Information Flow Management of Vendor-Managed Inventory System in Automobile Parts Inbound Logistics Based on Internet of Things

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Abstract—**Reducing inventory levels is a major supply chain management challenge in automobile industries. With the development of information technology new cooperative supply chain contracts emerge such as Vendor-Managed Inventory (VMI). This research aims to look at the literature of information management of VMI and the Internet of Things, then analyzes information flow model of VMI system. The paper analyzes information flow management of VMI system in automobile parts inbound logistics based on the environment of Internet of Things.**

Index Terms—**Automobile Parts Inbound Logistics, Vendor-Managed Inventory(VMI), Information Flow Management, Supply Chain Management, Internet of Things**

I. Introduction

The competition in supply chain management among vehicle manufacturers such as General Motors, Ford, Toyota and Volkswagen is as intense as that at race tracks or automobile shows. To sharpen their competitive advantage, vehicle manufacturers choose third-party logistics (3PL) specialists to reduce logistics costs and improve the satisfaction of their customers. The average new vehicle is assembled from more than 2,500 parts. In this sense, automobile parts inbound logistics is very important to automobile supply chain management.

The concept of VMI has received much research attention and evidence has shown that VMI can improve supply chain performance by decreasing inventory costs for the supplier and buyer and improving customer service levels, such as reduced order cycle times and higher fill rates. [1] VMI is a collaborative commerce initiative where suppliers are authorized to manage the buyer's inventory of stock-keeping units. It integrates operations between suppliers and buyers through information sharing and business process reengineering. [2] A number of research papers have studied information flow management through VMI or similar programs.

Automation of information services could make members of the supply chain perceive, predict and respond timely to changing market conditions and accelerate the transfer of critical information among its members, which is necessary to improve the controllability, flexibility, performance and capabilities of abnormal events of supply chain. It is critical to control information flow in VMI supply chain. In addition to information sharing structure and information flow management, it is equally important to define information flow in supply chain (parameters design). Description of the information flow process by information parameters and optimization of the process can help us identify and reduce information distortion and information transmission delay because of the unreasonable process of supply chain business. This paper will use United Modeling Language (UML) to model information flow of VMI system in automobile parts inbound logistics.

The Internet of Things (IoT) is an emerging global Internet-based information architecture facilitating the exchange of goods and services in global supply chain networks. From a technical point of view, the architecture is based on data communication tools, primarily RFID-tagged items (Radio-Frequency Identification). The IoT has the purpose of providing an IT-infrastructure facilitating the exchange of "things" in a secure and reliable manner. [3] This paper aims to study information flow management of VMI supply chain based on Internet of Things.

II. Literature Review

In this section, we review the literature on VMI System in Automobile Parts Inbound Logistics, information management of VMI and the Internet of Things. The literature review provides the theoretical foundation for this research.

In automobile supply chain management, inbound logistics is considered to be the most complicated and technical operation because of the huge number of variety automobile parts. Inbound logistics management can help achieve the important objective in automobile industry to assure the building of cars with low lead and supply times, low stock and high flexibility. Figure 1 shows the process of Automobile Parts Inbound Logistics. The primary objectives of inbound logistics are to guarantee low supply times or low waiting times in the dispatch area, in order to minimize costs. [4] Different automobile parts need different replenishment methods, as shown in Figure 2.

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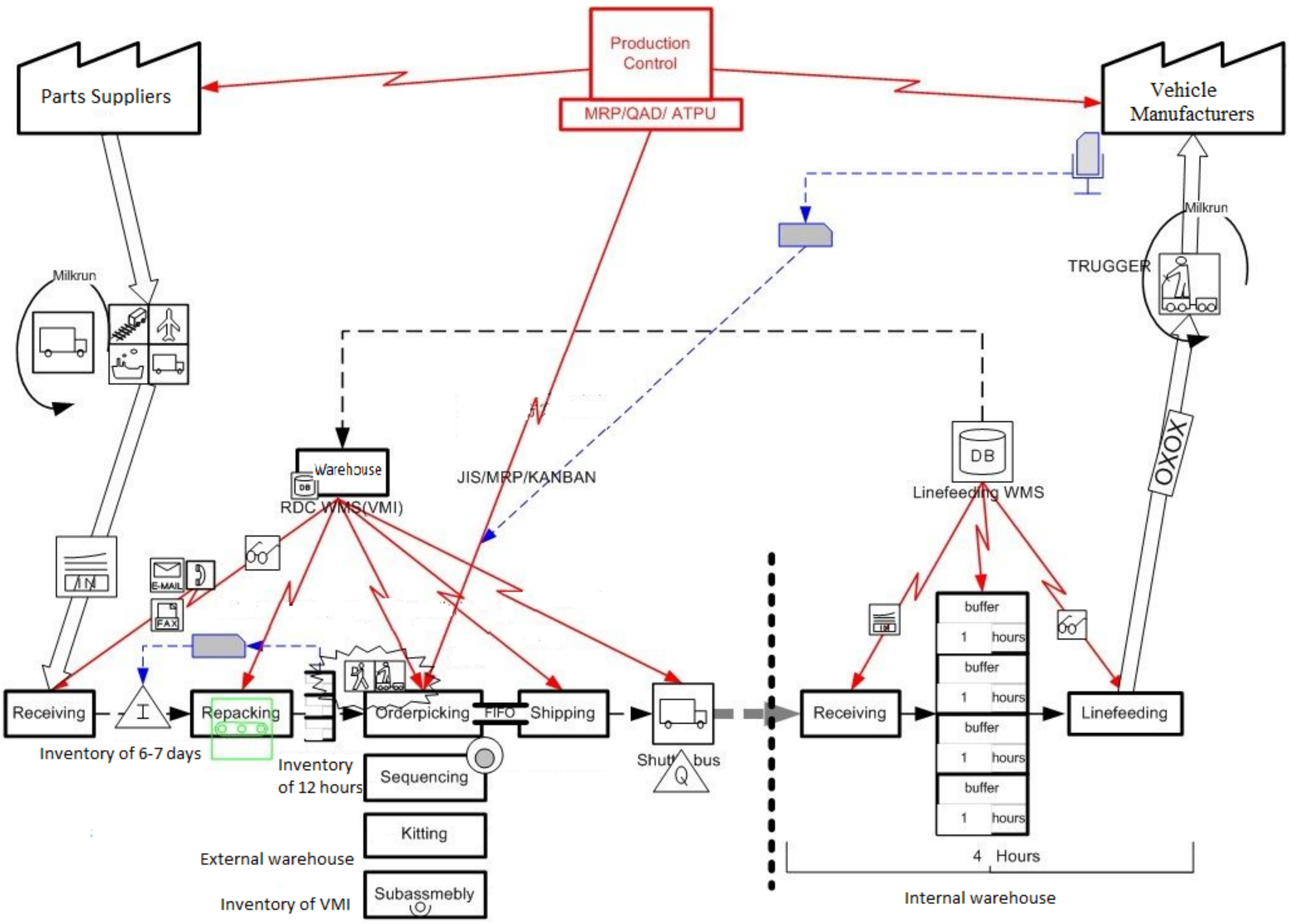

Figure 1. Overview of Automobile Parts Inbound Logistics.

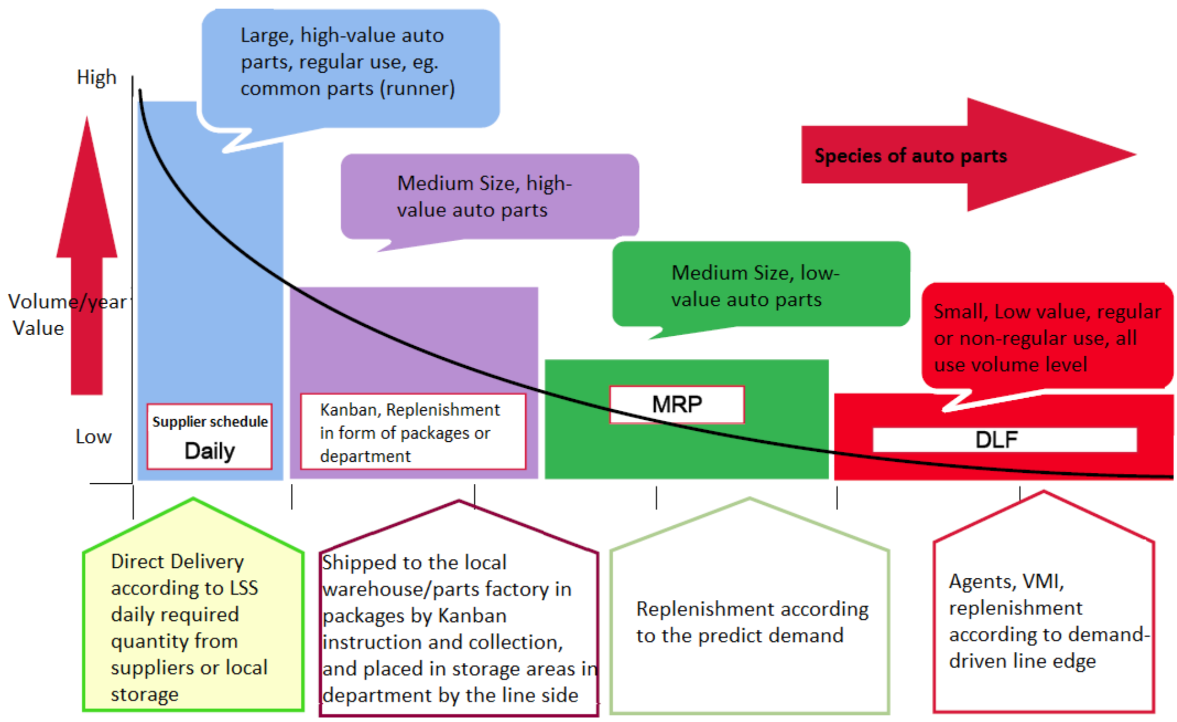

Figure 2. Different replenishment methods in automobile parts inbound logistics

There is a rich body of literature on the value of information sharing in supply chains, for example, Cachon and Fisher (2000) [5], Chen et al. (2000) [6], Gavirneni and Kapuscrinski (1999) [7] and Lee et al. (1997) [8] concluded that the bullwhip effect could be minimized through information sharing. And Cachon and

Zipkin (1999) et al found that policies such as VMI can decrease the bullwhip effect, thereby improving supply chain efficiency, such as by lowering inventory levels and reducing cycle time. [9] Yuliang and Dresner (2008) analyze the benefits realized for manufacturers and retailers under information sharing, continuous replenishment programs (CRP) or vendor managed inventory (VMI) and compare the distribution of benefits between manufacturers and retailers. Their analysis shows that IS, CRP, and VMI bring varying benefits in terms of inventory cost savings to firms, and that the benefits are not consistently distributed between retailers and manufacturers. And their findings also point out the managerial implications on how managers decide the product sets and replenishment frequency for improved benefit realization under CRP and VMI. [10]

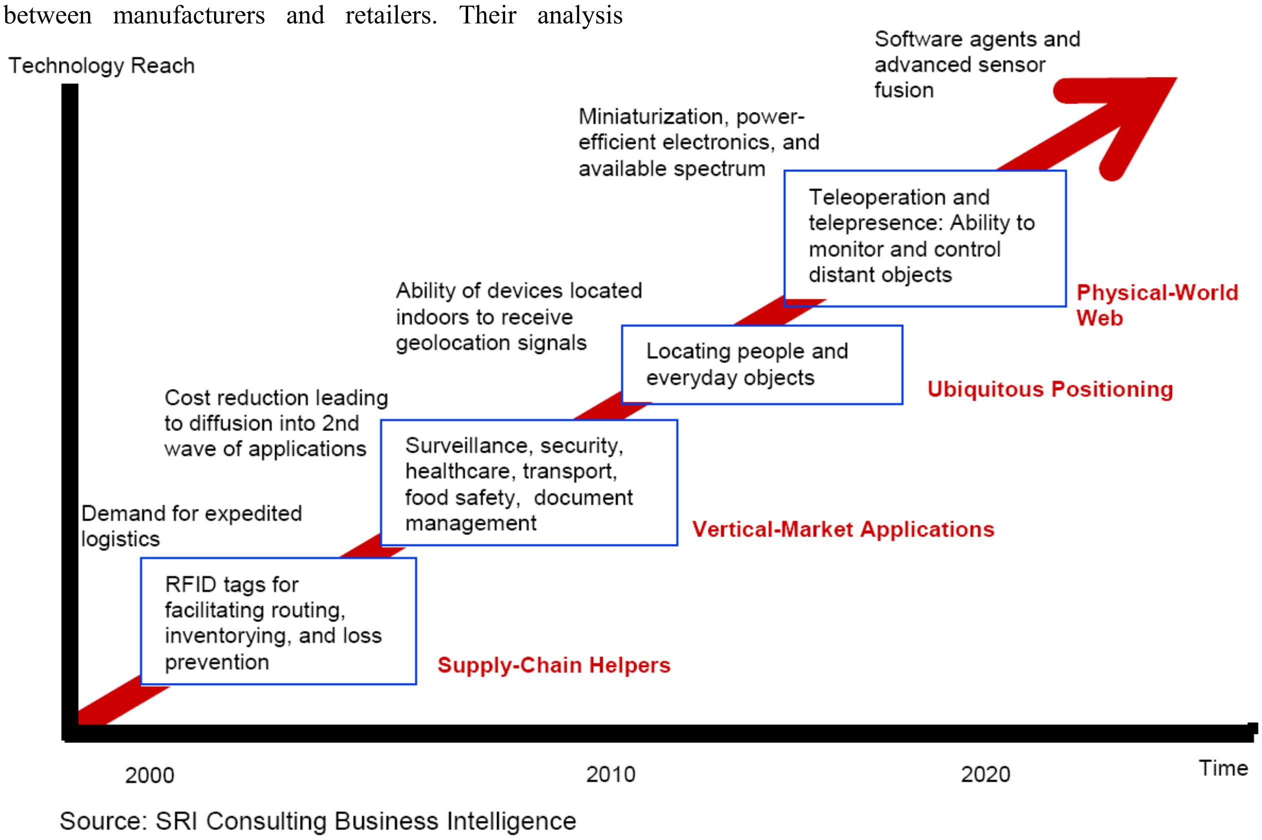

Figure 3. The technology roadmap of Internet of Things [12]

The IoT-idea is not new[1]. The term of IoT was firstly used by Kevin Ashton in a presentation in 1998. [11] It only recently becomes relevant to the practical world, mainly because of the progress made in hardware development in the last decade. Figure 3 shows the technology roadmap of the IoT. [12] The IoT is an emerging global Internet-based information architecture facilitating the exchange of goods and services in global supply chain networks. The IoT could provide an IT-infrastructure facilitating the exchanges of “things” based on an Electronic Product Code (EPC). The information of “things” could be available through linking and cross-linking with the help of an Object Naming Service (ONS). Based on Domain Name System (DNS), the ONS can be considered as subset of the DNS and will also inherit all of the well-documented DNS weaknesses [13].

III. Information Flow Model of Vendor-Managed Inventory in Automobile Parts Inbound Logistics

A. Information Flow of VMI in Automobile Parts Inbound Logistics

A great deal of evidence has shown that VMI approach can improve supply chain performance by decreasing inventory-related costs and increasing customer service. In VMI supply chain, the supplier (vendor) is responsible for the replenishment of its partners, as summarized conceptually in Figure 4[14]. The information shared by members of the supply chain includes sales data and forecasts, order status, production and distribution arrangements and capacity, performance indicators, etc.

[1]Early mentors of the IoT and similar concepts include Gershenfeld (1999), Ferguson (2000), Kindberg at al. (2002), Schoenberger et al. (2002) and Wright et al. (2004).

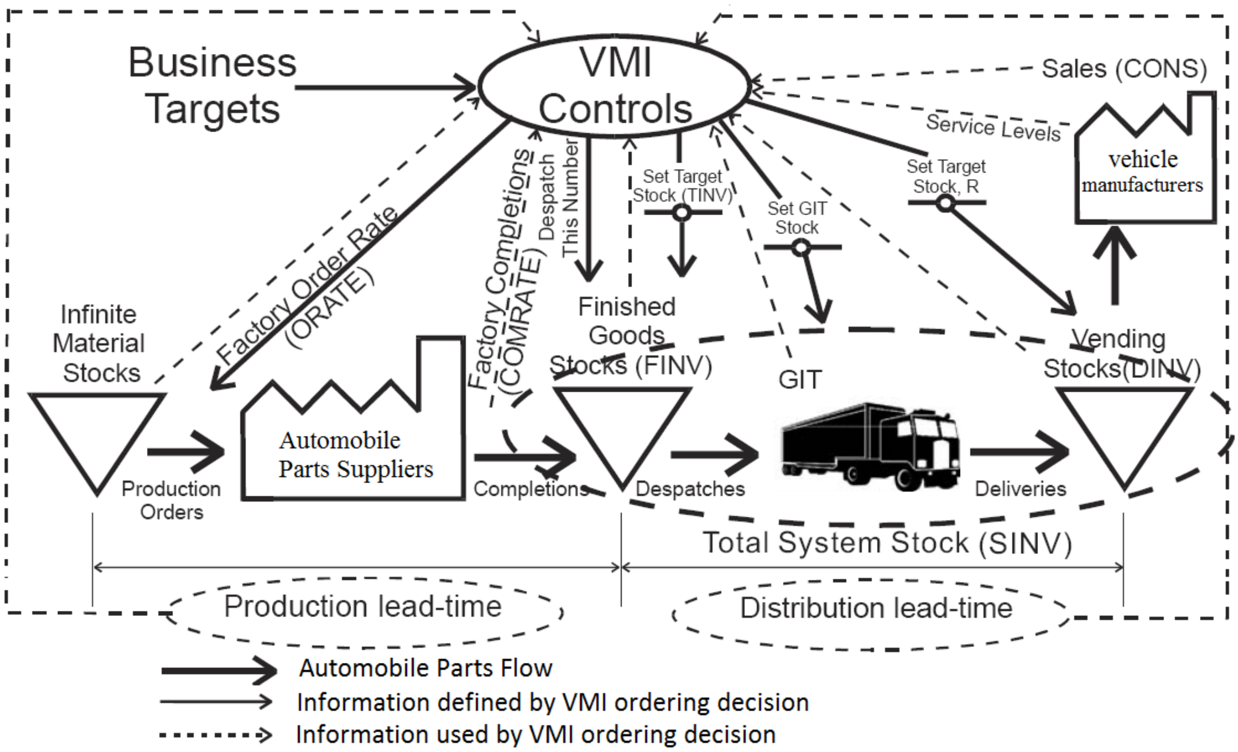

Figure 4. Overview of the VMI in Automobile Parts Inbound Logistics Scenario [14]

B. Information Flow Model of VMI in Automobile Parts Inbound Logistics

UML is a model standard describing process and it can be used to: ① easily describe information sharing structures of specific supply chain environment; ② build the reference way of model easily to share with other members by direct reference or converted into XML (eXtensible Markup Language). According to the semantics of activity-object flow graph of UML, the information to send is described as Action, the information flow as Object flow. As analyzed in Figure 5, there exists two-way information flow between automobile parts suppliers and vehicle manufacturers in VMI supply chains and needs extensive collaboration. So information sharing can not apply the simple linear structure (sequential structure). For example, if the state in Figure 5 is more than one replenishment order, it is suitable to adopt the whole channel structure (reciprocal structure) for the replenishment orders; and for the order sending, information sharing is still a linear structure. Identified on Figure 5 in the 1, 2, 3 to describe the information flow are as follows:

1. SendUsage

Event: Predetermined time events, such as 24:00 on Friday

Sender: Manufacturers

Receiver: Supplier

Data_ object: the Amount of week (or month, quarter, etc.)

Data_template: EDI # format numbe

Req_action: Proposed (suggested) Order

Mode: Batch

2. ProposeOrder

Event: the Amount received

Condition: Inventory levels < Reorder point (ROP)

Sender: Supplier (vendor)

Receiver: Manufacturer

Data_ object: the Proposed Replenishment Orders

Data_template: EDI # format number

Req_action: Order confirmation (Y or N)

Mode: Batch

3. RejectOrder

Event: Recommended Order received

Condition: Order Fulfillment Rate < 95%

Sender: Manufacturer

Receiver: Supplier (vendor)

Data_ object: the Modified Replenishment Orders

Data_template: EDI # format number

Req_action: Generating Shipping Notice

Mode: Batch or Real-time[15]

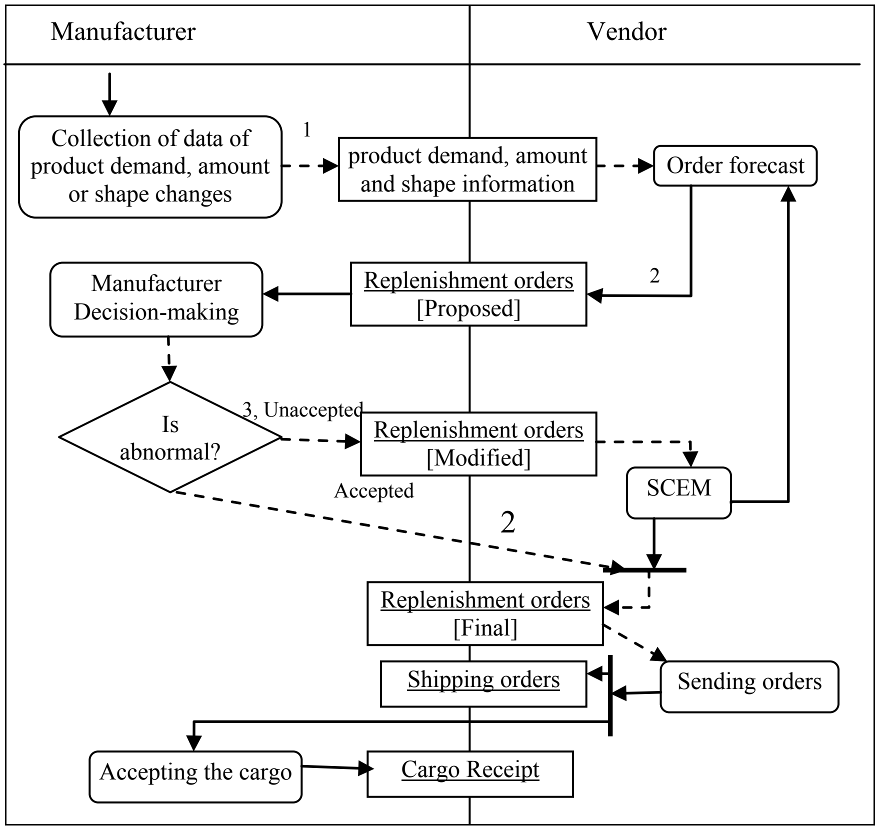

Figure 5. Modeling VMI with UML Activity Diagram[15]

IV. Information Flow Management of VMI in Automobile Parts Inbound Logistics Based on Internet of Things

A. Information Transparency in VMI Supply Chain

From the above information flow management mode and Figure 5, the traditional VMI still has a lot to improve. First, the batch mode may result in the delay of the shared information and cause that fluctuation in demand could not be promptly reflected in forecast prediction, which results in wrong or abnormal forecast. So the anomaly caused by inaccurate information flows should be reduced and real-time information is necessary. At this point, EDI appears to lack flexibility because of its batch processing and data exchange turns to the data template based on XML format. Second, the information shared in VMI supply chain is asymmetric. Most of the information flow is from the manufacturer to the supplier while the supplier's information flow is opaque. Suppliers should provide some scene analysis, such as displaying the effect of modified information flow, analog forecasting and replenishment strategies etc. in order to increase transparency of information.

From the above discussion, in most cases information is exchanged in batch mode in VMI supply chain because the need of information has a well defined structure. Therefore a linear sharing structure is mainly adopted rather than Hub (center) sharing structure.

B. Information Flow Management of VMI Based on Internet of Things

The IoT is an emerging Internet-based information architecture facilitating the exchange of goods and services in global supply chain networks. The basic idea of the IoT is that virtually very physical thing in this world can also become a computer that is connected to the Internet.

In VMI supply chain network, information flow is large and complex, usually in state of a high degree of uncertainty and multi-directional links between members. In this case, real-time information sharing is required so as to monitor the status of supply chain and exceptions in the supply chain broadcast. In order to increase transparency, visibility, availability and improving level of coordination of the supply chain, hub (center) type of information-sharing structure should be used. Integrating promising information technologies such as RFID can help improve the effectiveness and convenience of information flow in VMI supply chain. The Internet of Things based on RFID provides an information sharing platform among all participants of the construction chain using web technology and RFID-enabled PDA[16].

The use of IoT is still in its early stage. Information flow management of VMI based on Internet of Things includes two ways. First, label the parts itself, known as hard links. Atypical example is the RFID tire tracking and management. According to Figure 2, the most appropriate is those medium-sized, high-value auto parts. Such parts are generally high value, safety requirements and characteristics of components and RFID can be used to effectively identify and track parts. This kind of auto parts affixed with RFID tags will be better monitored when shipped to the local warehouse or parts factory in packages by Kanban instruction and collection and placed in storage areas in department by the line side. Second, the label affixed to the packaging or shipping rack parts can reduce the cost of RFID use. But the need for RFID in the container and the container has been posted in parts of the link between the database, which is known as soft links or soft tracking. IBM shows that Global Automobile Industry has focused on RFID application for container management.

On this basis, the architecture of information flow management of VMI based on Internet of Things is shown on Figure 6.

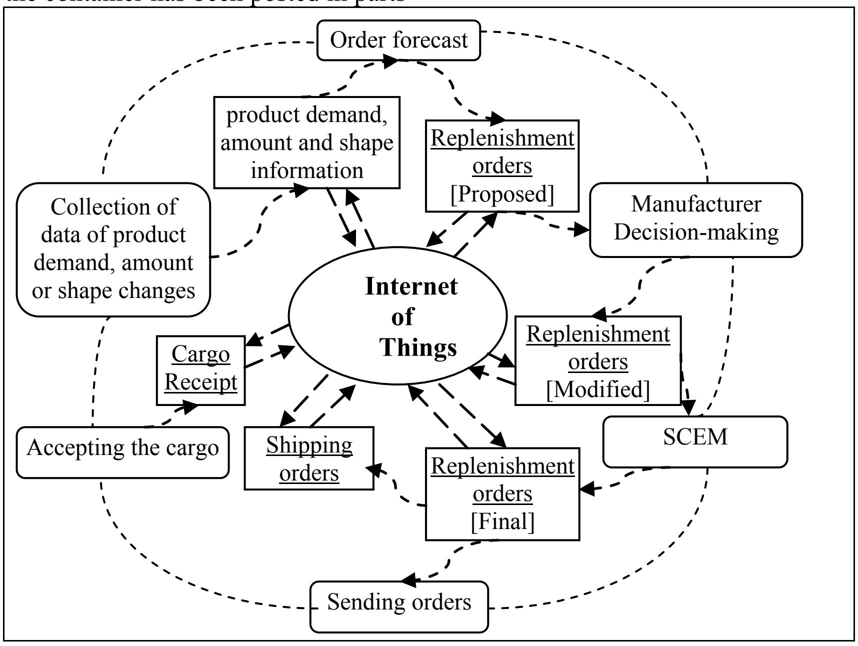

Figure 6. Information Flow Management of VMI in Automobile Parts Inbound Logistics Based on Internet of Things

V. CONCLUSION

Both information flow management in VMI supply chain and the Internet of Things are focus on research in present-day society. Actually, Honda UK has used passive RFID technology for management containers in the whole supply chain areas, and they are studying to expand the application to container-level part management in the next step. Volkswagon is still in active RFID pilot phase for inter-company stamping part containers management. Benz is in passive RFID pilot phase for DC empty container management, and they will expand RFID application for the whole supply chain in the next step. This paper is carried out to make analysis of information flow management of VMI in Automobile Parts Inbound Logistics based on the environment of Internet of Things. This analysis aims to provide a new vision to research logistics and supply chain management.

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