Cows production > Milk station deliveries > Factory collection.
- (2) Quality: Cows produced = Milk station delivered = Factory collected.

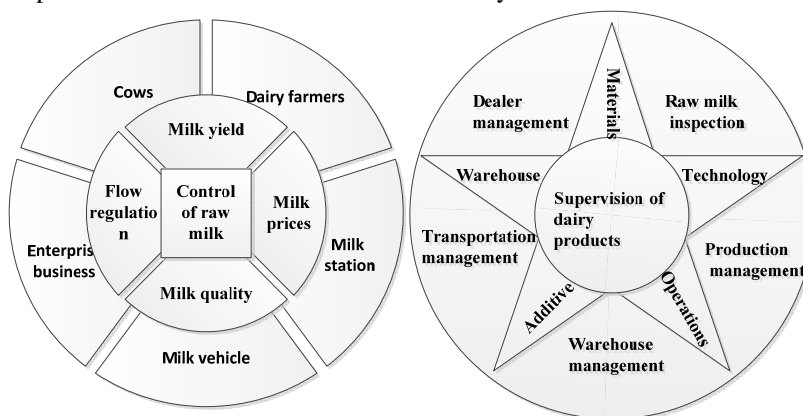


Figure 1. Quality management items of the dairy industry

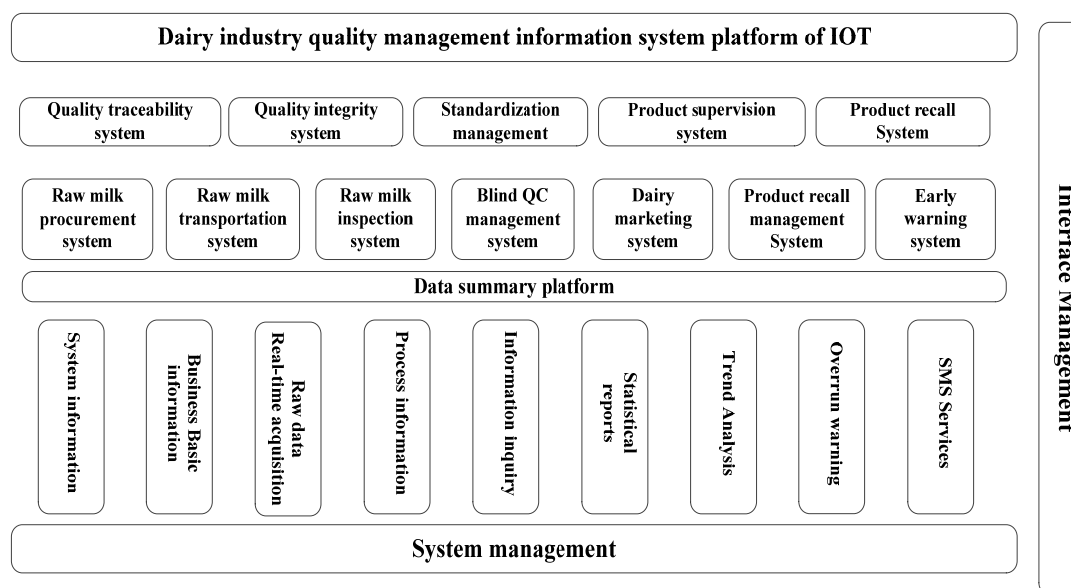
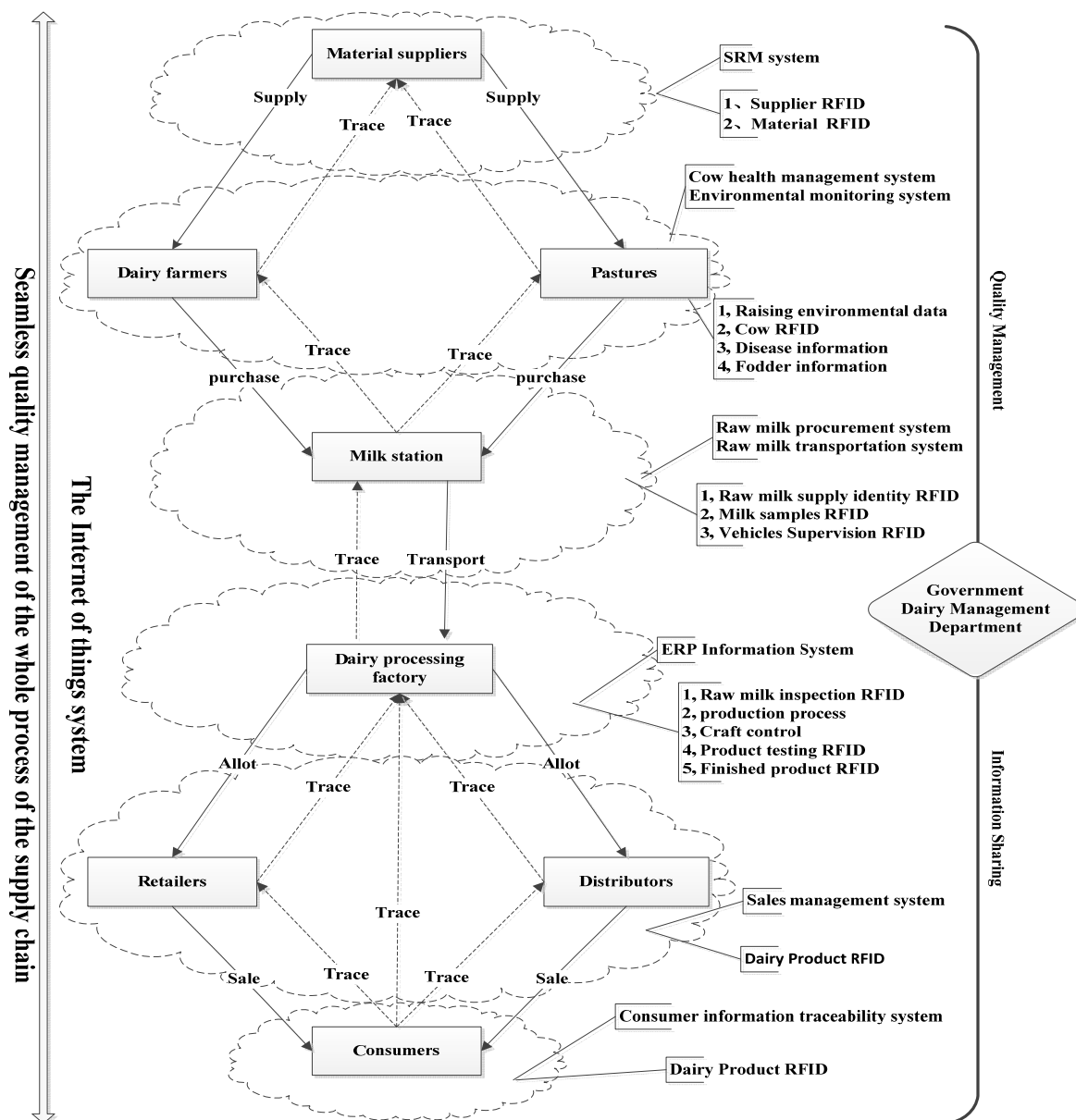


Figure 2. Dairy industry quality management information system platform of IOT



**Figure 4. Information mode of quality management of dairy industry based on IOT**

The application of IOT system, refine the dairy industry supply chain business process. The IOT-enabled quality management framework makes each process responsibility department, responsible person clearly. Any person from any process can be traced back to any business at any time for anything by the system data. The IOT system is conducive to the manager to carry out the work of quality management of dairy products<sup>[11]</sup>. Managers can simplify the supply chain processes with the frequency analysis of enterprise business and government supervision. The IOT-enabled quality management framework makes business management more clearly and effectively. Dairy industry apply the IOT system can achieve the seamless quality management of the whole process of the supply chain. The model is shown in Figure 4.

### 3. BUSINESS PROCESS MODELING OF IOT-ENABLED QUALITY MANAGEMENT BASED ON DATA FLOW PERSPECTIVE

Workflow refers to the flow of work in organizational circumstance, the study of workflow is a classic field<sup>[12]-[14]</sup>. As a diverse and rich technology, workflow management has been applied over an ever increasing number

of industries. There are four perspectives for workflow modeling approach: function, behavior, organization and data. Recently, scholars have made great effort in data flow view modeling approach<sup>[15]-[17]</sup>. This paper examines the information of dairy quality under the IOT-enabled quality management framework from the data flow perspective. Table 1 reports the Core elements of these focus business stages (AD): Related organizations (A), functional roles (R), production activities (T), and product quality (Q).

**Table 1. Core elements of focus business stages**

| Stage                       | A  | R   | T       | Q  |
|-----------------------------|--|---|---------|--|
| Raw milk<br>Purchase(AD1)   | Milk stations(A11)<br>Dairy farmers(A12)<br>Pasture(A13)                     | Station administrator (R11)<br>Milker (R12)<br>Raw milk acquisition subsystem(R13)  | T11-T19 | Cows (Q11)<br>Raw milk (Q12)               |
| Raw milk<br>Transport (AD2) | Milk stations(A21)<br>Transport Organization(A22)                            | Station administrator (R21)<br>Transportation staff (R22)<br>Raw milk transportation subsystem(R23)                           | T21-T27 | Raw milk (Q21)<br>Transport vehicles (Q22) |
| Dairy<br>Process(AD3)       | Processing factory(A31)<br>Transport Organization (A32)                      | Factory staff (R31)<br>Transportation staff (R32)<br>Raw milk acceptance subsystem(R33)                                       | T31-T38 | Raw milk (Q31)<br>Dairy products (Q32)     |
| Dairy<br>Sales(AD4)         | Processing factory(A41)<br>Logistics Organization (A42)<br>Distributors(A43) | Enterprise Administrators (R41)<br>Logistics staff (R42)<br>Distribution clerk (R43)<br>Dairy sales management subsystem(R44) | T41-T48 | Dairy products (Q41)                       |

Combined with the operation of China's dairy industry, we hackle the production activities (T) of these stages to sort out the information of quality control. Figure 5 shows the activities and the corresponding data of raw milk (AD1&AD2). Figure 6 provides the process data and activities of dairy processing and selling (AD3&AD4). Production activities are combed as follows:

|   |   |
|---|---|
| T11: Identity authentication  | T12: Cows information scanning                |
| T13: Sanitary treatment before milking  | T14: Mechanized milking                       |
| T15: QC of row milk sample  | T16: Milk metering                            |
| T17: Calculate the cost of acquisition  | T18: Raw milk storage                         |
| T19: Transaction data meta-analysis   |   |
| C1: Determine whether there are cows need to be milked                        |   |
| T21: Identity authentication  | T22: Milk vehicle cleaning                    |
| T23: Raw milk filling   | T24: Confirm the amount of milk delivered     |
| T25: QC of delivered milk sample  | T26: Transport raw milk to processing factory |
| T27: Generate reports of the transportation, upload and share the information |   |
| T31: Identity authentication  | T32: Raw milk reception                       |
| T33: Purification of raw milk   | T34: QC of received milk sample               |
| T35: Metering of received milk  | T36: Raw milk storage                         |
| T37: Generate reports of the inspection                                       | T38: Dairy processing                         |
| T41: Identity authentication  | T42: Dispatch the shipped vehicle             |
| T43: Dairy shipping.  | T44: Dairy transportation                     |
| T45: Unloading goods  | T46: Products stock                           |
| T47: Products sales   | T48: Dairy market analysis                    |

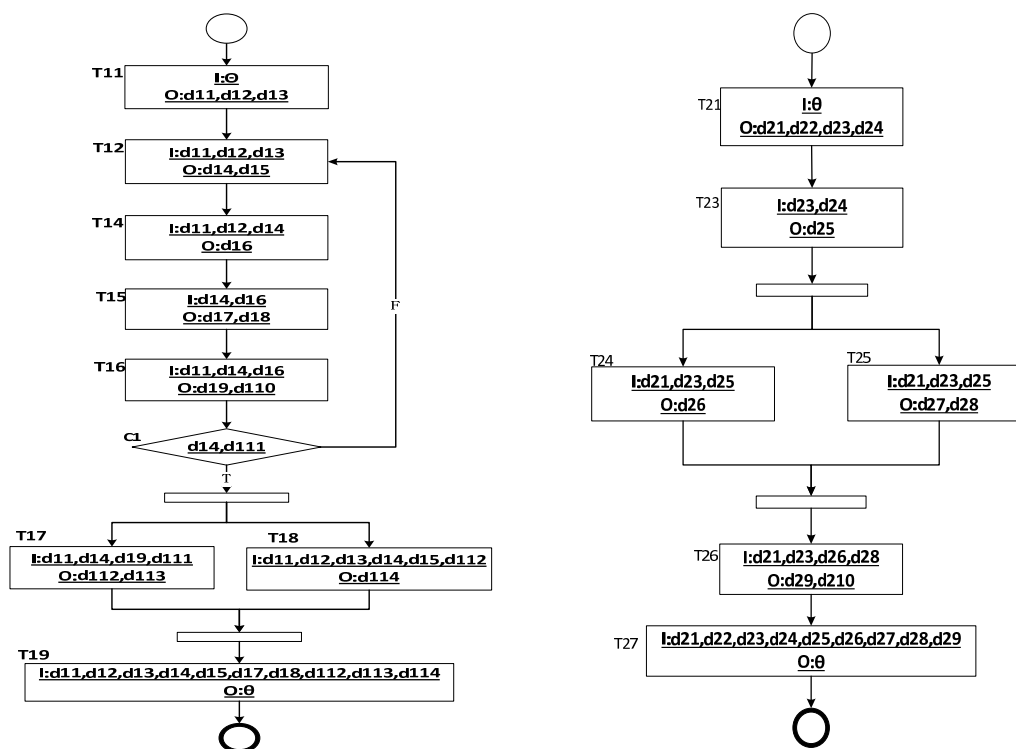


Figure 5. Raw milk procurement and transportation activities

The data items in these stages are shown as follows:

|       |  |       |   |
|-------|--|-------|---|
| d11:  | Milker RFID                            | d12:  | Acquisition operating time                    |
| d13:  | Dairy farmers RFID                     | d14:  | Cows RFID                                     |
| d15:  | Cows quality information Q11           | d16:  | Milking bucket RFID                           |
| d17:  | Sample milk RFID                       | d18:  | Quality information of milk sample Q12        |
| d19:  | Milk yield                             | d110: | Production time                               |
| d111: | Cows feeding information               | d112: | Total milk amount of the farmer               |
| d113: | Dairy transaction information          | d114: | Raw milk storage information                  |
| d21:  | Transportation driver RFID             | d22:  | Transportation time                           |
| d23:  | Transport vehicle RFID                 | d24:  | Vehicle quality information Q22               |
| d25:  | Transport milk tanked information      | d26:  | Total amount of transported raw milk          |
| d27:  | Milk sample vial RFID                  | d28:  | Milk sample quality information Q21           |
| d29:  | Milk vehicle environmental information | d210: | Quality information of milk being transported |
| d31:  | Transportation driver RFID             | d32:  | Transportation arrival time                   |
| d33:  | Transport vehicle RFID                 | d34:  | Quality information of milk transported Q21   |
| d35:  | Raw milk reception time                | d36:  | Raw milk reception amount                     |
| d37:  | Milk sample vial RFID                  | d38:  | Milk sample quality information Q31           |
| d39:  | Total amount of raw milk received      | d310: | Receiving staff RFID                          |
| d311: | Raw milk inventory information         | d312: | Dairy processing information                  |
| d313: | Dairy product quality information Qt   |       |   |
| d41:  | Distribution clerk RFID                | d42:  | Distributors business information             |
| d43:  | Dealer Application time                | d44:  | Demand for dairy species                      |
| d45:  | Number of dairy demand                 | d46:  | Dairy product Quality Information             |
| d47:  | Inventory information of factory       | d48:  | Delivery time of dairy products               |
| d49:  | Number of dairy products shipped       | d410: | Logistics vehicle RFID                        |
| d411: | Logistics staff RFID                   | d412: | Logistics Vehicle Information                 |
| d413: | Dairy actual shipping information      | d414: | Logistics information of dairy products       |
| d415: | Actual time of dairy arrival           | d417: | Actual quality information of dairy arrival   |
| d416: | Actual number of dairy arrival         | d418: | Distributors inventory information            |
| d419: | Dairy Sales Information                | d420: | Quality information of selling products       |

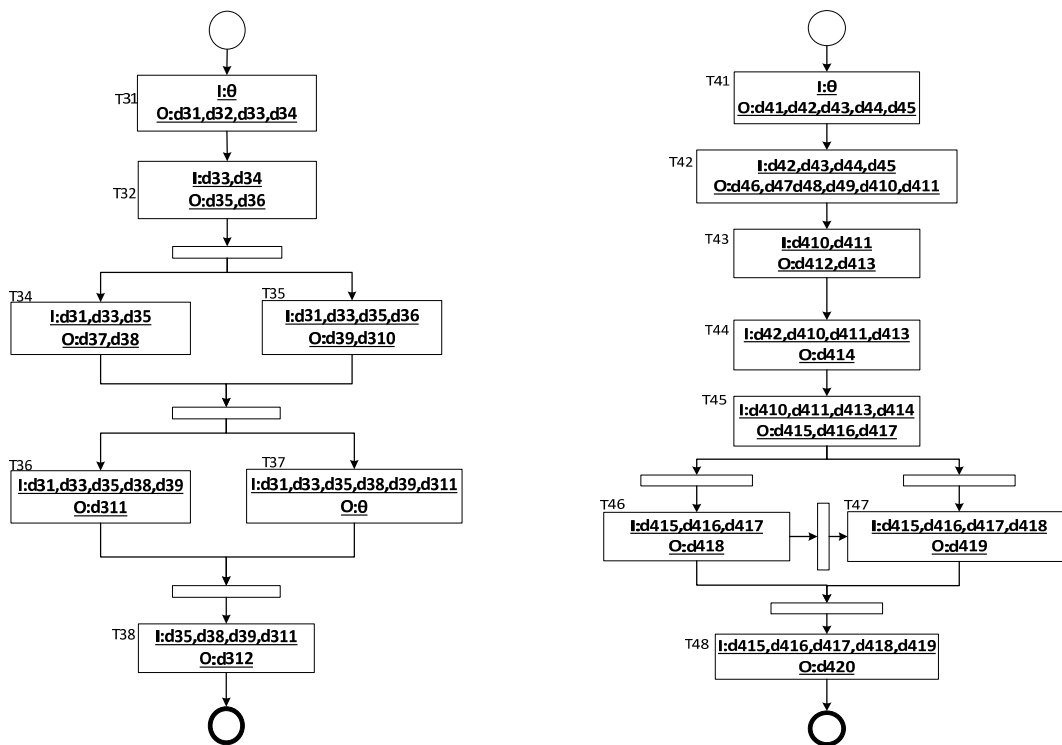


Figure 6. Dairy processing and selling activities

#### 4. INFORMATION TRACEABILITY UNDER IOT-ENABLED QUALITY MANAGEMENT FRAMEWORK

After business process modeling and data analysis of these stages, we conclude that the dairy products quality information can be tracked all over the supply chain under the IOT-enabled quality management framework. We have summarized the traceability information in each stage, as shown in Table 2.

Table 2. Products quality information in supply chain

| expressions              | Quality information of output product | = | Operation    | * | Quality information of input product  |
|--------------------------|---------------------------------------|---|--------------|---|---|
| Raw milk Purchase (AD1)  | $Q_{12}$                              | = | $0_s Q_{11}$ | = | $[T_{13} \ T_{14} \ T_{18}] \begin{bmatrix} M_{1j} \\ P_{2j} \\ E_{3j} \end{bmatrix}_{3 \times n} = [d_{18}]_{1 \times n}$  |
| Raw milk Transport (AD2) | $Q_{21}'$                             | = | $0_t Q_{21}$ | = | $[T_{22} \ T_{23} \ T_{26} \ 0 \ 0] \begin{bmatrix} Pr_{1j} \\ Ps_{2j} \\ Pc_{3j} \\ Pt_{4j} \\ Pv_{5j} \end{bmatrix}_{5 \times n} = [d_{210}]_{1 \times n}$      |
| Dairy Process (AD3)      | $Q_t$                                 | = | $0_p Q_{31}$ | = | $[T_{Q1} \ T_{Q2} \ T_{Q3} \ 0 \ 0] \begin{bmatrix} Pr_{t1j} \\ Pst_{2j} \\ Pct_{3j} \\ Ptt_{4j} \\ Pvt_{5j} \end{bmatrix}_{5 \times n} = [d_{313}]_{1 \times n}$ |

$$\begin{array}{l} \text{Dairy} \\ \text{Sales} \\ \text{(AD4)} \end{array} \quad Qc = OvQt = [T44 \quad T46 \quad T47 \quad PN \quad 0] \begin{array}{l} Pr \quad c_{1,j} \\ Psc \quad 2,j \\ Pcc \quad 3,j \\ Ptc \quad 4,j \\ Pvc \quad 5,j \end{array} \Bigg]_{5 \times n} = [d420]_{1 \times n}$$

In the phase of raw milk purchase, factors that affect the quality of cows include: the feed cow breeding, like feed, drug additives, metallic elements and other additional information (including information of dairy farmers, feed sources, etc.), represented by  $M_{ij}$ ; Breeding process includes cows grow time, disinfection of farms, manure disposal, milking cycle, represented by  $P_{ij}$ ; Breeding environment, including the distribution of farming land, population distribution, environmental pollution, etc. denoted by  $E_{ij}$ . Cows quality information matrix denoted by Q11. In the procurement process, operation matrix expressed as  $Os$ . Raw milk the milk stations acquired expressed as Q12.

In the other phases, the product is the milk. The evaluation index of milk quality include: sensory indicators, physical and chemical indicators, microbial indicators, pollutant index, and microbial indicators<sup>1</sup>. Sensory indicators include color and odor, etc., denoted by  $Pr_{ij}$ ; Physical and chemical indicators include fat content, protein content, and other non-fat milk solids content, expressed by  $Ps_{ij}$ ; Microbial indicators include total bacterial count, coliform, etc., with  $Pc_{ij}$  represents; Pollutant indicators include total mercury, inorganic arsenic, etc., with  $Pt_{ij}$  representation; Microbial indicators include aflatoxin, etc., with  $Pv_{ij}$  expressed. The quality information of raw milk the milk station stored expressed by Q21. Transport operations information can be represented as  $Ot$ . The quality information of raw milk during the transportation denoted by Q21'. After the acceptance of milk processing factory, raw milk quality information recorded as Q31. Then, the operation matrix denoted by  $Op$  at production process, divided into three main areas: Processing additives (TQ1); Production recipes (TQ2); Equipment and environment (TQ3). The mass storage matrix  $Qt$  express processed dairy products' information at the stage of dairy sales. The operation matrix denoted by  $Ov$ . The quality information of dairy products eventually reached the hands of consumers denoted by Qc.

Table 2 provides all information of the supply chain which has been recorded. All data can be tracked under the IOT-enabled quality management framework. All information can be queried timely with the information traceability. The business data is consistency, accuracy and timeliness. The dairy quality information flow in dairy industry is complete and coherent. The IOT-enabled quality management framework will guarantee the quality dairy products efficiently.

## 5. CONCLUSIONS

In this paper, we analysis the quality management issues of China's dairy industry: business data error-prone, information transmission course. after detailed analysis of these quality management issues, we propose an IOT-enabled quality management framework which is an innovation mode of quality management in China's dairy industry supply chain. We then employ a business process modeling approach based on data flow perspective to describe this innovation management mode. The research analyses the main stages of the dairy industry quality supervision, including the raw milk purchase stages, raw milk transport stage, dairy processing stages, dairy sales stage in detail. Finally, we summarize the information traceability under the IOT-enabled quality management framework.

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