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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 [1], [2]. 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 [3]. 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 [4]-[6]. 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 [7].

The key quality management problems in dairy industry are unscientific supervision, incontrollable data, and confused business process [8]. 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 [9]. We employ a business process modeling approach based on data flow view to describe the innovation management mode. [10].

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.

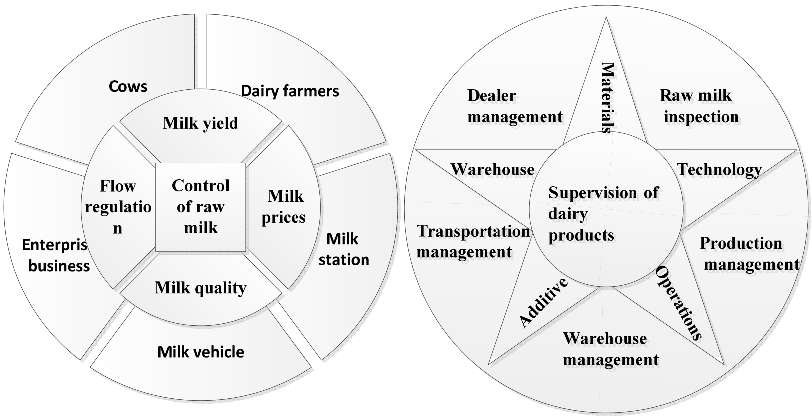

Figure 1. Quality management items of the dairy industry

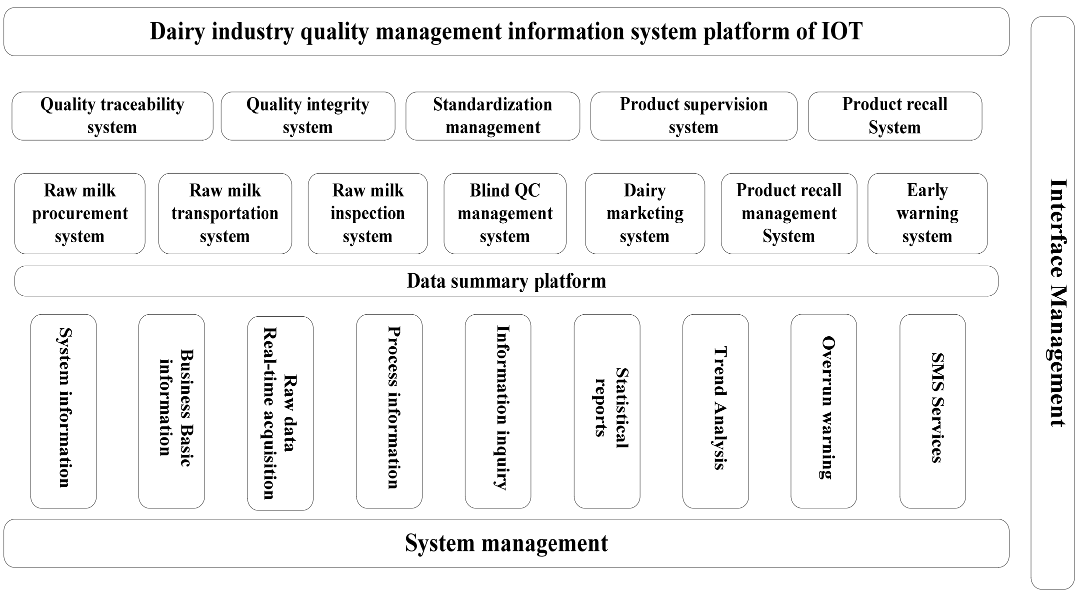

Figure 2. Dairy industry quality management information system platform of IOT

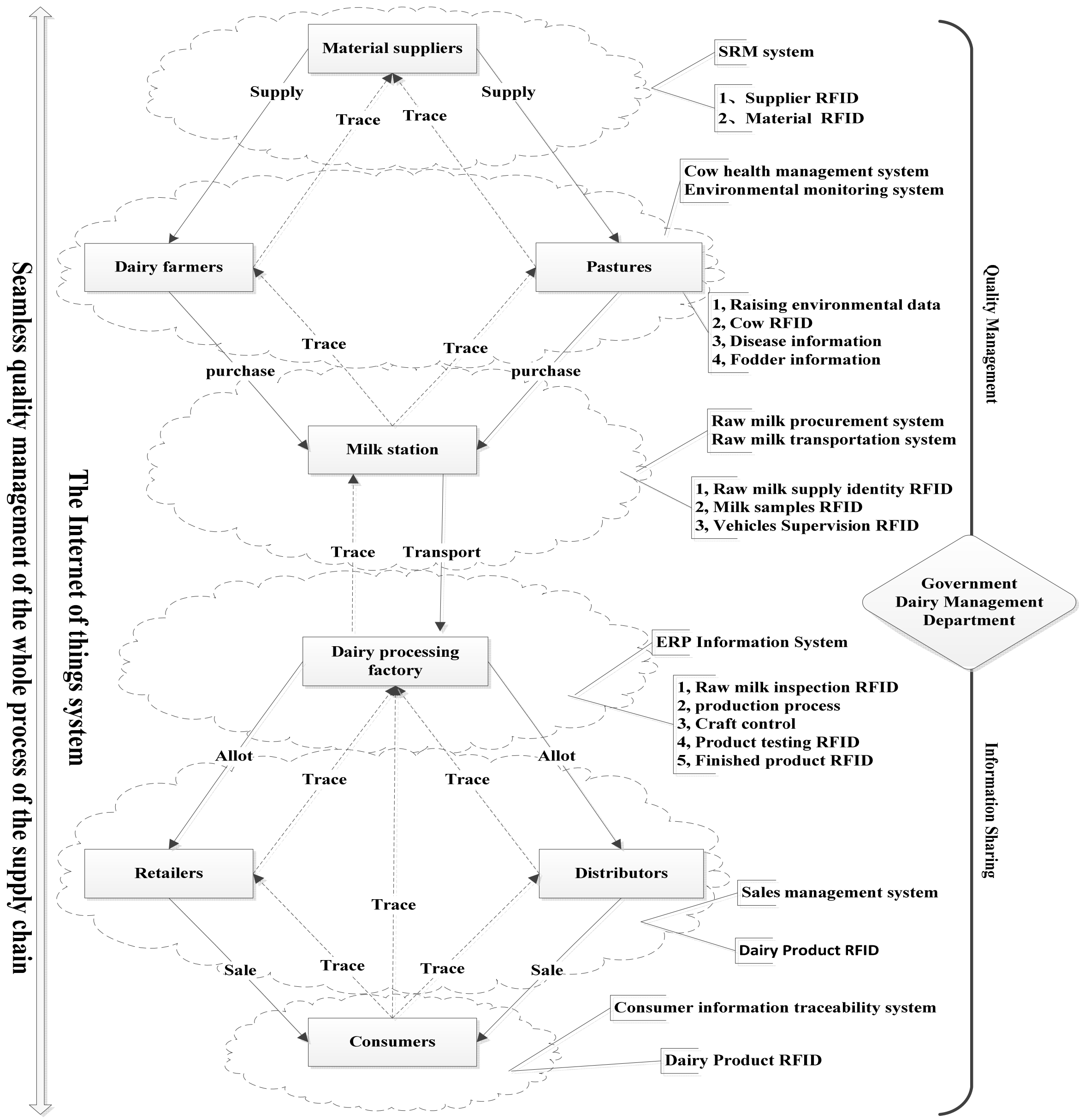

Figure 4. Information mode of quality management of dairy industry based on IOT

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 [11]. 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 [12]–[14]. 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 [15]–[17]. 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 Purchase(AD1)	Milk stations(A11) Dairy farmers(A12) Pasture(A13)	Station administrator (R11) Milker (R12) Raw milk acquisition subsystem(R13)	T11-T19	Cows (Q11) Raw milk (Q12)
Raw milk Transport (AD2)	Milk stations(A21) Transport Organization(A22)	Station administrator (R21) Transportation staff (R22) Raw milk transportation subsystem(R23)	T21-T27	Raw milk (Q21) Transport vehicles (Q22)
Dairy Process(AD3)	Processing factory(A31) Transport Organization (A32)	Factory staff (R31) Transportation staff (R32) Raw milk acceptance subsystem(R33)	T31-T38	Raw milk (Q31) Dairy products (Q32)
Dairy Sales(AD4)	Processing factory(A41) Logistics Organization (A42) Distributors(A43)	Enterprise Administrators (R41) Logistics staff (R42) Distribution clerk (R43) 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

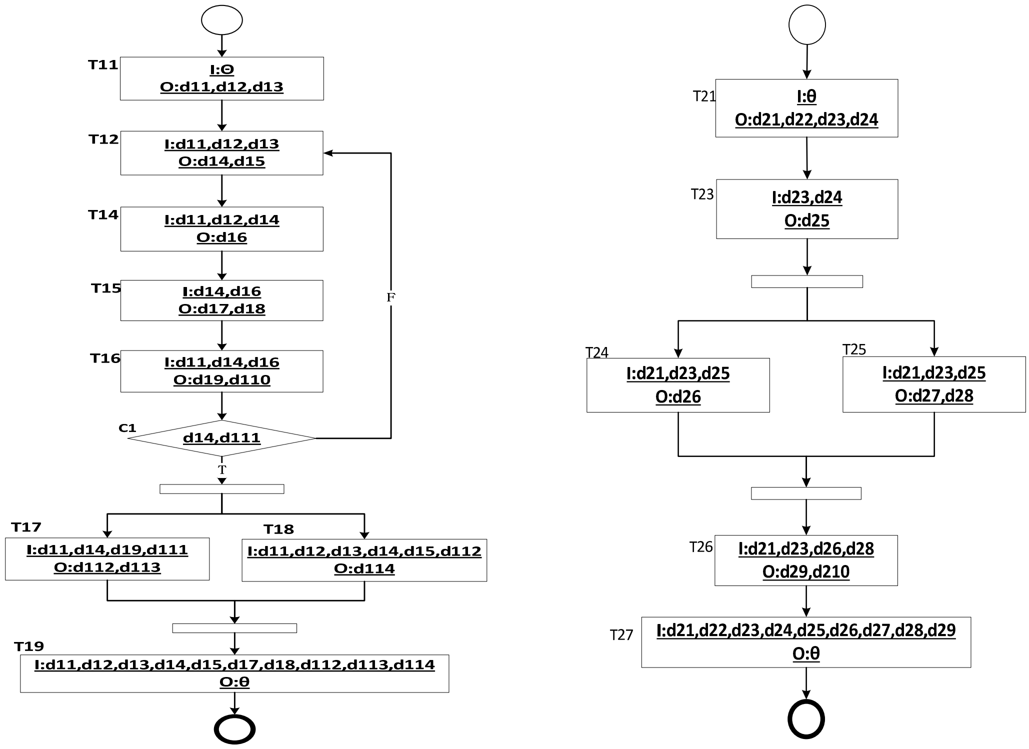

Figure 5. Raw milk procurement and transportation activities

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

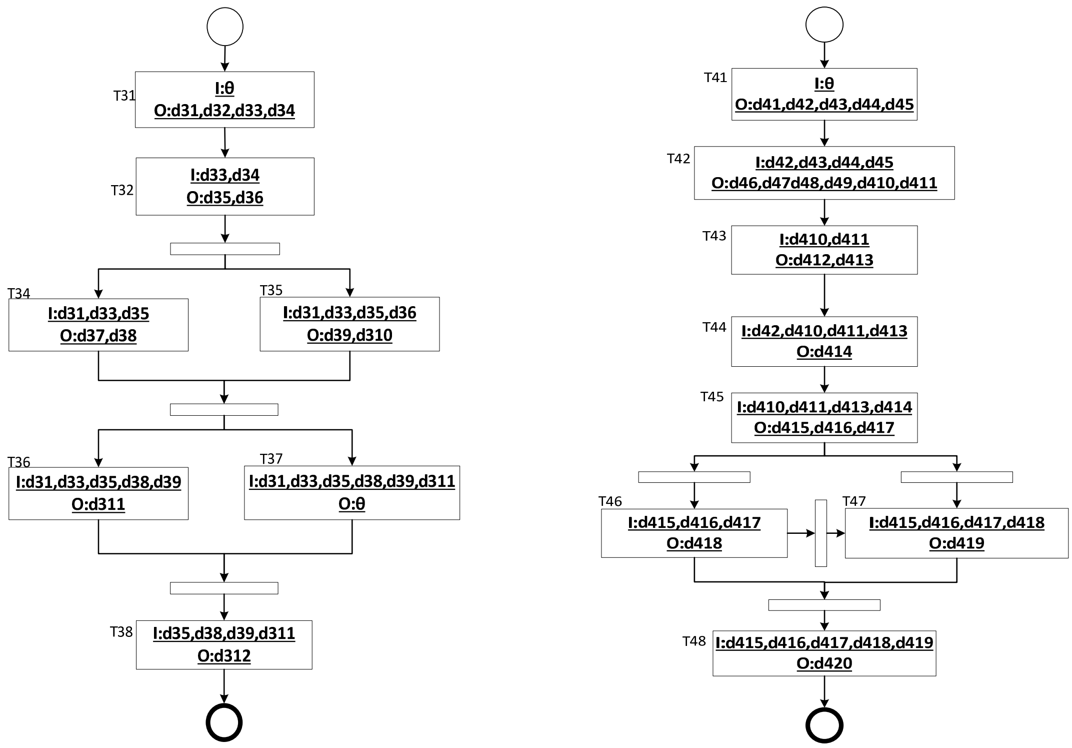

Figure 6. Dairy processing and selling activities

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)	$Q12 = OsQ11 = [T13\ \ T14\ \ T18]\begin{bmatrix} M_{1j} \\ P_{2j} \\ E_{3j} \end{bmatrix}_{3\times n} = [d18]_{1\times n}$
Raw milk Transport (AD2)	$Q21' = OtQ21 = [T22\ \ T23\ \ T26\ \ 0\ \ 0]\begin{bmatrix} Pr_{1j} \\ Ps_{2j} \\ Pc_{3j} \\ Pt_{4j} \\ Pv_{5j} \end{bmatrix}_{5\times n} = [d210]_{1\times n}$
Dairy Process (AD3)	$Qt = OpQ31 = [TQ1\ \ TQ2\ \ TQ3\ \ 0\ \ 0]\begin{bmatrix} Prt_{1j} \\ Pst_{2j} \\ Pct_{3j} \\ Ptt_{4j} \\ Pvt_{5j} \end{bmatrix}_{5\times n} = [d313]_{1\times n}$

Dairy Sales (AD4)	$Qc = OvQt = [T44 \;\; T46 \;\; T47 \;\; PN \;\; 0] \begin{bmatrix} Prc_{1j} \\ Psc_{2j} \\ Pcc_{3j} \\ Ptc_{4j} \\ Pvc_{5j} \end{bmatrix}_{5\times n} = [d420]_{1\times n}$

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. Row 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]. 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 flew 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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