

# Designing a Flexible Production Flow Using IDEF1x --- an IC Packaging WIP System

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## **Abstract**

*The IC packaging industry relies heavily on shop floor information, necessitating the development of a data model to flexibly define shop floor information in the production flow. For this purpose, this work designs a novel data model by using IDEF1x. The proposed data model consists of four modules: operation template setup, general process setup, enhanced bill of manufacture (EBOM<sub>fr</sub>) setup, and work-order process setup. In addition to allowing the user to flexibly define the required shop floor information and decision rules, the data model provides the flexibility to allow one to adopt changes. Since the data model is static, to handle manufacturing data timely this work also suggests a WIP (work-in-process) execution module to monitor and control production flow. Finally, an illustrative example, the MIRL WIP System*

*integrated the data model with a WIP execution module (developed by Mechanical Industrial Research Laboratories of Industrial Technology Research Institute), demonstrates the effectiveness of the proposed data model.*

*Keywords ---* Bill of manufacture, IDEF1x, Manufacturing execution system, Shop floor information system, WIP system

## **Introduction**

Integrated circuit (IC) manufacturing can generally be divided into five major parts: design, fabrication, chip probe testing, packaging and final testing. IC packaging transforms wafers into chips. Since the product cycle time is short and the arrival of the product can not be planned, IC packaging

industry managers heavily rely on shop floor information to timely handle dynamic shop floor environments and respond to customer requests. Therefore, improving the competitiveness of a company mostly depends on flexibly incorporating shop floor information into the production flow and handling manufacturing data quickly according to the production flow.

A standard IC packaging production flow consists of the following operations: wafer grinding, wafer sawing, die bonding, epoxy cure, wire bonding, post-bonding inspection (PBI), molding, marking, dejunking/trimming, solder plating, forming/singulation, open/short testing, lead scan, final inspection, packaging, outgoing QC *et al.*. Typically recorded on a run card, the manufacturing information of the production flow for each lot is manually noted by floor personnel, and later summarized by an assigned department. This card is filled out as the production batch arrives on the floor, recorded by the floor people based on the production facts at every operation, and finished when the production batch reaches completion.

Although easy to process, the run card creates several problems: (1) The exceptions on the floor cannot be effectively handled since such information is difficult to obtain timely; (2) The best resolution time is missed due to the slow rate of accumulating time critical information; and (3) The data is invalid due to human error.

To overcome the above problems and ensure good customer service, an IC packaging WIP system is required. The WIP system should allow the user to perform the following tasks: (1) Flexibly define shop floor information in the production flow before production; (2) Timely handle the lot activities of customer orders according to predefined production flow during

production; and (3) Easily modify production flow information to allow fulfilling of changing product requirements and floor situations.

Generally, a WIP system is the core of the shop floor information system. Meanwhile, the shop floor information system bridges the planning and control levels. This system takes orders from the planning level, then coordinates, controls, monitors equipment in the control level. Melnyk (Melnyk, 1985, 1987) defined a shop floor information system narrowly as including the following five functions: order review and release, detailed assignment, data collection and monitoring, feedback and corrective action, and order disposition. Besides these functions, Vollman, Berry & Whybark (Vollman, 1992), and Sartori (Sartori, 1988) also cited scheduling, dispatching, and monitoring. The system can also be broadly defined as a manufacturing execution system (MES). Many investigations (Deuel, 1994; Hakanson, 1996; Leibert, 1997) have stressed the role of MES in bridging Manufacturing Resource Planning (MRPII) and the shop floor supervisory system. In addition to integrating individuals, materials, machines, time, and cost via a relational database, this system also provides operation tracking, feeds information back to the planning system, and produces managerial reports for decision support.

Narrowly defined, shop floor information system uses BOM and routes in the planning level, and is combined with a shop floor reporting system to monitor production flow. Thus, its application is limited by the lack of a flexible production flow data scheme capable of assisting the user to define what shop floor information to collect and how to handle exceptions timely. Shop floor information systems such as Promis (Promis, 1990), WorkStream

(Consilium, 1991), Poseidon (IBM, 1994) *et al.* provide a flexible production flow data scheme to support the user. However, the data scheme of such commercial systems is proprietary. Therefore, modifying the data scheme in these commercial systems for future requirements is difficult. However, not many small, medium firms can afford such systems, since they are highly complex, customized, and costly.

Hastings and Yeh (Hastings, 1992) described a data structure called the bill of manufacture (BOMfr), capable of integrating routing and BOM. BOMfr has the following features: (1) A product may have one or more operations; and (2) Materials required by an operation should be presented in the corresponding BOM as the next lower level of component items, and resources such as labor, machines and cost information can also be added. An advantage of BOMfr is its ability to incorporate a data structure with integrated manufacturing information into an operation at the planning level. However, it also lacks the necessary shop floor information and decision rules to facilitate shop floor activities, such as how to define the data items to be collected and rules for handling exceptions. Therefore, its shop floor applications are limited.

To overcome the above problems, this study presents a novel flexible production flow data scheme for the shop floor. The proposed scheme comprises four modules: operation template setup, general process setup, enhanced bill of manufacture (EBOMfr) setup and work-order process setup. This data model is characterized by the ability to flexibly define shop floor production flow, allowing effective response to changes on the shop floor. Additionally, the proposed model can cooperate with a WIP execution module to monitor and control the production flow to timely handle manufacturing data and enhance the floor

decision making.

## Designing a Flexible Production Flow

Figure 1 schematically depicts the shop floor activities of the IC packaging industry. According to this figure, the proposed data model views the shop floor activities of IC packaging as an accumulation of sequential operations. Applying the four basic modules of the data model, that is, operation template, general process, enhanced bill of manufacture (EBOMfr), and work-order process, as Fig. 2 depicts, allows shop floor production flow to be designed in a configurable manner.

Basically, a product, semi-product or product family can own multiple sets of EBOMfr. Meanwhile, each EBOMfr contains available materials setup, available equipment setup and override attributes. A work-order process is a specific EBOMfr with corresponding available material assignments, equipment assignments and override attributes, based on customer requirements before the review and release of a work order. Each EBOMfr is linked to a general process. Meanwhile, a general process, consisting of a group of sequenced operations, is used to control production flow. An operation is the basic tracking unit on a shop floor. The contents of an operation are copied and modified from the corresponding contents of an operation template. Meanwhile, the contents of an operation template can be defined freely by the user. For example, a user can establish attributes of operation templates, such as yield rate, input quantity, or define exceptional rules, such as low-yield-rate rule and unmatched-input-quantity rule. The template contents are summarized according to shop floor activities. The concept of EBOMfr closely resembles that of BOMfr. However, the EBOMfr described herein is

made after the general process and operation template. A user can easily alter the production conditions of a production flow either by (1) adding, modifying or deleting an operation in the general process or (2) adding, modifying or deleting the contents of an operation template to effectively respond to changing product requirements and floor situations. This data model is characterized by its ability to provide users with the following functions: (1) flexible definition of production flows and the pertinent data consisting of items to be collected and action control rules through early standardization of an operation template, general process and EBOMfr. (2) To establish related attributes, equipment and materials according to customer requirements at the time of work order review and release through late customization of the work-order process.

### *Operation template*

The contents of an operation template include attribute setup (including preset value setup, check-in value setup, check-out value setup and calculated value setup), formula setup, check-in rule setup, check-out rule setup, and global parameter setup. These setups are also the basic components of the EBOMfr and general process.

The data scheme of the operation template can be described in IDEF1x (Kusiak, 1997) presentation as Fig. 3 illustrates. Table tblWipOPData provides the name (OPNo) of each operation template. Meanwhile, Table tblWipAttibData defines the name (AttibName), type and property of each attribute. The type of attribute can be classified as either user-defined or system-defined. System-defined attributes, such as, sample number and acceptance number of the inspection operation template, do not allow the user to do any editing. Meanwhile, checking the properties of attribute, such as, numerical number, date, bin, percentage and

string, reveals whether or not the system legitimates their value.

### *General process*

A general process controls production flow and handles shop floor exceptions. This process includes operations and operational sequence. Operational sequence is the order of an operation in a process. The contents of an operation in the general process, including attribute setup, formula setup, check-in rule setup, check-out rule setup, and global parameter setup, are copied from an operation template. According to the predefined operation template, a user can easily add, modify, or delete an attribute, rule, or formula of operation contents to create the production flow. Automatic transfer and exceptional handling of the shop floor are then performed based on the rule defined in each operation of the general process.

Figure 4 illustrates the data scheme of a general process which can be described in IDEF1x presentation. Table tblWipProcessData defines the name (ProcessNo) and related information of each general process. Each record in tblWipProcessData corresponds to several records of tblWipProcessOP. Meanwhile, the ProcessOPPK, incorporates of process name (ProcessNo), operation name (OPNo), and order (OPOrder) of the operation in the process, is the primary key of table tblWipProcessOP. As mentioned earlier, the major contents of the operation in the general process, except primary key (including attribute, formula, check-in rule, check-out rule, and global parameter setup), are copied from the operation template. The user can modify the above data through addition, modification, or deletion. The operational sequence is established in the field (OPOrder) of tblWipProcessOp. Additionally, Table tblWipProcessOP can

also define the properties of an operation, such as alternate operation, checklist operation, and check-in and check-out options. The result (ThenOption) of operation rules defines the flow controls.

#### *Enhanced bill of manufacture (EBOMfr)*

Table tblWipMBom defines EBOMfr. MBomNo is the primary key of table tblWipMBom. Its foreign keys consist of a product name (ProductNo) from Table tblWipProduct, and a general process name (ProcessNo) from Table tblWipProcessData. Those keys imply that several different processes can be defined for a specific product, or a process can be defined for several different products. Figure 5 depicts the data scheme of EBOMfr. In EBOMfr, its associated factors can be further divided into two categories: (1) Factors related to the product and operation of the process (as shown in the shaded portion) and (2) Factors related only to the product.

#### *Work-order process*

Table tblWOData defines the work-order process. The primary key of table tblWOData is WoNo. The foreign keys consist of only a product (ProductNo) from Table tblWipProduct, and an EBOMfr (MbomNo) from Table tblWipMBom. Those keys imply that the production planner can specify an appropriate EBOMfr for the product according to the special product requirement, and then reassign the product related factors, including (1) Factors related to the product and operation of the process; (2) Factors related only to the product. The information used by the work-order process is modified from the information of EBOMfr. The work-order process can then be carried by a lot, i.e. a basic tracking quantity on the floor, and the production flow is guided all the way on the floor. Figure 6 illustrates the data scheme of the

work-order process.

### **Executing a Flexible Production Flow**

Through its early standardization of operation template, general process and EBOMfr, and late customization of work-order process, the data model of shop floor production flow gives the user a flexible descriptive mechanism to define the relevant production information and action control rules of shop floor activities. However, to timely handle manufacturing data in IC packaging industry, the data model incorporates a WIP (*i.e.* work-in-process) execution module to monitor and control the production flow on the shop floor as Fig. 7 illustrates.

The WIP execution module normally monitors any transferred quantity from the first to the final operation according to the predefined work-order process, and controls the following events in each operation. (1) During check-in, the module can assess whether or not an operation can be executed based on user check-in attributes and predefined check-in rules. (2) During check-out, the module can assess what the next operation is based on the user check-out attributes and the predefined check-out rules. If exceptional production problems occur in a certain operation, the WIP execution module initiates the predefined handling procedure. To accumulate information on shop-floor production lots for every operation in the packaging industry, including associated material, equipment, people, quality, and time, an additional data scheme called lot-based tracking process, is required, to record lot status and course.

#### *Lot-based tracking process*

Figure 8 depicts the IDEF1x presentation of lot-based tracking process.

Table tblWipLotData defines the name of the lot (LotNo). When the lot status is “ready for release”, the WIP execution module creates a record of the lot in Table tblWipLotState, and adds a corresponding record (LotSerial) in the table tblWipLotTracking. Additionally, the module records the material (MaterialNo) used in the table tblWipLotMaterialContent, notes the equipment (EquipmentNo) used in the table tblWipLotEquipmentContent, and documents the attribute name (AttribName) and value (AttribValue) used in the table tblWipLotAttribContent. If defects exist, the number of defects, defective lot, and defective reasons (ErrorNo) are recorded in Table tblWipLotFailContent. Normally, the lot proceeds from the first to the final operation according to the predefined work-order process. If an abnormality occurs in a specific operation, a record (LotErrorSerial) will be added to Table tblWipLotErrorLog, and the cause of the error (ErrorNo) will be inserted into Table tblWipLotErrorContent. The lot will then be put in the exceptional handling procedure. According to the results, the lot-based tracking process records the information and events and, simultaneously, reflects exactly what occurred on the floor.

### *Example*

Figure 9 illustrates the post-bonding inspection (PBI) operation (which can originate from the PBI operation template established previously) of the production flow of a certain product in the packaging industry. The lower portion of this figure depicts the setup of the operation. The attribute setup determines the characteristics of “key-in quantity”, “good quantity”, “scrape quantity”, “lost quantity”, “output quantity”, “move-in quantity”, and “target quantity”. Meanwhile, three calculated formulae such as “output quantity = good quantity + scrape quantity + lost quantity”, “move-in quantity = transfer quantity” and

“transfer quantity = good quantity” are established. Moreover, the operation also defines the check-in, check-out rules and the global parameters like transfer quantity. The upper half of the picture represents the processing of a WIP execution module. The module is executed according to the operation defined in the lower half of the figure. Thus, performing a check-in at PBI operation requires inputting the key-in quantity while performing check-out, and needs to input good, scrape and lost quantities. When the input number satisfies the defined check-in and check-out rules, the module issues actions (such as displaying warning messages) according to the handling procedure. Otherwise, if the input scrape quantity does not equal zero, which is the target quantity, the user is asked to input the cause of the scrape. As stated above, each product lot is executed according to the operation defined in the production flow for the product.

To let users easily modify information in the production flow to fulfill varied floor dynamics with little or no programming skill, the MIRL WIP System combines the data model with a WIP execution module, which provides generic user interfaces for most operations. The interfaces include check-in interface, check-out interface, exceptional handling interface, and close lot interface. The user can also develop their own specific interfaces. Figure 10 presents the example screen of the general process setup. The upper portion of the screen presents the name, type and valid date of the general process. Meanwhile, the lower portion depicts the operational sequence setup of the corresponding general process. The operation setup button provides an entry to the attribute setup, formula setup, check-in rule setup, check-out rule setup, global parameter setup, as Fig. 11 indicates.

When the operator enters employee

identity and lot number during login, the system can inform the user of the lot status and immediately take the appropriate action. For example, Fig. 12 represents the check-out screen. This figure also contains the required information for viewing and checking out entries. The upper portion of the screen shows the operation name and move-in quantity, the left portion shows the preset attributes, material description and material used, and the right portion depicts the selected equipment and operator entries. Meanwhile, the check-in screen displays information on selected material, equipment and check-in values which is the same as in the check-out screen.

### Conclusion

This work presents a data model of flexible production flow which incorporates four modules: operation template setup, general process setup, enhanced bill of manufacture (EBOMfr) setup, and work-order process setup. The proposed data scheme provides users with a descriptive scheme for the shop floor execution level: (1) to flexibly define shop floor information and decision rules required for production flow, and to allow easy adjustment of the system to fulfill the floor dynamics, (2) to monitor and control the execution of production flow through a WIP execution module, and thus facilitate reliable and timely managerial decisions. In the future, industry can adopt the WIP system to construct shop floor information systems and enhance productivity.

### Acknowledgements

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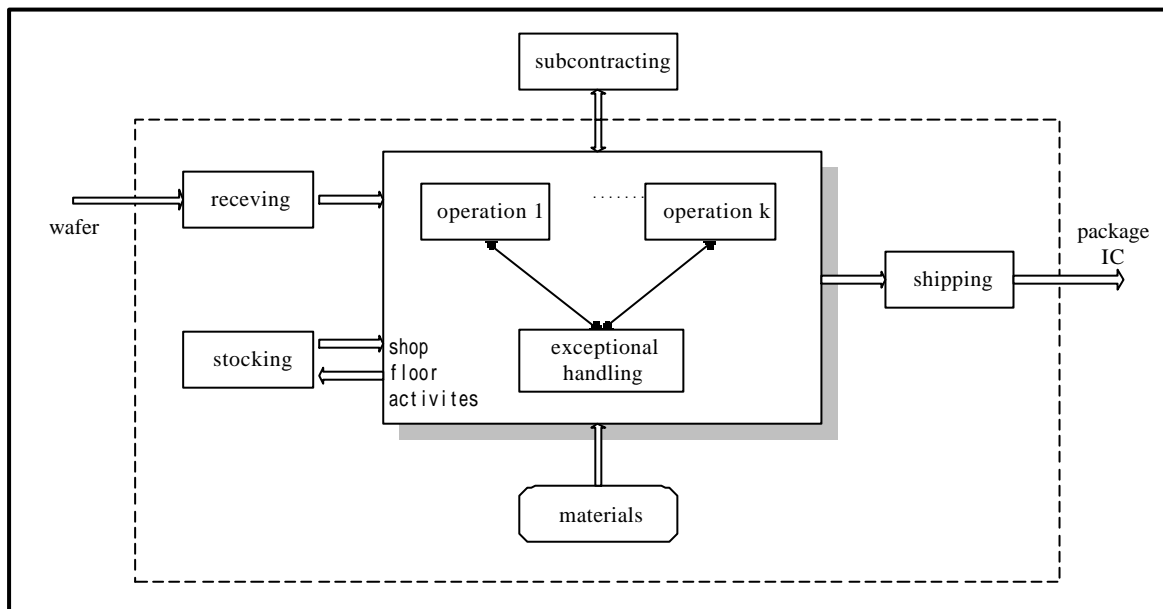


Figure 1: The shop floor activities of IC packaging industry



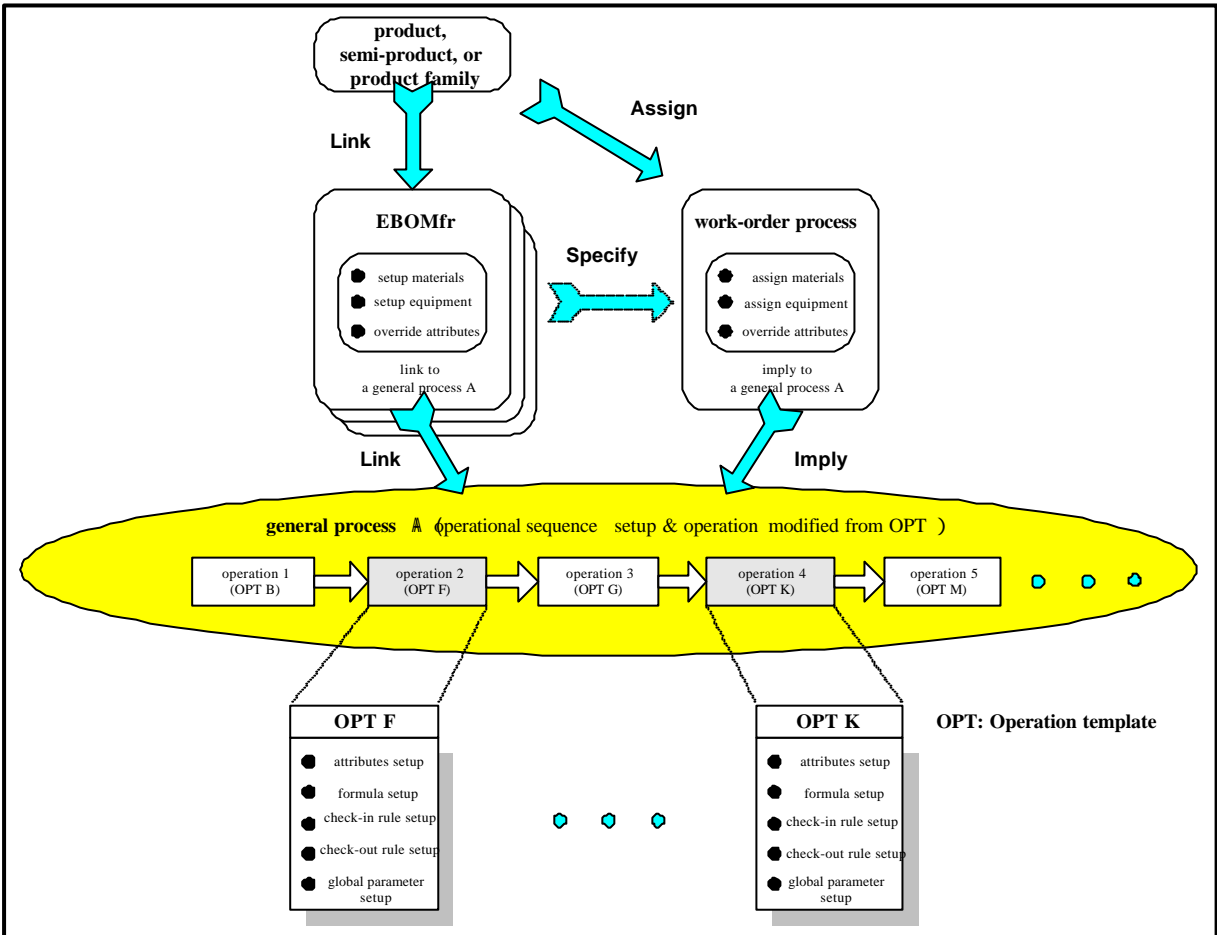


Figure 2: The proposed structure of flexible production flow

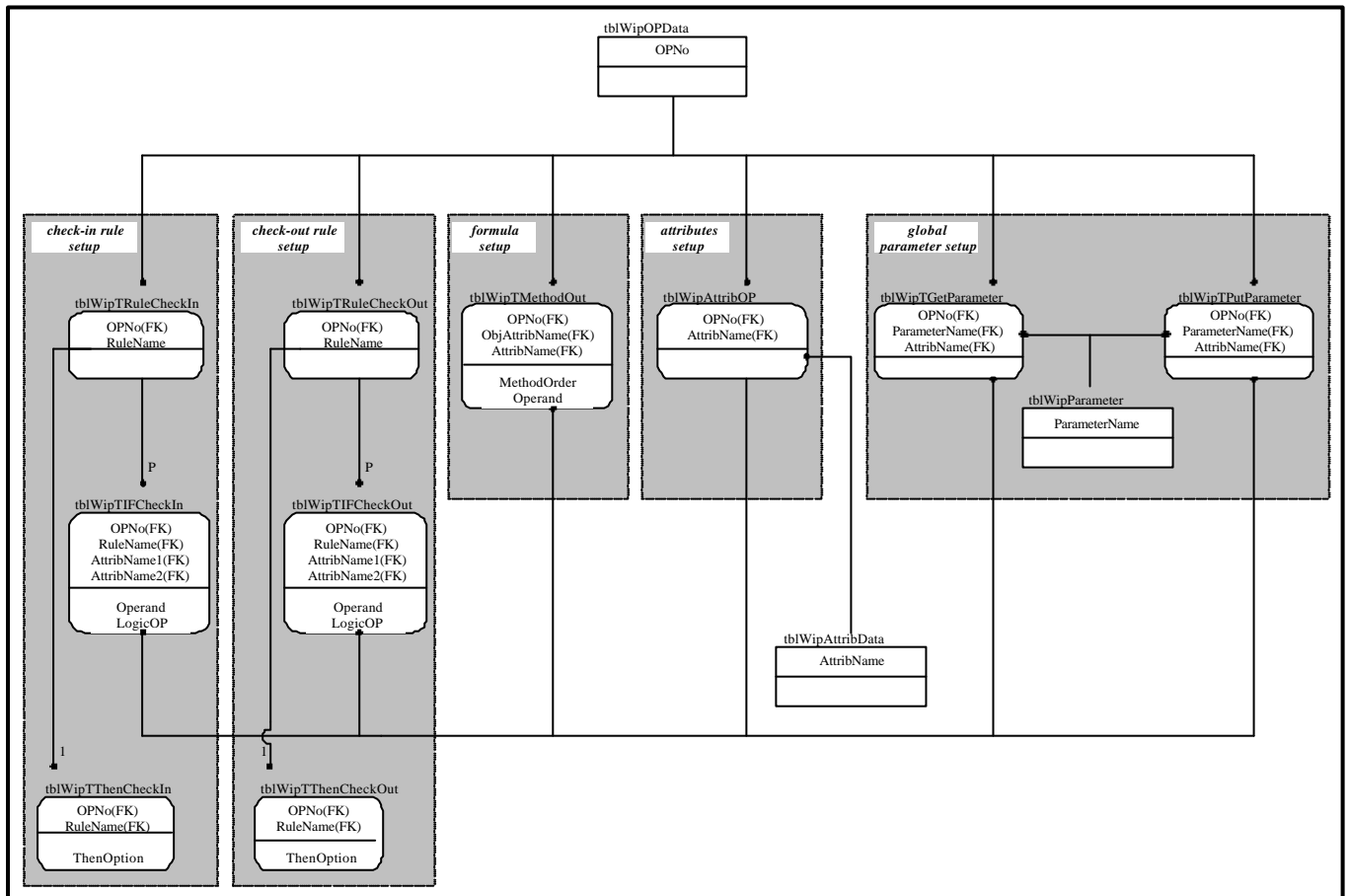


Figure 3: The data scheme of operation template

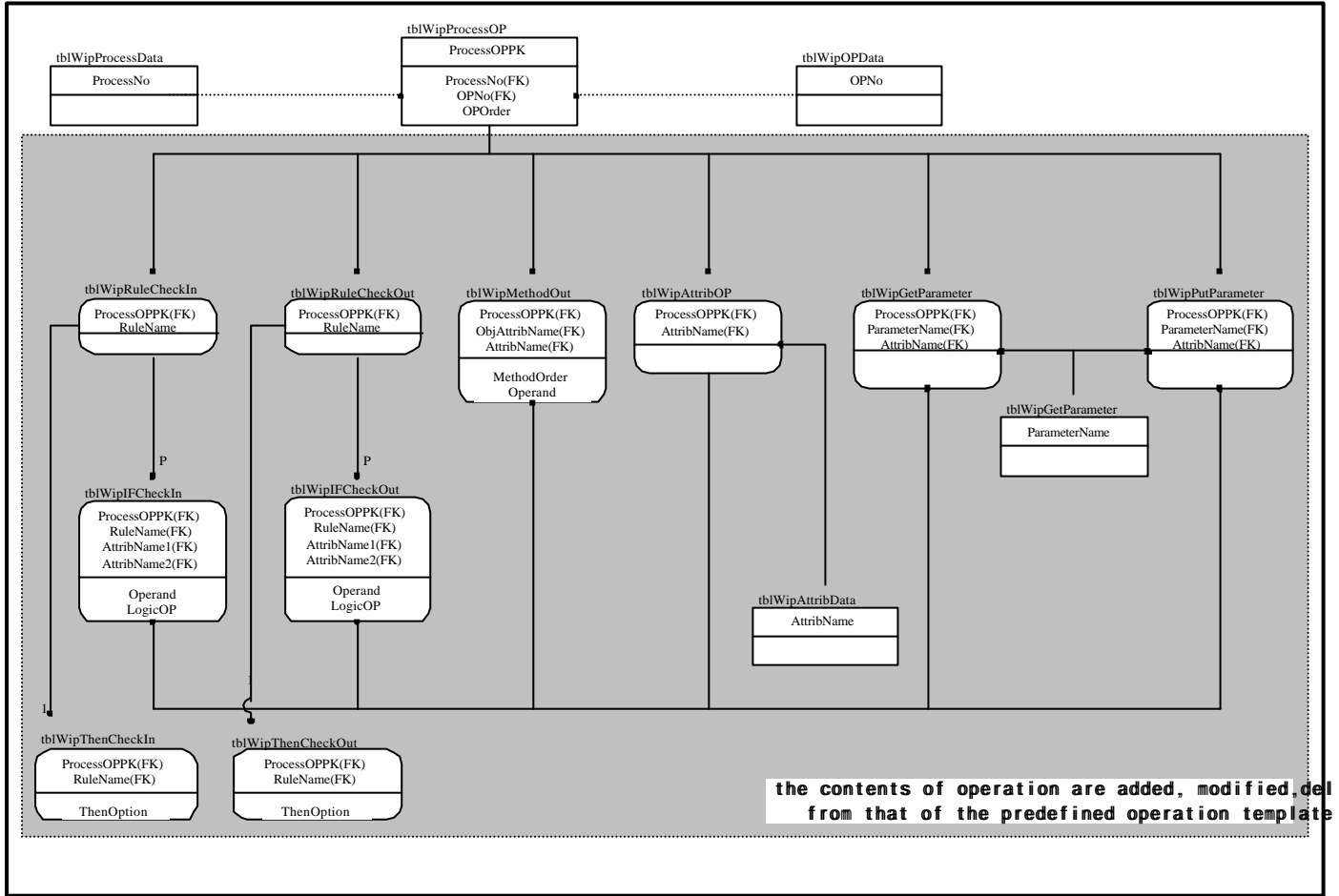


Figure 4: The data scheme of general process

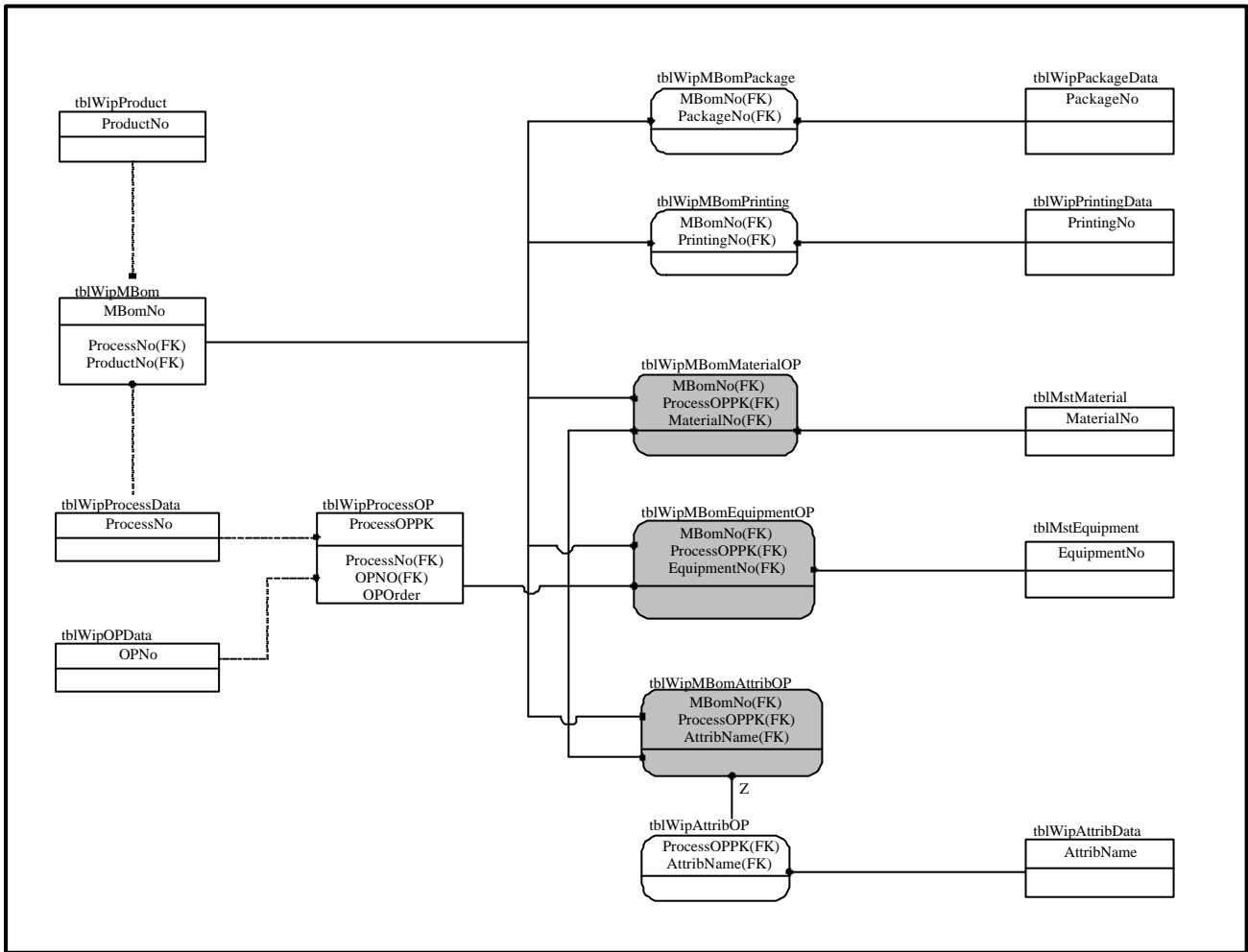


Figure 5: The data scheme of EBOMfr

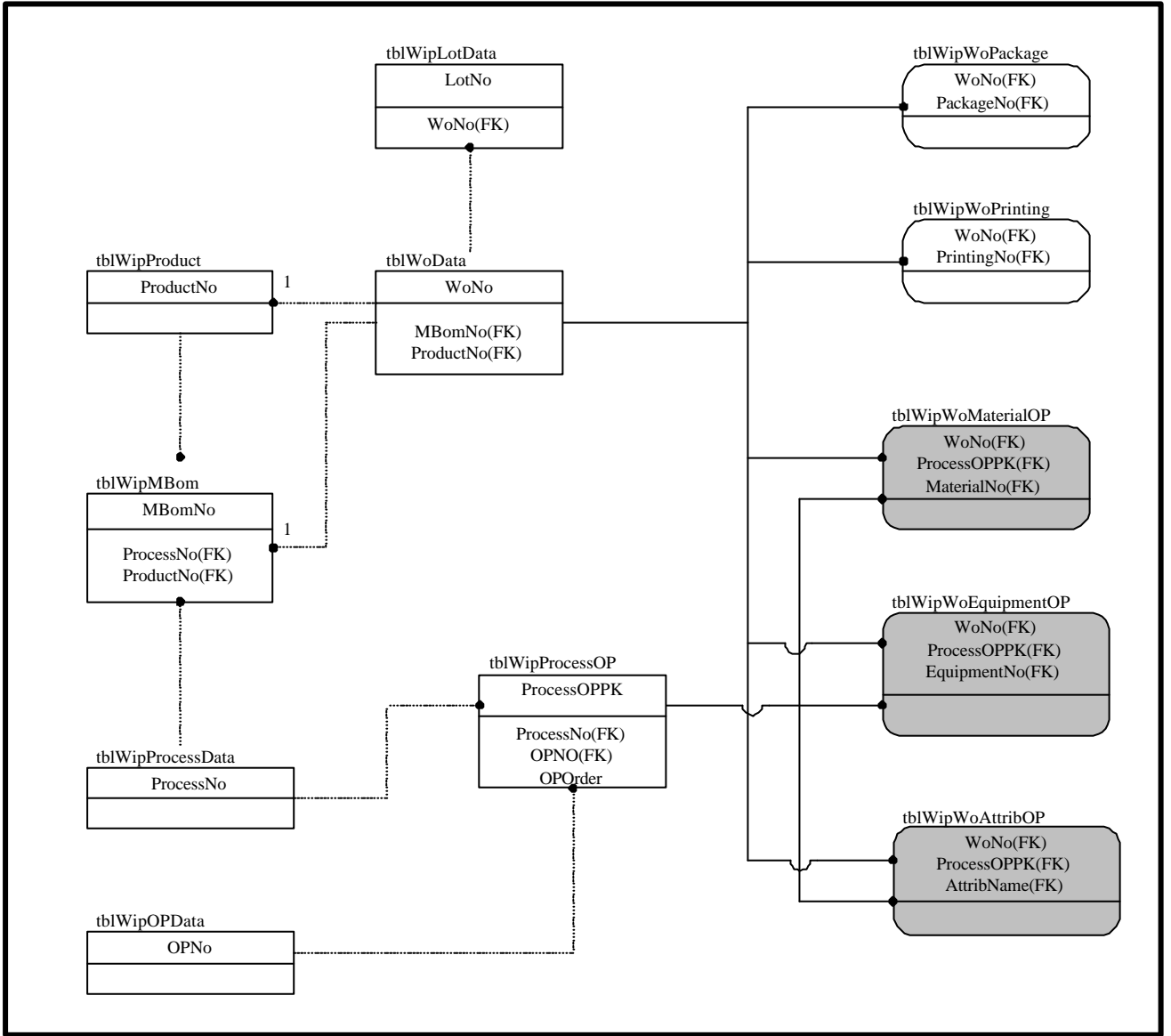


Figure 6: The data scheme of work-order process

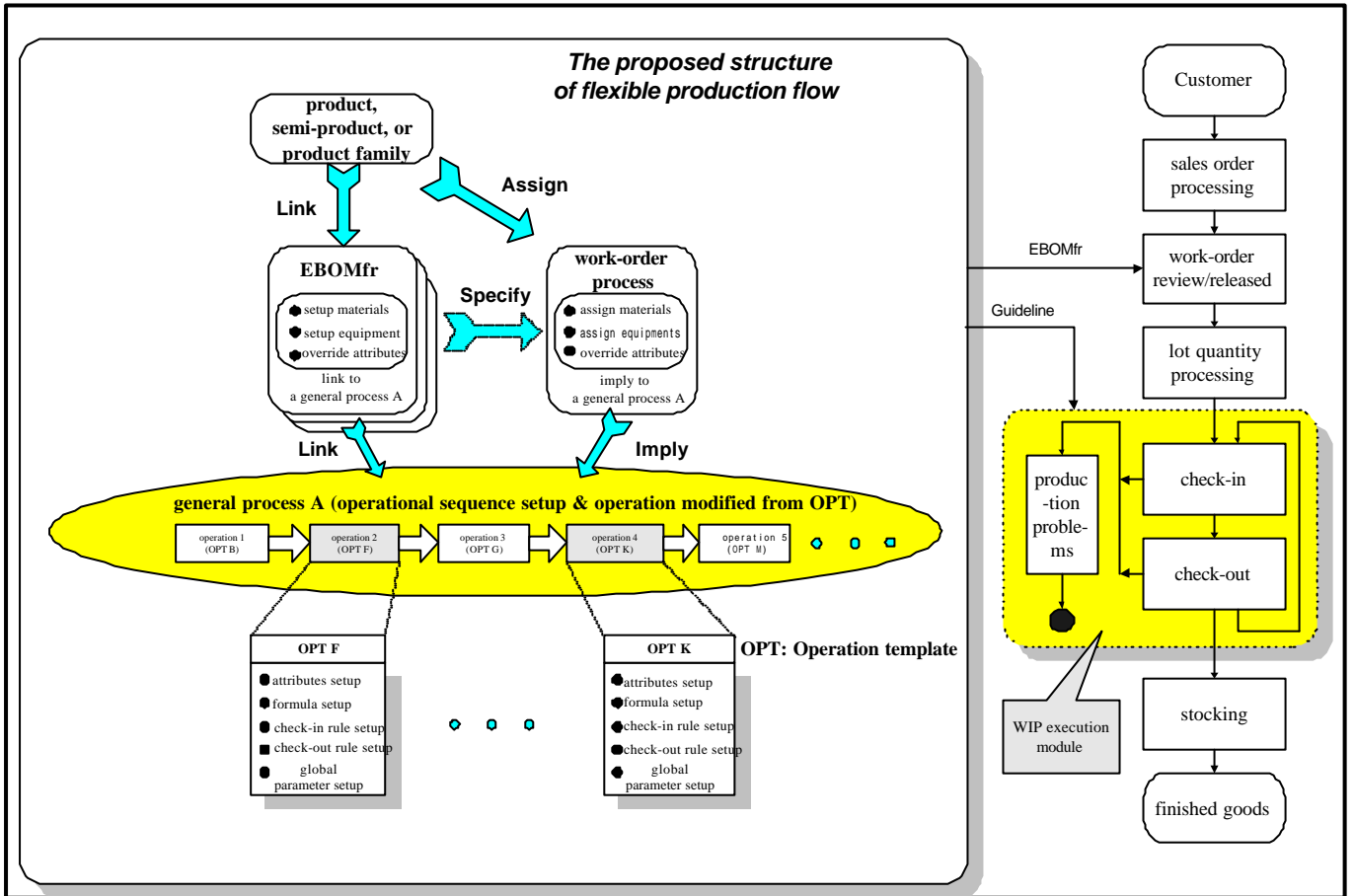


Figure 7: The flexible production flow and the WIP execution module

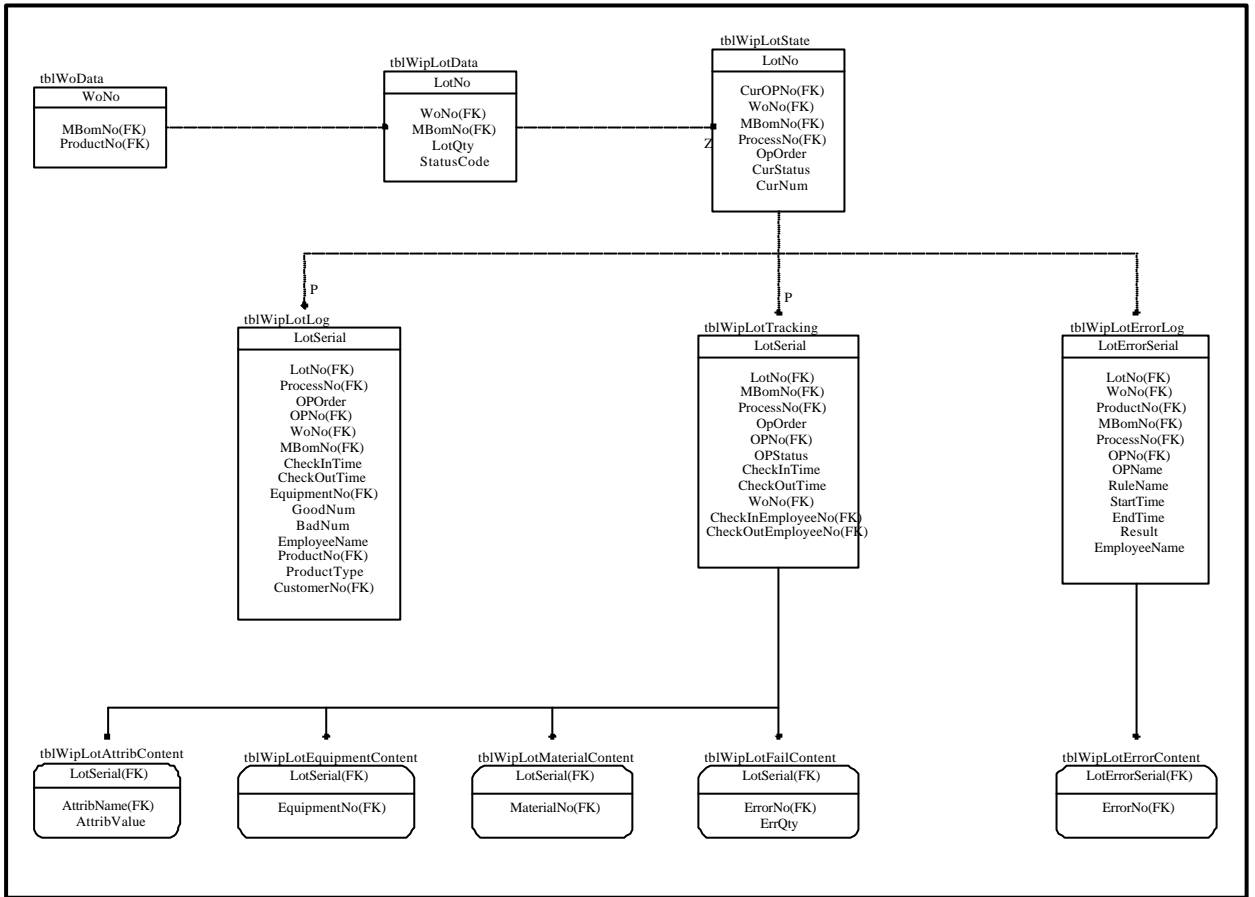


Figure 8: The data scheme of lot-based tracking process

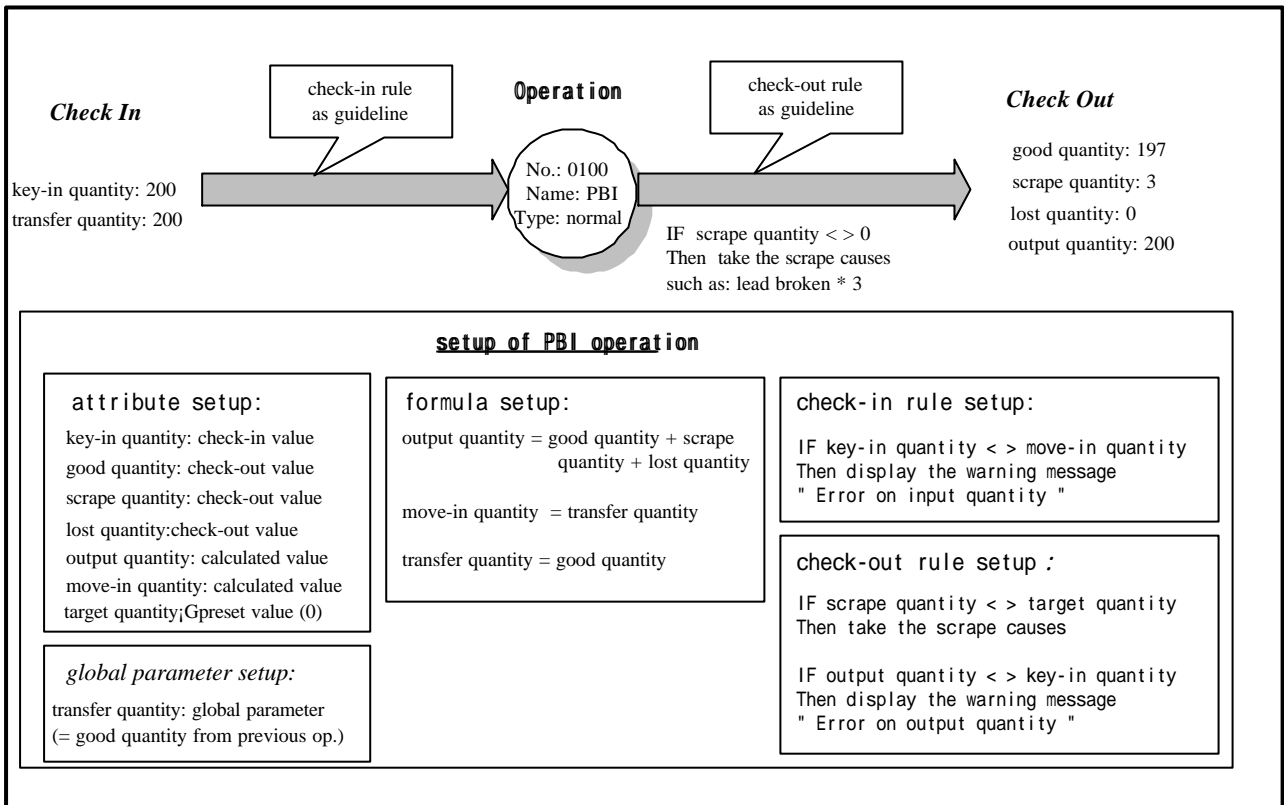


Figure 9: Setup of the post bonding inspection operation (PBI)



**General Process Setup**

Name	Type	Approved	Published Date	Effe
BGA352-001	BGA	Y	1997/12/16 11:40:57	1998/12
TSOP40-001	TSOP40	N	1997/12/16 12:27:14	1998/12
TSOP50-001	TSOP50	N	1997/12/18 04:55:10	1998/12
test	TEST	N	1997/12/31 01:35:47	

ADD  
MODIFY  
DELETE  
COPY

---

Process No : BGA352-001

Ord.	No.	Name	Check IO Option	Type	Memo	Creator
1	OP001	Grinding	IO	N		Jack
2	OP002	Wafer Mount	O	N		Jack
3	OP003	Die Saw				Jack
4	OP004	2nd V/M				Jack
5	OP005	QC Gate				Jack
6	OP006	Die Bond				Jack
7	OP007	D/B Coating				Jack

ADD  
INSERT  
MODIFY  
DELETE

OP Setup

Approved    Disapproved    PRINT    BACK

Figure 10: The example screen of general process setup



<b>Check-out Screen</b>		Lot No. : M80302-003-001																							
OP. Name: <b>Wire Bond</b>		Move-in Quantity: <b>200</b>																							
<table border="1"> <tr><th colspan="2">Preset value</th></tr> <tr><td>▶ 0</td><td>0</td></tr> </table>		Preset value		▶ 0	0	<table border="1"> <tr> <th>Available Equipment</th> <td></td> <th>Selected Equipment</th> <td></td> </tr> <tr> <td>W002</td> <td rowspan="3">▶ &lt;</td> <td>W001</td> <td></td> </tr> <tr> <td>W003</td> <td></td> <td></td> </tr> <tr> <td>W004</td> <td></td> <td></td> </tr> <tr> <td colspan="2">Wire Bond</td> <td colspan="2">Wire Bond</td> </tr> </table>		Available Equipment		Selected Equipment		W002	▶ <	W001		W003			W004			Wire Bond		Wire Bond	
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Available Equipment		Selected Equipment																							
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W003																									
W004																									
Wire Bond		Wire Bond																							
<table border="1"> <tr><th colspan="2">Available Materials</th></tr> <tr><td>▶ Gold Wire</td><td>9714-5000-01</td></tr> </table>		Available Materials		▶ Gold Wire	9714-5000-01	<table border="1"> <tr><th colspan="2">Input value</th></tr> <tr><td>▶ Good Quantity</td><td>200</td></tr> <tr><td>Scrape Quantity</td><td>0</td></tr> <tr><td>Lost Quantity</td><td>0</td></tr> </table>		Input value		▶ Good Quantity	200	Scrape Quantity	0	Lost Quantity	0										
Available Materials																									
▶ Gold Wire	9714-5000-01																								
Input value																									
▶ Good Quantity	200																								
Scrape Quantity	0																								
Lost Quantity	0																								
Memo:																									
Defect		Conform																							
		Cancel																							

Figure 12: The example screen of check-out procedure