

Article

Data Integration in IT Systems in Supply Chains

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Abstract

Integrating IT systems in the automotive industry remains a technically complex and costly process, particularly in environments based on legacy ERP and WMS platforms. Existing research discusses QR codes and process automation separately. However, little attention is paid to non-intrusive integration architectures that combine standardized identification and intelligent automation. This study develops and implements a universal logistics integration model based on GS1-compliant QR codes and JSON data structures combined with intelligent process automation (IPA). A case study from an automotive company is presented. Analysis indicates that the main loss factors include misidentification of assets, manual data entry, and lack of feedback on delivery status. The architecture proposed in this manuscript consists of three modules: INTELOGBOT (2.07), IPABOT (1.79), and APIBOT (1.79). A structured QR-JSON identifier schema was also designed to ensure platform-independent data exchange. This eliminated manual data re-entry and enabled real-time inventory and delivery synchronization. Furthermore, it also automated logistics documentation and reduced identification errors in inbound and outbound operations. The research contribution consists of developing a solution that enables the connection of QR codes with intelligent IPA-based bots, providing a repeatable framework for advanced automation of logistics processes in complex supply chains.

Keywords: intelligent process automation; QR code; data integration; IT system integration; IPA bot; logistics process

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1. Introduction

The challenges related to information technology (IT) that logistics and supply chain management face are complex and stem from the ongoing digital transformation and the development of new technologies.

A significant number of companies continue to utilise obsolete IT systems. In order to address these issues, it is essential to invest in modern, scalable systems that incorporate built-in data analysis mechanisms [1]. Moreover, the volume of data generated within the supply chain is substantial. This presents a number of challenges relating to its processing, collection, timeliness, accuracy and accessibility to all users of the process and the

supply chain [2]. To make decisions that are oriented towards optimizing logistics processes, companies must possess the capability to analyse the data that has been collected.

The automotive industry demands that IT architecture ensure compliance with quality standards such as IATF-16949 [3]. The implementation of process control mechanisms at each stage of the production process is of paramount importance from both a manufacturing and a logistics perspective. Consequently, IT systems should facilitate the recording and tracking of data pertaining to the quality of raw materials, components and finished products. The automation of IT system operations is not merely a response to the increasing intricacy of business processes; it is an imperative that is underpinned by the necessity to adhere to the highest quality and security standards. Conventional manual methodologies are inadequate in the face of mounting data volumes and the necessity for uninterrupted system functionality. The integration of information technology (IT) within this sector is imperative to ensure data consistency and the effective management of a company's resources. To ensure high efficiency in production and management processes, it is necessary to exercise control over the entire supply chain by integrating all logistics processes. A failure of communication between systems can result in inefficiencies and errors.

The integration of disparate IT systems, which frequently exhibit divergent data formats and communication protocols, poses a considerable challenge [4]. This is primarily attributable to the presence of heterogeneous ERP, WMS and TMS systems, in addition to the potential for partners to utilize disparate systems. In a multitude of industrial contexts, notably within the automotive sector, systems have been developed in a gradual and piecemeal manner, employing various data formats and communication protocols. It is a common occurrence that such platforms are legacy systems for which there is limited or no support for modern application programming interfaces (APIs). Consequently, data exchange between supply chain participants frequently relies on manual transcription, local identifiers, email communication, spreadsheets or semi-structured documents. This approach increases the risk of delays, semantic inconsistencies and operational errors.

Despite the valuable capabilities offered by existing integration approaches, such as EDI, the creation of dedicated APIs, iPaaS platforms and native WMS/ERP integration, in practice these approaches also have significant limitations. The Enterprise Integration Standard (EIS) necessitates substantial standardization efforts and coordination between partners. API-based integration requires implementation on both sides and can incur significant costs during development and maintenance. Integration Platform as a Service (iPaaS) solutions offer flexibility but can be challenging to adapt to legacy systems and non-standard operational interfaces. Built-in Enterprise Resource Planning (ERP)/Warehouse Management System (WMS) integration mechanisms are frequently vendor-locked and inadequate to ensure cross-organisational interoperability.

Consequently, the authors set themselves the aim of proposing a lightweight and non-intrusive approach to integration that can be implemented without redesigning the internal architecture of existing systems, whilst enabling automatic identification and structured data transfer, as well as real-time process feedback.

The innovation of the proposed solution does not derive from the utilization of novel technologies; rather, it is derived from the integration of existing technologies to form a functional IT architecture. It is important to note that process automation and integration have been achieved in a non-invasive manner, without the need to overhaul existing systems.

The article is structured as follows: Section 2 provides a detailed exposition of the research approach. Section 3 then presents the reader with an exposition of Information and Process Automation (IPA) and Quick Response (QR) technologies, along with their application and role in the flow of information and goods within the automotive industry.

Sections 4 and 5 of this text are dedicated to the integration of these technologies. Section 6 presents the results achieved following the implementation of the system. The conclusions of the study are summarized in Section 7.

2. Research Implementation Process

The research process comprised two complementary stages. The initial stage of the research comprised a targeted literature review, which focused on IT integration within the supply chain, QR code-based identification, GS1 standards, RPA/IPA technologies, and the challenges associated with interoperability in legacy environments. The objective of this stage was to identify the primary technological and organizational constraints of current approaches to integration and to define the conceptual framework of the proposed solution. The second stage of the research involved the utilization of a case study at an automotive company. The case study was employed in the design, implementation and evaluation of the proposed integration model in a real-world operational environment.

The decision to adopt a case-study approach was informed by the recognition that the research problem is characterized by its high degree of context dependence and its embedding within a complex manufacturing environment. This environment is characterized by the presence of multiple users (people and subsystems) who are engaged in various activities, a closed system architecture, and a multitude of operational constraints. The automotive sector, within which the research was conducted, provides a suitable empirical context.

As a preliminary measure, an investigation was conducted into the origins of losses and disruptions in logistics processes. The analysis yielded three predominant categories of problems.

Firstly, there is an issue with the accurate identification of goods, locations and logistics documents.

The second issue pertains to the manual entry of data and the transcription of data across different systems, a process that is both repetitive and laborious.

Thirdly, the provision of feedback regarding delivery fulfilment and dispatch confirmation was found to be inadequate.

In consideration of the findings and a review of the extant literature, a set of functional requirements for a non-intrusive integration architecture was defined, and a prototype integration model was designed.

The solution was subsequently implemented for selected scenarios, and its effectiveness was determined through a pilot operational deployment across three functional areas: integrated delivery management, internal order fulfilment, and smart goods-in processing. The data utilized for the evaluation process was obtained from various sources, including process observations, operational records, system logs, and comparative measurements of selected indicators before and following the implementation of the process under investigation. The indicators encompassed the number of manual data entry operations, the frequency of identification errors, and the average order or delivery processing time.

3. Automatic Identification and Data Adjustment with IPA and QR Codes

Presently, QR codes are extensively utilized to oversee the movement of products throughout the supply chain. These codes are designed to store information that can be modified at every stage of the process. This approach is designed to guarantee that all participants within the supply chain have access to the most recent data [5]. The utilization of QR codes within the context of supply chain management facilitates the automation of

numerous processes. It is evident that QR codes can be categorized into two distinct types, the first being standard QR codes, and the second being extended or specialized variants. The initial category encompasses both static and dynamic QR codes. The former contain fixed information that remains unchanged once generated. The latter, however, permit the updating of data without the necessity of altering the QR code itself [6]. Conversely, extended QR codes contain an image within the code. The utilization of such codes is conventionally employed in brand-building initiatives [7]. The category of extended codes also includes encrypted QR codes, which provide an additional layer of security by encrypting the data contained within the QR code [8]. It is evident that specialized QR codes encompass a diverse range of variations, including colour, 3D, and executable codes. Notable examples include eQR and SQR. The decoding of these specific types of codes is facilitated by the implementation of specialized algorithms, which are employed in applications that demand elevated data density. In the context of the manufacturing sector, three-dimensional QR codes have been identified as a particularly effective solution for product tracking. The utilization of eQR and SQR codes is notable for their capacity to contain executable programmes, thereby enabling seamless execution on mobile devices, independent of an internet connection [9,10].

The potential applications of these codes are extensive. As demonstrated in Reference [11], the implementation of QR codes within the context of stock management has been shown to facilitate the expeditious transmission of information, thereby ensuring the minimization of errors. This is beneficial for maintaining transparency regarding stock levels within a company and throughout the supply chain. This is not the only area highlighted in logistical applications. As stated in Reference [12], the utilization of QR codes in the context of parcel sorting has been demonstrated. It is evident that sorting systems frequently employ QR code recognition technology to facilitate the effective identification of consignments. Furthermore, QR codes are utilized in warehouse environments to enhance the navigation of AGVs. The items were positioned on the floor, whereupon the AGVs conducted a scan to retrieve location information, thereby providing positional data [13]. In the domain of logistics, QR codes have the capacity to facilitate the encryption of user data. The utilization of these systems in this domain guarantees that solely authorized personnel possess access to designated information, thereby mitigating the risk of data breaches [14].

The integration of QR codes with other technologies, such as NFC or RFID, is used to track shipments throughout the supply chain [15].

From a technological perspective, QR codes, RFID and NFC belong to different identification paradigms. Radio-frequency identification (RFID) facilitates identification and automatic scanning of large numbers of objects in the absence of direct line-of-sight, though it generally necessitates dedicated infrastructure and carries higher implementation costs. Near Field Communication (NFC) facilitates secure short-range interaction, yet its optimal application is in proximity-based scenarios, such as contactless payment and automatic Bluetooth pairing. Its efficacy is less pronounced in large-scale warehouse and supply chain operations. Conversely, QR codes offer a favourable balance between cost, accessibility, data capacity and compatibility with widely available devices such as smartphones, industrial scanners, tablets and cameras. It is evident that QR technology is particularly well-suited to non-intrusive implementation in decentralized supply chain environments, including those involving small and medium-sized enterprises or older IT systems.

The integration of both QR codes and RPA (Robotic Process Automation) has been demonstrated to yield a multitude of benefits, including enhanced efficiency and cost-effectiveness. The term 'RPA' was first coined in 2012, but it was not until 2014 that it gained widespread popularity. RPA employs conventional information technology to au-

tomate rule-based business processes [16]. Advancements in software methodologies have led to an expansion in the range of potential RPA applications. These technologies, among other things, enable software bots to analyse large datasets, which is significant for decision-making and the management of logistics processes [17].

The most effective strategies for integrating QR codes with RPA, as evidenced by research, involve the combination of these technologies for tracking and identification purposes [18]. In [19], the utilization of these technologies in the domain of navigation was indicated, while in [20], the employment of QR codes and RPA technologies in the domain of real-time data processing and automation was demonstrated.

Furthermore, Robotic Process Automation (RPA) has begun to be integrated with artificial intelligence (AI) and machine learning (ML) techniques, creating a new standard known as Intelligent Process Automation (IPA) [21]. Rather than relying on conventional process automation techniques that are dependent on inflexible operating rules, the integration of AI procedures has facilitated the management of exceptions, variability and uncertainty. In comparison to RPA, IPA has been shown to possess the capability of managing unstructured tasks and making decisions [22], which can enhance the accuracy and efficiency of automated systems [23]. The integration of QR codes with IPA has the potential to form the basis for modern and intelligent logistics process management systems.

The implementation of solutions such as RPA and advanced IPA has been demonstrated to enable organizations to achieve continuous operation of processes with near-zero downtime. This is a capability that is imperative for the effective functioning of automotive supply chains and production. The employment of software bots has been demonstrated to enable operations on a scale that is unattainable by human beings. It is evident that this will result in considerable enhancements in operational efficiency and a reduction in maintenance costs.

The automotive industry imposes particularly stringent requirements for the elimination of maintenance errors. Errors in IT system management have the potential to result in production downtime, increased costs, or, most critically, a threat to user safety.

4. System for Automatic Identification and Adjustment of Data—Case Study

A team was established within a manufacturing company that supplies components to prominent automotive manufacturers. The primary objective of this team was to ascertain the most significant causes of disruptions and errors in the supply chain, and to assess their impact on the efficiency of logistics processes. Additionally, the team was tasked with estimating the financial losses incurred as a result of the identified waste. The report delineates a number of effects that have been shown to result in quantifiable financial losses. The underlying causes of these effects are as follows:

1. The identification of resources is a process of paramount importance within the supply chain. The incorrect identification of resources, such as goods, locations, and documents, can have a significant impact on the supply of components and the shipment of products.
2. The data was manually entered into the IT system, and there was an absence of identifiers on labels and documents.
3. The absence of feedback pertaining to the implementation of the delivery and approval of the shipment is indicative of a systemic issue.

The report elucidates numerous losses for which root causes have been identified.

- The utilization of disparate identification systems for individual goods within the supply chain is imperative.

- It is evident that there is an absence of integration between customer identifiers and warehouse identifiers.
- The absence of automation in the data entry and editing processes within the IT system is a salient issue.

To address the identified issues, the following operational concept for the aforementioned system (henceforth referred to as the System) was adopted:

- The establishment of a resource identification system facilitates the exchange of information between stakeholders (suppliers and recipients) without the necessity of modifying extant IT solutions.
- The system has been designed to ensure the automation of logistics operations and the exchange of data between different IT systems. This is achieved without the need for physical integration of IT systems, i.e., without requiring direct interference in their structure.
- The generation of logistics documents within existing information systems is typically initiated by the completion of the relevant forms. The generation of the forms is performed in one of two ways: either automatically or manually, with the former option employing HTML format.
- The system operates in an ongoing manner in the background, with the function of monitoring the completion of various forms. The programme automatically populates the forms with known field values and saves the document in a predefined format.
- The system has been programmed to automatically read incoming documents, thereby acquiring the capacity to recognize and link relevant identifiers and codes on both its own side and that of the counterparty.
- It is evident that the system has the capacity to store links that have been recognized, and it subsequently utilizes these links in the subsequent stages of its operation.

It is hypothesized that, under these assumptions, communication between partners may proceed as follows:

- The party initiating the process—the Recipient—commences the selected business process by generating the appropriate action plan (this takes place outside the system in question). At a subsequent point, the Recipient generates a document (using existing information systems), e.g., an order, which triggers the logistics process. It is now that the issue discussed becomes evident. It is imperative that the generated document is comprehensible to both parties. For example, in instances where the designations and identifiers (e.g., for goods and characteristics) are inconsistent between the Client and the Supplier, there is a necessity to establish links between the relevant designations. (my code/your code). It is not necessary for the recipient to be aware of the precise codes and designations utilized by the supplier to whom the order is addressed. Consequently, at this stage, a link between the order's identification data on both sides of the supply chain does not yet need to exist, and the form fields corresponding to these codes remain blank.
- The system has been designed to retrieve data from completed forms and prepare the relevant document, containing all the necessary data. The document is then transmitted to the Supplier.
- The Supplier peruses the document that has been sent to them. During the reading process of the document, the system instance is operational in the background on the supplier's side, facilitating the reading and storage of all received information. Upon finalization of the order, the relevant documentation is generated in the Supplier's systems, including a delivery note and labels for the goods. The system automatically populates the form with data provided by the recipient. It is incumbent upon the

Supplier's employee to manually complete the missing fields, e.g., the relevant codes and designations used by the Supplier.

- Upon the occurrence of a delivery receipt, the Client's system automatically processes the goods label, converting it into an electronic format. The system is designed to identify the fields that have been completed by the supplier. It establishes and stores the link between the supplier's and recipient's designations and codes. To ensure that the data currently being processed is correctly linked to information obtained previously, the document contains an ID field that uniquely identifies the relevant process and stakeholder. This prevents information received from, for example, two different suppliers from being mixed up.
- Should the necessity arise for the generation of additional documentation intended for the Supplier, such as a delivery receipt, the System will automatically populate the designated fields of the HTML form with the appropriate codes for both the Supplier and Recipient.

Consequently, a database of links between corresponding designations and codes—both those of the present institution and those of our partners—is automatically created. The database is updated automatically at the point of each subsequent exchange of documents. Concurrently, staff involvement in document preparation is reduced to an absolute minimum, thereby minimizing the possibility of errors.

In the course of the project, a solution was formulated that facilitates the integration of QR codes with the JSON (JavaScript Object Notation) data exchange standard

The following points were adopted in the solution below:

- The QR code is used as a carrier of integration data and, concomitantly, as a trigger (tag) for the relevant process.
- QR-JSON is used as a platform-independent semantic layer.
- At the operational integration layer between physical logistics events and forms/ERP/WMS systems, an IPA-compliant approach is adopted.

The utilization of QR codes facilitates the efficient processing of substantial volumes of data, with JSON serving as the foundational data exchange format (independent of the underlying programming platform). This paradigm is exemplified in the API standard, where JSON is employed for REST APIs and XML for SOAP. To establish a comprehensive, universally applicable identification system, the JSON format (with the option of XML) was integrated with the QR code standard. To facilitate the updating of information without the replacement of the data carrier, the GS1 Digital Link standard version 1.2 was utilized. The combination of these two technologies, which are frequently utilized in various contexts, facilitates the establishment of data exchange systems. The implementation of this solution is pivotal in ensuring seamless integration with various IT systems. This, in turn, has the significant consequence of automating logistics processes in the supply chain to a considerable degree.

The subsequent task during the project was to develop a system (application) that would facilitate the implementation of the following functions:

1. The INTELOGBOT module (LOGISTICS INTEgration bot) has been developed for the purpose of "listening" to data from QR code reading devices (cameras, 2D readers, phones, tablets) and transmitting it to the central data processing unit, INTELOG (LOGISTICS INTEgration). The structure of an example identifier utilized in the aforementioned study is presented in Table 1. The fields appearing in the QR JASON form were defined following an analysis of the forms used within the organization. Table 2 provides a comprehensive overview of the definitions for the designated fields.

Table 1. QR code structure and tag description.

KOD QR (JSON)	DESCRIPTION
"IDBOOT": „#D\$123",	Bot Initialization Key (Startup)
"Owner": "COMPOL",	Owner
"Contact": "www.comp.pol.pl",	Link to contact details
"Document":	Document description section
{	
"DocType": "DD"	Document type
"DocName": "Delivery",	Document name
"DocNo": "DD034 04 2026",	Document number
"DocDate": "12/04/2026",	Date of issue
"DocNote": "www.comp.pol.pl/DD/DD034/04/2026"	Document link
},	
"Identifier": [	Table of identifiers
{	
"IdType": "Product",	Type of identifier: product
"IdNo": 1,	Item number
"IdItem": "AL.-S06-0002",	Index (designation): product
"IDQnt": 12.000,	Quantity
"IdPrice": 34.56,	Price
"IdNote": "www.comp.pol.pl/AL-S06-0002"	Link do product card
}, {	
}	Notes:
{	The type of identifier may indicate: storage location, customer product index. Depending on the type of identifier,
{	the Index tag may refer to other designations, e.g. the
}	picking location. Similarly, the link may identify the map
}	of the storage location or the customer product description card, or a detail in the processing process.
}	

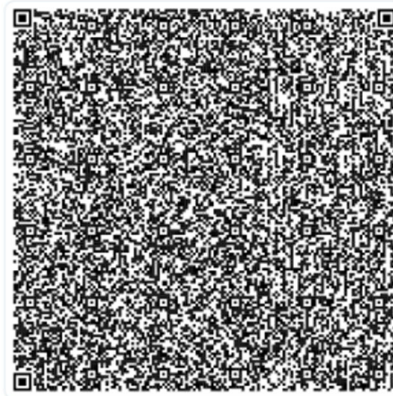


Table 2. Defined fields in the QR JSON form.

JSON field	Data type	Required	Constraints/Range of Values	Procedural Significance
IDBOOT	string	Yes	Fixed initialization ID, e.g., DS123	Activates the process and identifies the stakeholder.
Owner	string	Yes	Data owner or organization code, e.g., COMPOL	Identifies the stakeholder responsible for the document or delivery
Contact	string/URI	No	Valid URL or contact ID	Identifies the owner's contact information
Document	object	Yes	An object that contains document metadata	Groups logistics document information
Document.DocType	string	Yes	Controlled values, e.g., DD, PO, ASN, INV	Specifies the document type, e.g., delivery, order, notice
Document.DocName	string	No	Max. 100 characters	Document name presented to the operator
Document.DocNo	string	Yes	Unique document number within the owner	Document number to associate the operation with the document
Document.DocDate	date	Yes	ISO 8601 format or local format accepted by the system [24]	Date of issue of the document
Document.DocNote	string/URI	No	URL or text description	Link to the source document or additional information
Identifier	array	Yes	One or more items	List of identifiers for items, locations, products or documents
Identifier[].IdType	string	Yes	Values: Product, Location, Customer, Document, Package	Specifies the semantics of the identifier
Identifier[].IdNo	integer	Yes	A positive integer	Item number in the document
Identifier[].IdItem	string	Yes	Product, location, customer or document code	Basic operational identifier used in ERP/WMS
Identifier[].IdQnt	decimal	Conditionally	A value > 0 for quantity lines	Quantity of goods, components or logistics units
Identifier[].IdPrice	decimal	No	A value of ≥ 0 , consistent with the document's currency	Unit value of the item, if required
Identifier[].IdNote	string/URI	No	URL or text description	Link to product sheet, location map, or instructions
Status	string	No	created, confirmed, in_progress, shipped, received, rejected	Current status of the logistics process
Timestamp	datetime	No	ISO 8601	Timestamp of data generation or update
Checksum	string	No	Hash or checksum	QR-JSON data integrity check

2. The functionality of the INTELOG module is such that it facilitates the management of logistics operations through the following means:

- IPABOT (BOT IPA—Intelligent Automation Process) is a software application that automates the data registration process in IT systems. The frontend of the system was developed using HTML. IPABOT employs artificial intelligence within the context of RPA (IPA) technology to facilitate the automation of data registration processes, thereby circumventing the necessity for physical integration at the level of IT systems.
- The APIBOT (BOT API) interface has been designed to comply with the relevant API (application programming interface) standard, thus facilitating seamless integration with other IT systems.
- The LABBOT (BOT Label) module has been developed for the generation of logistics documentation (including the creation of labels for goods), in accordance

with the standards and requirements stipulated by stakeholders. The module ensures the unambiguous identification of the logistics operation on both sides of the supply chain.

5. A Model for Data Integration in the Supply Chain

Section 4 provides a detailed exposition of the system's operational dynamics in the context of communication between two users. The following section delineates the system's architecture, illustrating the modules that facilitate data processing, the automation of logistics processes, and the communication between participants in the supply chain. The operational processes of individual modules, in addition to the movement of data and materials, are illustrated in Figure 1. The figure illustrates the areas of intersection between supply chain links, indicating the zones where communication occurs. The implementation of a system that functions to divide these areas ensures the confidentiality of information throughout the supply chain. In the course of the communication process, each module is responsible for linking important information, albeit exclusively within the confines of the designated area. The manufacturer's instance of the system integrates all data related to customer order fulfilment. The following section provides a detailed description of the modules.

M01 Information flow: Enterprise ↔ Suppliers (2, 3)

The function of the module is to facilitate the integration of data between the company's IT system and supplier systems, without necessitating extensive modification to existing ERP/WMS systems. The system utilizes standardized identifiers, including GS1-compliant QR codes and JSON data structures, to uniquely identify deliveries, components, documents and logistics labels. The primary function of the system is to automate the delivery process, encompassing order confirmation, preparation and labelling of the shipment, and the provision of information on the order status. The module has been developed to reduce manual data entry, identification errors, and to ensure the ongoing exchange of information about completeness, compliance, and delivery status. The function of the layer is to serve as an integration point between suppliers and the enterprise throughout the system. This serves to increase the transparency and reliability of material and information flow.

M02 Information flow: Enterprise ↔ Production (4, 5)

The function of the module is to manage data flow within the company, thereby establishing a link between the areas of procurement, warehousing, order picking, production and customer orders. The function of the system is to ensure the synchronization of information regarding the availability of components, the delivery status, the location of warehouses, production orders and the preparation of goods for dispatch. The system has been designed to automatically initiate the relevant logistics process upon scanning of a QR code. In addition, it can indicate the storage location to the operator, record the completion of the operation, update stock levels and generate the required labels or documents. This module is of paramount importance for the maintenance of production continuity, by virtue of its capacity to facilitate rapid and reliable data transfer between logistics and production processes. This approach serves to mitigate the risk of downtime, which can be precipitated by a number of factors, including erroneous component identification, a paucity of current data, or delayed operation registration.

M03 Information flow: Enterprise ↔ Customer (1, 6, 7)

The purpose of this module is to facilitate the integration of data between the manufacturer's system and the systems of product or goods recipients. The function of the system is to manage information related to the processes of picking, shipping, product identification, logistics documents, and order confirmation. The utilization of QR codes, JSON data, and automation mechanisms facilitates the establishment of a clear link between the

identifiers employed by the manufacturer and those stipulated by the customer. The purpose of this module is to facilitate the generation of labels and documents that are consistent with the requirements of the recipient, in addition to providing updates on the status of shipments and offering feedback on the fulfilment of orders. The objective of this initiative is to enhance data consistency between the manufacturer and the customer, mitigate shipping errors, and ensure enhanced transparency in the order fulfilment process. The module has been shown to enhance the reliability of customer service and to enable a faster response to discrepancies in outbound logistics processes.

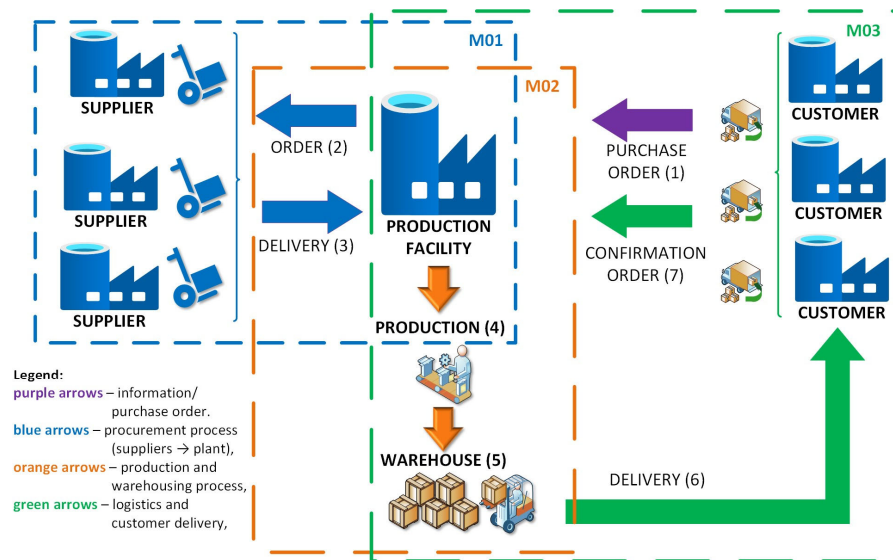


Figure 1. A model for the integration of information systems.

The system developed as part of the project enabled the design, implementation and operational implementation of innovative solutions in the following functional areas of the company. The integration of supply management processes for components and goods, the implementation of a picking system, and the introduction of an intelligent delivery acceptance system are all crucial elements in this context.

5.1. Integrated Supply Management of Components and Goods

The implementation of the system's operational requirements necessitated the design of an order document with a uniform structure. The document incorporates, among other things, unique identifiers for the supplier and the purchaser. Following the transfer of responsibility to the supplier, the order document is also published on the INTELOGDOC (3.12) (INTE-gration of LOGistics DOCumentation) platform. This approach ensures transparency and inclusivity, making the process visible to all relevant parties. Moreover, it is possible to verify the document, e.g., the product code and description, process the order further, e.g., print labels, monitor changes in the order status ("confirmed", "in progress", "completed"), etc. The detailed procedure is illustrated in Figure 2.

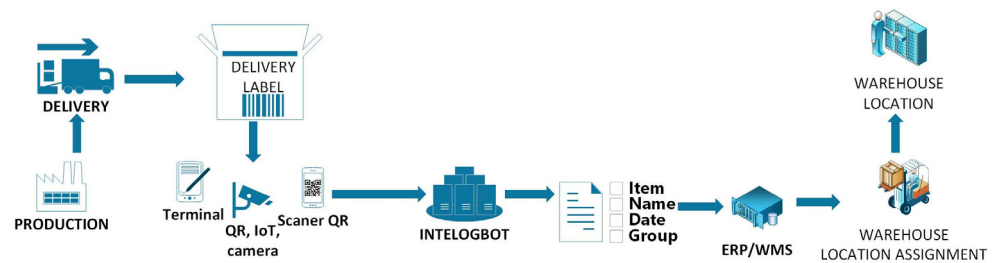


Figure 2. Delivery management.

The process of order verification can be approached from two distinct viewpoints: from the perspective of the supplier and from the perspective of the recipient. The process initiated by the supplier commences with the scanning of the QR code from the order document or the generated identification label.

The recipient of the delivery is prompted to activate their INTELGBOT by scanning the QR code, which in turn verifies the delivery and issues a confirmation of receipt.

INTELOGBOT has been developed to facilitate the synchronization of data between the ERP system and the INTELOGBOT platform, thereby ensuring the accuracy and currency of information. This process is initiated by the supplier and completed by the recipient, resulting in the updating of delivery statuses on both the ERP system and the INTELOGBOT platform.

5.2. Internal Picking System

In the domain of internal logistics resource identification, a standardized QR code format has been developed, facilitating the automation of the delivery process. The process of initiating the operation of the INTELOGBOT bot is initiated by scanning the QR code of the delivery document and the goods item (document or label). The INTELOGBOT bot controls the entire completion process through an interactive operator panel. This panel indicates the precise storage location and records confirmation of the operation. It also generates labels (LABBOT (1.79)) containing identifiers and descriptions in accordance with the recipient's specifications, as shown in Figure 3.

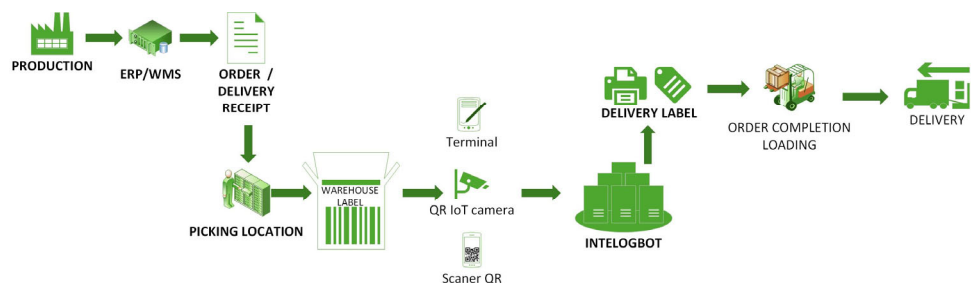


Figure 3. Picking system.

After the scanning of all labels pertaining to the delivery, the system automatically generates an order confirmation and updates the stock in real time. The supervision of the entire picking process is conducted by INTELOGBOT in accordance with the algorithm presented in Figure 4. This results in a significant reduction in the probability of errors.

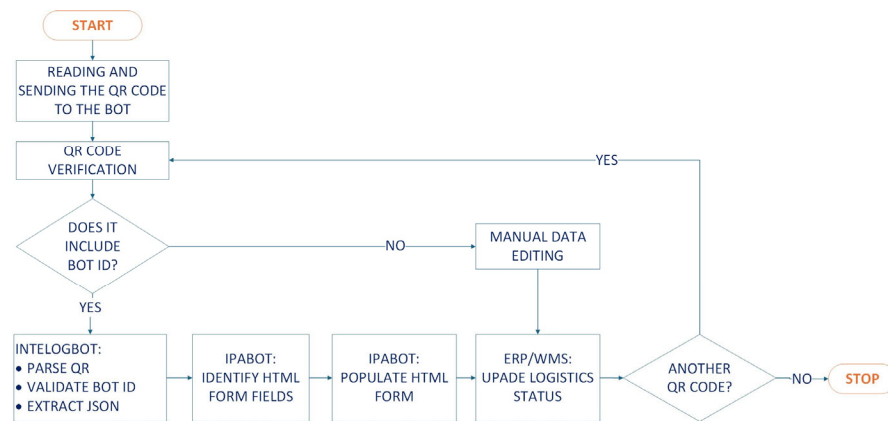


Figure 4. The process of implementing the concept of integrating data from different systems using QR codes, IPA and a Bot.

The fragment of the Bot initiation code looks like this:

```

# Finding ID from QR code
match = re.search(r'#ID\$(\d+)', qr_code_data)

if match and match.group(1) == "123":
    logging.info(f"Correct initialization code recognized: {qr_code_data}")

# Generating a session ID
self.session_id = f"INTELOGBOT-{
datetime.now().strftime('%Y%m%d%H%M%S')}"
self.is_active = True
self.last_scan_time = time.time()

# Platform notification about bot initialization
response = self._send_api_request(
    "bot/initialize",
    {
        "session_id": self.session_id,
        "bot_type": "INTELOGBOT",
        "initialized_by": qr_code_data,
        "initialization_time": datetime.now().isoformat()
    }
)
logging.info(f"Bot initialization completed. Session ID: {self.session_id}")
else:
    logging.warning(f"Invalid initialization code: {qr_code_data}")
  
```

5.3. Intelligent Delivery Acceptance System

The IPABOT (Intelligent Automation Process BOT) module is employed for the identification and documentation of deliveries. Its operational mechanism is analogous to that of the INTELOGBOT module. The IPABOT module is initiated following the scanning of a QR code with the designated tag. IPABOT employs artificial intelligence algorithms to identify the relevant form fields in the HTML code and automatically enters the appropriate data.

IPABOT employs a hybrid field-mapping mechanism that integrates deterministic rules, HTML DOM analysis, text similarity assessment, supervised learning based on ver-

ified examples, and operator-assisted exception handling. The objective of this system is to identify the structure of ERP/WMS electronic forms and allocate QR-JSON values to the pertinent input fields without the necessity for direct user intervention.

IPABOT functions in a four-step sequence:

1. The active electronic form is parsed at the HTML/DOM level. For each form field, the bot extracts structural and semantic attributes, such as the identifier, name, label, ID, aria-label attribute, field type, section context and DOM path.
2. The QR-JSON data is then organized into structured document attributes, including document number, document date, item ID, quantity, and status.
3. The system calculates a match score between each QR-JSON attribute and each form field.
4. If the confidence of the mapping exceeds a predefined threshold, the fields with the highest score are to be automatically mapped. In the absence of such a scenario, the operator is required to enter the data manually, and the approved mapping is stored for future reuse.

The bot was created using an LLM developed by OpenAI and made available via the relevant API.

The supervised learning component is based on examples generated during the process of completing a form with operator assistance. When an operator manually assigns a value from a QR code to a specific field in the ERP/WMS system, the system records this mapping as an accepted value. It is evident that, over time, the repository of accepted mappings evolves into a domain-specific knowledge base, thereby enhancing future matching processes. It is evident that the model discussed is not a general-purpose image classifier or a sequence labelling model. Rather, it is a supervised field-mapping mechanism supported by rule-based constraints and similarity analysis, with the additional consideration of DOM.

This hybrid approach is particularly well-suited to industrial environments, where the forms being processed are usually only partially completed, business semantics are known, and explainability is more important than the accuracy of 'black box' predictions.

The aforementioned factors provide the system with certain advantages, including the capacity to verify the values entered by the user, facilitate the gradual improvement of the bot, and enable new functionalities to be integrated into existing systems with a closed architecture. Furthermore, upgrading the system does not necessitate alterations to the bot's structure.

5.4. API Module (Third Party)

The integration of IT systems within the API standard (JSON: API or XML: SOAP) is facilitated by an additional module. This module enables IT system partners (ERP, WMS) to develop and implement modules that integrate IT systems. The module has been developed to facilitate reduced integration costs by virtue of the fact that it employs standard solutions that are frequently utilized in IT systems. This module offers a further advantage in that it permits the selection of either the REST API or the SOAP standard. It should be noted that both of these are frequently utilized in the context of IT systems.

6. Results Achieved Following the Implementation of the System

To confirm expectations that the proposed system would eliminate or significantly reduce the manual entry of logistics data, improve the real-time synchronization of stock levels and delivery statuses, and reduce the risk of identification errors in inbound and outbound operations, a quantitative assessment was carried out of the volume of data entered manually, the number of errors identified, and the time taken to prepare docu-

ments. The assessment was conducted in two phases: before and after the implementation of the pilot system. The assessment yielded the following findings:

- A 64% reduction in manual data-entry operations;
- A 78% reduction in identification errors;
- A reduction in the average order or delivery processing time from 26 to 17 min.

Table 3 shows the quantitative parameters of the operations carried out during the assessment. Table 4 shows the indicators obtained during the assessment.

Table 3. Quantitative parameters of the operations carried out during the assessment.

Parameter	Value	Description
Observation period (pre-implementation)	11,768 deliveries → ~1961 deliveries per month Of these 3864 shipments → ~644 per month	6 months
Observation period (post-implementation)	6586 deliveries → ~3293 deliveries per month Of these 1756 shipments → ~878 per month	2 months
Number of orders/deliveries analyzed	18,354 deliveries (before and after)	Total number of cases
Number of suppliers	8 suppliers/4 recipients	Number of partners in the sample
Number of operators	5 employees/2 shifts 3 delivery staff, 2 shipping staff	Number of system users
Number of logistics processes	2	Receipt, Shipment
Average number of items per document	~8 for delivery/~3 for shipping	Positions

Table 4. Indicators obtained during the assessment.

Indicator	Before Deployment	After Implementation	Change [%]	Calculation Method
Total number of operations	11,768 → 1961/month	6586 → 3293/month	$\Sigma 18,354$	number of cases
Number of identification errors	1560	340	↓ ~78%	number of errors/number of documents
Average Process Time [min]	25'58" average (22' delivery—30' shipping)	17'01" (12' delivery—22' shipping)	↓ ~34%	arithmetic mean
Average Time to Identify [min]	2'04"	0'45"	↓ ~64%	arithmetic mean
Error rate [%]	1560/11,768 = 13%	340/6586 = 5%	↓ ~61%	Errors/Operations

7. Summary

The present study addressed the problem of costly and technically demanding integration of heterogeneous IT systems in logistics, particularly in environments based on legacy ERP and WMS solutions.

The conclusions that can be drawn from the case study are set out below.

The primary scientific contribution of this study is the development of a reference data integration model that combines three elements that are generally discussed separately in the literature: The following elements are of particular relevance in this context: GS1-compliant QR-based identification, platform-independent JSON data structures, and intelligent process automation (IPA). In this respect, the paper contributes to the current body of knowledge by demonstrating that cross-system interoperability in logistics can be achieved without directly interfering with the internal architecture of existing IT systems.

The findings indicate that, within intricate supply chains, logistics losses emerge not solely from disruptions in material flows but also from semantic inconsistencies in identifiers and the absence of real-time information continuity across systems.

The implemented solution has been shown to be practically effective in three areas of functionality: integrated supply management, internal picking, and intelligent delivery acceptance. In all three areas, the model facilitated a unified identification logic and the automatic triggering of logistics workflows based on QR code scanning.

From a theoretical standpoint, the study posits that QR codes should not be regarded exclusively as identification carriers; rather, they should be conceptualized as event initiators within the context of automation architecture. When combined with standardized data structures and IPA/API mechanisms, QR codes become part of a broader cyber-physical coordination layer for logistics process management.

The findings suggest that the proposed model has the capacity to eliminate or significantly reduce manual logistics data capture, enhance real-time synchronization of inventory levels and delivery status, and mitigate the risk of identification errors in inbound and outbound operations.

The findings of this study imply that a simplified, standards-based integration approach may be a viable substitute for deep system-level integration in multi-actor supply chains. This hypothesis warrants further investigation to ascertain its broader scientific implications. This is particularly relevant in industries such as the automotive sector, where high process reliability is required, while the full replacement or redesign of legacy systems is both costly and organizationally challenging.

The study is also subject to several limitations. Firstly, it is important to note that the findings are based on a single case study from the automotive industry, which limits their direct generalizability. Secondly, the paper does not yet provide a comprehensive long-term performance evaluation or a comparative benchmark against alternative integration approaches. Such approaches may include RFID-based integration or fully API-native architectures. Thirdly, the effectiveness of the IPA layer may be contingent upon the stability of user interfaces, the quality of QR data, and the digital maturity of partner organizations.

Consequently, future research should concentrate on:

1. Multi-case validation in other industries;
2. Comparative cost-benefit analysis against conventional ERP/WMS integration projects;
3. Quantitative measurement of operational improvements over a longer time horizon;
4. Extension of the model toward AI-based exception handling and predictive logistics control.

The particular characteristics of the automotive industry impose a number of stringent requirements on the IT architecture that supports supply chains. Such environments necessitate the implementation of sophisticated optimization algorithms and predictive systems that facilitate precise task scheduling and accurate identification of logistics operations. The IT architecture must be highly reliable, as even short-term system downtime may generate significant financial losses resulting from production stoppages. Concurrently, flexibility is imperative to facilitate expeditious process reconfiguration in response

to potential disruptions, as well as integration with other IT systems using available technological solutions that enable more rapid and cost-effective implementation.

A high degree of automation is of particular importance for the efficiency of logistics processes, especially in the identification of logistics resources such as products, materials, and components, as well as in the registration of logistics operations, including deliveries, picking, warehouse activities, and orders. Manufacturing companies in the automotive sector utilize a broad spectrum of sophisticated IT systems that facilitate optimal logistics performance. However, it should be noted that these systems are typically built on different platforms, developed in different technologies, and based on diverse IT solutions. Despite their demonstrated efficacy in the domain of internal logistics processes, these entities are constrained by their inability to integrate with the IT systems of disparate supply chain partners.

The integration of IT systems has been shown to be a costly and time-consuming process. This challenge is further compounded when multiple systems, or even a dozen systems, must be connected. There is a broad consensus within the automotive industry that such integration is both necessary and highly desirable. It is evident that solutions which facilitate IT system integration, and which are especially designed to reduce the cost and complexity of these processes, are both necessary and highly valuable. This is not only the case in the automotive sector, but also in other industries.

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