Application of Radio Frequency Identification in Intelligent Distributed Manufacturing System

Aliakbar Akbari

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Prof. Dr. Elvan Yılmaz
Director

I certify that this thesis satisfies the requirements as a thesis for the degree of Master of Science in Mechanical Engineering.

Assoc. Prof. Dr. Ugur Atikol
Chair, Department of Mechanical Engineering

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Master of Science in Mechanical Engineering.

Prof. Dr. Majid Hashemipour
Supervisor

Examining Committee

1. Prof. Dr. Majid Hashemipour
2. Asst. Prof. Dr. Sahand Daneshvar
3. Asst. Prof. Dr. Ghulam Hussain

ABSTRACT

Radio-frequency identification (RFID) has become a remarkable technology among industrial manufacturers to enhance automation systems. It provides the unique identification number with conforming international global standards for each tagged item which is monitored or traced. RFID system competes with other automated identification devices e.g. barcode scanners and smart cards with regard to high speed scanning, reliability and accuracy.

The purpose of the current study is to propose a reference model based on RFID application for the process control of industrial distributed system in order to enhance productivity, efficiency, utilization as well as decreasing idle time. The reference model is composed of production and assembly systems which are integrated with RFID system. In addition, the real time data monitoring, allocated to activities of tagged products throughout the manufacturing cells, was illustrated with the purpose of satisfying operation types.

Three cases were simulated for measuring performance of the system in the Petri Net Toolbox which portrays graphical scenes in the MATLAB programming based on the mathematical modeling. The first case represented the impact of RFID in the mixed mode manufacturing system. The second case demonstrated the comparison between RFID and barcode reader. It also contributed the benefits driven by RFID to improve system performance. The last case presented the comparison model between RFID and Wireless Sensor Networks (WSN) for the process control of distributed system.

Keywords: Radio-frequency identification (RFID), intelligent system, distributed manufacturing system, Petri Net

ÖZ

Radyo frekans tanımlama (RFID) otomasyon sistemleri geliştirmek için sanayi üreticileri arasında kayda değer bir teknoloji haline geldi. Bu takip veya takip her etiketli öğe için uluslararası küresel standartlara uygun olan benzersiz bir kimlik numarası içerir. Diğer otomatik tanımlama cihazları, örneğin RFID sistemi yarışıyor yüksek hızlı tarama, güvenilirlik ve doğruluk ile ilgili barkod tarayıcıları ve akıllı kartlar.

Bu çalışmanın amacı, endüstriyel dağılımlı sisteminin proses kontrolü için RFID uygulama üretkenlik, verimlilik, kullanım yanı sıra boş zaman azalan artırmak amacıyla dayalı bir referans modeli önermektir.Referans modeli RFID sistemi ile entegre, üretim ve montaj sistemleri oluşur. Buna ek olarak, imalat hücreleri boyunca etiketli ürünlerin faaliyetlerine ayrılan gerçek zamanlı veri izleme,, tatmin edici bir işlem tipleri amacı ile izah edildi.

Üç olguda matematiksel modellemeye dayalı MATLAB programlama grafik sahneleri canlandıran Petri Net Toolbox sistem performansını ölçmek için simüle edilmiştir.İlk durumda karma mod üretim sistemi içinde RFID etkisini temsil etti.İkinci vaka RFID ve barkod okuyucu arasındaki karşılaştırma gösterilmiştir. Aynı zamanda sistem performansını artırmak için RFID tarafından tahrik fayda sağlamaktadır.Son durumda dağıtık sistem proses kontrolü için RFID ve Kablosuz Sensör Ağları (WSN) arasındaki karşılaştırma modeli sundu.

Anahtar Kelimeler: Radyo frekans tanımlama (RFID), akıllı sistem, dağıtık üretim sistemi, Petri Net

To My Family

My Father and Mother

My Beloved Brother

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Chapter 1

INTRODUCTION

Currently, automated identification technology, which encompasses a diversity of devices such as optical memory cards, barcodes, smart cards and etc., has developed to facilitate wide range of processes among industrial manufacturing systems. By its implementation, the human errors which may happen during the system can be increasingly decreased. Automatic identification system is one of the best methods referred to recognizing target objects automatically. Furthermore, required data about the objects is captured and entered into the system in order to be utilized in a convenient time.

Radio-frequency identification (RFID) is a sort of competent automated technology which has been playing an increasingly important role by establishing intelligent system in the manufacturing processes, industrial management, warehouse management system, and supply chain management. It provides the unique ID number related to the stuff and wireless communication between readers and tagged objects by using radio frequency waves to transfer data. Meanwhile, it has the ability to retrieve, store, and recall information concerning the particular item in the database.

In the most applications in industry, RFID system is preferred rather than other automated identification technologies such as barcode scanners due to high speed scanning, accuracy, timely information, and reliability [1].

RFID is a complicated system and consists of wide variety of jobs including part tracking, inventory control management systems, identification of part diversions, counterfeit protection, as well as faster retail checkout systems [2]. The main benefit of RFID driven in the manufacturing is to trace and record movements and positions of objects on the RFID application software accurately. Although various methods may be used for tracking goods by automated devices, a unique serial number or ID number indicating related information about products is offered for identifying items or objects by means of RFID system [3].

In the past years, high value assets might be tracked by operators manually. Thus, the risk of loss would arise since stuff is not located on its place appropriately. Moreover, traditional tracking objects led to increasing outcomes and labor costs. Regarding this issue, firms could not satisfy their customers [4]. RFID technology enables the real time to asset tracking in the supply chain and warehouse management. As an illustration, in tracking assets in the value chain, RFID is capable of providing real-time visibility induced to cost saving and enhancing efficiency with delivering process between multiple nodes by automated identification numbers [5].

Nowadays, industrial companies seek to implement the automated distribution systems for the purpose of manufacturing processes based on systems intelligence. In the absence of intelligent systems, diversity of problems, comprising of real time data traceability or real time data monitoring of objects, may arise in such a manufacturing type. Therefore, systems cannot be automatically updated for performing further required processes once different decisions have to be carried out in accordance with characteristic objects. RFID technology is one of the automated devices that it enables intelligent system to dominate such problems. RFID system is also capable of integrating with the whole flexible manufacturing equipment to send allocated commands to the relevant destinations.

The main object of the present study is to propose the reference model including production and assembly systems based on RFID system for the distributed industrial processes. It determines distribution of products types in order to improve system performance. Moreover, the real time data monitoring will be elaborated by applying RFID system to display activities of tagged objects crossing through various terminals for the industrial manufacturing systems.

Chapter 2

LITERATURE SURVEY ON RFID SYSTEM

2.1 Introduction

This section will present different applications of RFID system considered in various areas. The vital role of RFID will be investigated for manufacturing industries. They are included in different fields of manufacturing such as production or assembly systems, warehouse management systems, and also supply chain.

2.2 RFID Applications in Manufacturing

Different applications of RFID have been discussed in the last decade. The novel passive RFID tag was investigated in the oil drill pipe aiming that they could predict the lifetime of pipe and manage inventory control [6]. In a discrete manufacturing system, RFID system was applied in production control in order to enhance the quality and management level of production efficiency. RFID detected the product during the producing stages and information could be updated in the database. Therefore, manager could check the status of products in real time [7].

A new Kanban management system in Lean manufacturing based on RFID was proposed to enhance Just-In-Time production mode [8]. The benefit of RFID technology in the emerging wireless internet manufacturing area was pointed out [9]. Applications of RFID in assembly line have been reported and the role of RFID for vehicle production was highlighted [10].

Through these applications, the concept of agile management based on RFID system was taken into account in a manufacturing area to track and monitor assembly equipment [11]. In a random mix automotive manufacturing, the automated production system for welding processes by a robotics assembly cell, corresponded to RFID by capturing data, was discussed [12]. Reconfigurable assembly systems was then investigated by this research to represent the enhancment of flexibility.

The novel concept of RFID in the distributed multi agent system with logistic control was applied in the manufacturing environment so that the explicit and reliable manufacturing operation monitoring could be acquired at each station. One of the essential problems which may occur in the production stage is to lose several products during the process. The framework RFID-based was investigated how to enhance the precision of products traceability [13].

The production control system based on the holonic control scheme with the RFID system was conducted to minimize expenses and lead time [14]. This study demonstrated the capability of updating RFID tags once they were delivered across the production line in order to satisfy any changes at workstations.

The method was elaborated related to shop floor automation and factory systems [15]. In addition, a framework, which made possibility to transfer appropriate information immediately by integrating of RFID, was proposed in the manufacturing area. This research also presented the benefit of RFID system to capture critical manufacturing parameters and store them on the local storage system.

The application of RFID technology was conducted for industrial management systems to improve tracking objects in granular production flows. By applying RFID technique, growing of quality and productivity was achieved [16].

Performance of RFID-based manufacturing system was elaborated [17]. Comparison of RFID and different kinds of barcode scanners were described for automatically tracking activity of objects. It presented the benefit of RFID system to enable quick tracking of materials and also, many features of it were explained in detecting operation policies, improving the performance of system. Finally, the system was simulated and its output was shown how the barcode device made poorer performance rather than RFID system. The real time control system by means of RFID system was pointed out for manufacturing execution system (MES).

The substitution of RFID to manual data transaction for one kind of production companies (OKP companies) was emphasized with the purpose of facilitating precise and spontaneous data capturing. As a case in point, a real life project in Guangdong Greatoo Molds Company was illustrated to depict adaptive control system by developing RFID system [18].

The framework of enterprise application, which was capable of being integrated with RFID, was offered to trace and control dynamic manufacturing operations in the shop floor environment. Moreover, this framework provided a reference model for semiconductor manufacturing area to enhance the shop floor monitoring in order to improve quality of operations [19].

Moreover, the framework was presented to influence the manufacturing operation as well as production quality by using item level information visibility [20]. RFID was developed into dynamic manufacturing system aiming to provide monitoring of work in progress (WIP) quality [21].A case study was simulated and its performance was measured in Colored Petri Net (CPN) program. The main benefit of this program involved supporting complexity of manufacturing system to indicate throughput of system under different job working.

The framework with integrating of RFID hardware and software services was recommended for distributing proper information through the collaborative manufacturing alliance. The main aim of this study was to overcome problems comprising of financial matters and technical risks which might happen during the collaboration [22].

The production management system (PMS) with RFID system was highlighted on the basis of real time data capturing for Locin motorcycle assembly line which is a kind of mixed model assembly system [23]. The real time PMS enabled some characteristics including synchronization of information flow and control of assembly workstations.

2.2.1 Warehouse Management Systems

The advantages of RFID were demonstrated in the production line and warehouse management through 3D modeling. Moreover, a specific model for warehousing operations was proposed [24].

The real time location system (RTLS) by employing RFID means and Wi-Fi communication was illustrated for warehouse management system (WMS) in manufacturing [25]. A case study was given in automotive manufacturing and production. Regarding this issue, the quantity of materials was located at particular places in order to be retrieved in allocated time and also, they were covered by reference tags embedded at specified places. Furthermore, several readers were fixed at each zone. This study contributed the method which represented errors reduction for delivering needed materials to various stages.

The role of RFID system was considered for the purpose of warehouse operations in management system. The main aim of this study was to satisfy the utilization of warehouse resources [26].

Integrating RFID in warehouse systems was taken into account in order to handle many types of processes [27]. This research explained how to determine the position of objects with RFID tags in order to make information sharing among warehouse resources. It also depicted the enhancement of warehouse processes by providing system monitoring. A real case study was given for the GSL Company to validate an improvement in visibility of diverse warehouse processes.

2.2.2 Supply Chain

The use of RFID system in management of enterprise internal production by using a remote monitoring system in supply chain was offered in order of providing transparent information concerning objects. The network using the wireless communication over the internet was also established to classify goods information flow and send data to relative destinations or terminals. This application contributed to enhance management efficiency as well as decrease cost in the manufacturing [28].

The RFID implementation in automotive manufacturer was analyzed [29]. The findings proposed the mathematical model for cost instructor in supply chain and investigated a case study how total costs could be decreased on the basis of RFID system.

The potential use of RFID and its obstacles were highlighted in supply chain networks. The aim of RFID system application in such an area is to control the total system costs as well as increasing the customer service level. Suppliers also have to take some risks of this technology into account which might happen in accordance with applications [30].

Chapter 3

RADIO-FREQUENCY IDENTIFICATION

3.1 RFID System

A typical RFID system is comprised of a reader, tags, antennas, middleware, and application software. Tags, attached to target objects, have an internal memory where all information concerning the object can be stored. Moreover, the exact location and status of each item can be tracked by receiving signal through RFID tags. An RFID reader corresponds to tags in transmitting radio frequency signals via antenna and subsequently, RFID application software is needed to monitor the data [31]. Figure 1 demonstrates the overview of RFID system.

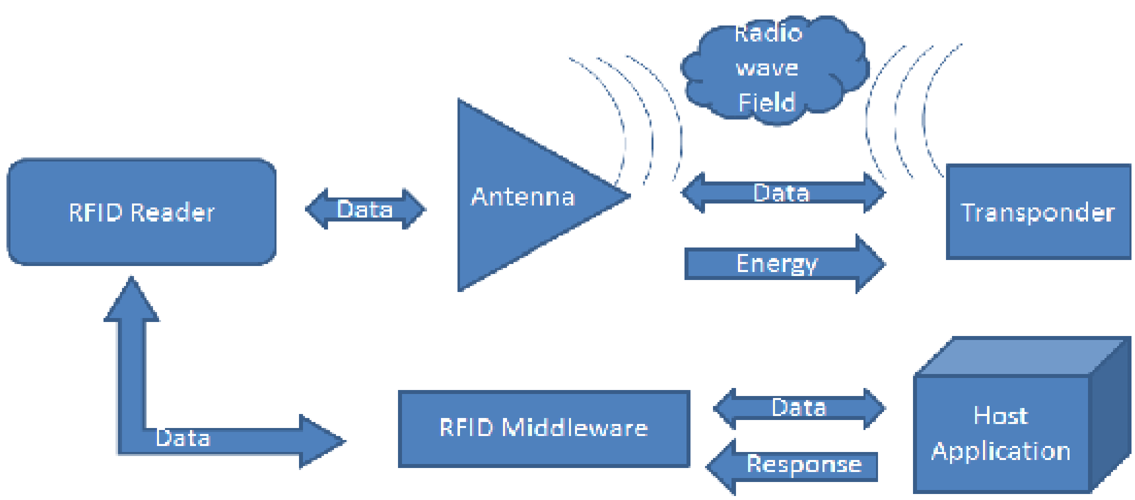

Figure 1: An overview of RFID system

RFID system can be used in various classes with variety of applications. As a case in point, the sorts of tags and readers, which are capable to track objects in the supply chain management [32], are different from the ones used in emergency medicine [33]. One of the most substantial RFID system features in industry and manufacturing places is to recognize error messages which may occur during processing. Stepwise, all objects are identified and traced by the integrator. Therefore, with RFID reader software, status of each object can be displayed.

Figure 2 demonstrates a type of RFID system which is applied by the present study in the manufacturing system. Two parts are specified as the green part and the red part. The green part is conveyed to the first station and the red one is sent to the second station. Once each part passed across the first gate, which has an RFID antenna, data is transmitted to the reader. The reader supports several ports in order to be connected to different gates. The RFID application software and middleware manage data and communicate with stations. Tagged products are defined to the RFID application software for detecting which part type is passed across the gate. Therefore, it communicates with stations to enable related controller. When parts approach workstations, the robots pick and place them to the machines.

When all transactions are processed, both parts are taken on the conveyor and goes through the second RFID gate. Consequently, all processes, which were completed on the parts, may be recorded and generated with the certain ID number on the database by the RFID system.

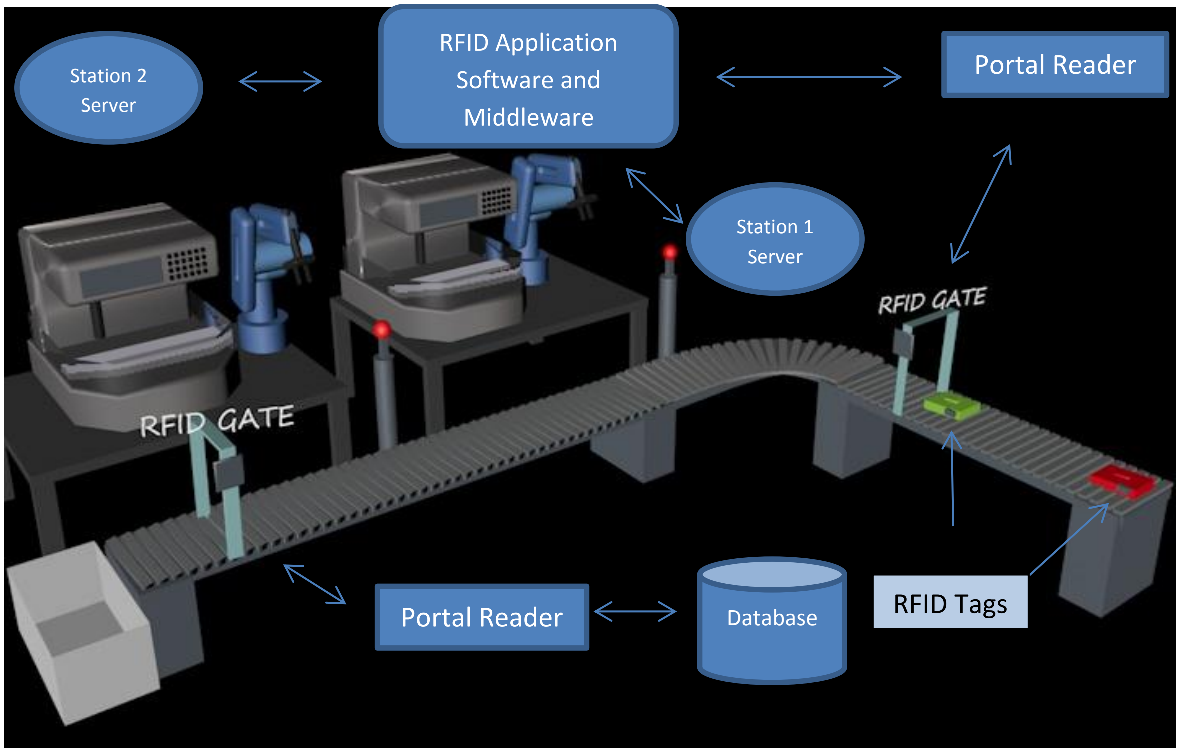

Figure 2: A type of RFID system in the manufacturing

3.2 The RFID System Components

3.2.1 RFID Tags

RFID tags or transponders, which consist of a receiver and transmitter, make possibility to send out and receive data. They have the unique serial or ID number defined to the RFID system and data on the tags can be encoded by the RFID reader in order to display all information about the objects. An internal memory, which information are recorded, is embedded on specific tags, so during special applications, data can be updated and stored automatically. Figure 3 depicts a common RFID tag which consists of chip and antenna.

Types of tags are categorized into four segments as follows:

- A passive tag uses an integrator's radio wave as a source of energy to make a communication with an interrogator. The range of frequency which has to be detected is finite. Passive tags can be found cheaper, smaller, and lighter than other types of tags.
- An active tag, which has an internal battery as a power source to run the circuitry of microchip, communicates with the reader via RFID gate. Active tags are larger and more expensive and can be detected at wider distances than other types of tags. Higher frequency tags are usually used for particular stuff and places such as baggage tracing in the airport.
- A semi-active tag is a type of active tag and can be woken up by signals received from the reader. On the other hands, they are in sleep until they can be awaken by radio waves from the interrogator. Semi-active tags can be detected by reader in a greater distance than passive tags the same as active tags.
- A semi-passive tag does not require receiving energy from interrogator or reader, so it can be woken up by battery to power on-board circuitry. Semi passive tags may act similarly to sensor tags since the battery is used to power the sensor. Ordinarily, in diversity of applications, semi passive tags have more functionality as compared with passive tags due to possessing more power [24].

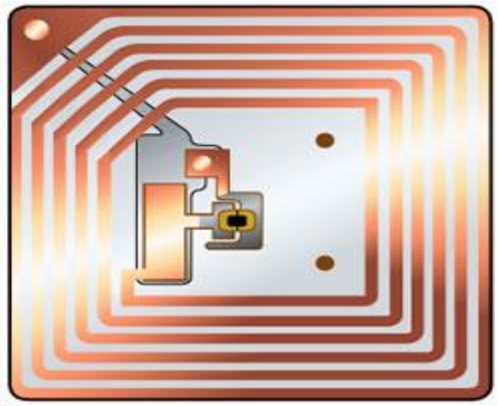

Figure 3: A common RFID tag

Tags are designed to be applied in a variety of applications by their having capability including memory, security, rang of frequency or privacy protection mechanism. In some cases, tags either can be inserted within the objects or attached to objects. Since tags are attached to the items, they are more endurable to inconvenience conditions such as humidity, dust, or excessive temperature. Thus, they are needed to be considered where they are going to be used before applying.

Memory: tag's memory provides limited space where tag's information is retrieved and stored. Memories are classified within three categories that data is just written once and it is read by any time, data can be read only or data may be modified or re-written in the memory by an interrogator. Moreover, they have the ability to be integrated with environmental sensors to record vibration, temperature, or humidity which can be decoded and displayed by the RFID reader.

Security: tag provides cryptography and password protection. By adding security mechanism to the tag, data and all private information are kept confidentially and the lock command is needed to extract information. This functionality of tags also is supported by international organization standards.

Privacy protection mechanism: tags conform the unique command called kill command to disable permanently traceability as well as ability of tags. When the kill command is activated, any access to the tag and its memory will be prevented automatically. This command is used to deactivate all accessibilities to the tagged objects before they sell to the consumer.

3.2.2 RFID Antennas

Transmission data between RFID tags and the reader is performed by the antenna which is displayed in Figure 4. As it was mentioned earlier, the range of frequency for passive tags, which has to be tracked, is limited. Since they are activated, all information about the tags can be transferred to the reader via antenna [1]. Furthermore, it is capable to update required information which is sent from the reader to the tags and data can be rewritten on the tags through antenna.

Figure 4: An RFID antenna

3.2.3 RFID Readers

The basic component of RFID system is an interrogator or reader. It reads the certain amount of data from the tags which is received by antenna and writes data to the compatible tags [31]. RFID readers are classified according to type of application. Handheld readers enable implementers to access items at different positions of work and track required tagged objects by a wireless communication. Furthermore, they are ideal devices used for asset tracking in the supply chain management or other areas. Portal readers are great devices to be applied in various applications that wide range of frequency is going to be recognized and provide several ports where RFID antennas can be connected. For instance, 8-Port Gen 2 RFID reader supports up to 8 inputs and outputs for 4 pairs antenna [34]. Fixed readers are adequate for objects traceability through dock doors, conveyors, and etc. RFID readers' modules in small size are designed to be inserted in the products in the manufacturing area. Figure 5 shows various sorts of RFID readers used in different applications.

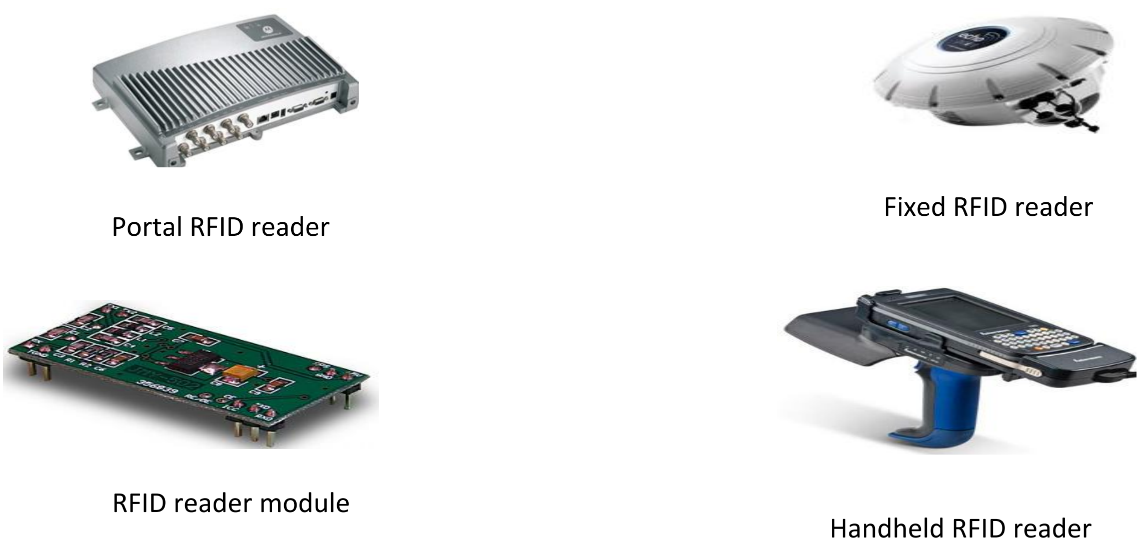

Figure 5: Types of RFID readers

3.2.4 RFID Middleware

The ordinary RFID middleware refers to set of software or devices in managing data captured by physical RFID devices to the application software. It provides aggregating, filtering and approving raw data in order to hide redundant data in the application interface [35].

3.2.5 RFID Application Software

RFID application software is a kind of independent software assigned for running instructions. It functions and collects data transmitted by transponders through RFID middleware. The application software then performs synchronization mode based on real-time tracking of tags locations among the system for updating information in the database.

3.2.6 RFID Printer

RFID printer is a generic printing device whereby data is encrypted on the RFID smart labels and also, it allows to print barcodes, text or alphanumeric characters on labels. The innovative RFID printers meet the high reliability of read/write for kinds of smart labels as well as high quality of performance and accuracy. They support to write, read or modify either class 0 or class 1 RFID chips. They are generally distributed by stationary and mobile printers (see Figure 6) that both of them may be connected to the application network and capture data by Ethernet or wireless.

Since all data were transferred completely to the local network, items are prepared to be sent for labeling by the RFID printer. Afterwards, parameters are needed to be defined for the printer and next, data is transferred for printing on a label design. Consequently, properties of content, encoded through the tag such as name of object, manufacturing date and etc., are visible on the label design.

Fixed RFID printer

Mobile RFID printer

Figure 6: RFID printers

3.3 Electronic Production Code (EPC)

Electronic Production Code is a universal number indicating identity of physical objects and conforms GS1 standards for tracking items in the world at once. Each RFID tag holds the unique ID number called Electronic Production Code which is the significant for the RFID identification in the global network. The EPC is read via RFID antenna by readers which are connected to the global network where the EPC can be stored [36].

EPC global divides RFID tags into 5 classes with regard to writing and reading data and their capability [37]:

- Class 0 (READ ONLY): This class is the first and ordinary kind of tags which are only programmed in the factory of manufacture tags and have the simple identification number (EPC). During process in the manufacturing area, data can be written just a time into the tag. Next, their memories would be disabled to accept any more updates. Class 0 is also named anti-theft or electronic article surveillance (EAS) devices as well. In this case, their attendance may be reported in spite of the fact that they are not detected by any ID numbers.

- Class 1 (WRITE ONCE READ ONLY or WORM): Typically, the current class is used for elementary identification. Not only can they be programmed by the factory, but also data can be written by RFID users into the tags once. On the other hand, tags are produced with the memory in which no information may be stored. Then, the data is recorded into the tags memory without further updating to be saved in memory; therefore, tags can only be read during the application process.
- Class 2 (READ -WRITE): In this case, users are allowed to write and read data into the tags memory. They commonly act as data loggers. In addition, further space is available in order to record further updates.
- Class 3 (READ -WRITE with sensors): In this case, on board sensors are embedded into the tags to record parameters which are stored in the tags memory such as motion, temperature, and pressure.
- Class 4 (READ/WRITE): Tags are integrated with transmitters and act to communicate with other devices among the system through radio waves. The most substantial benefit of these kinds of tags is that RFID reader is not required to capture data from tags, so they use battery power source to be active the whole time.
- Class 5 (READ/WRITE): All capabilities of class 4 are included and then, these tags also have the ability to correspond with passive tags.

The EPC global network is classified as follows [36]:

- EPC Discovery Services
- EPC Security Services
- Object Naming Service (ONS)
- EPC Information Services (EPCIS)

The major aim of EPC global is to consider suitable cheap on tags in terms of storing amount of data on them. Types of class 0 and class 1 of EPC global tags are sorted into 4 sections and consist of 96 bits in length. For instance, the part produced with "01.000A89.00016F.000169DC0 "EPC represented by Figure 7 [38]:

1) "01" shows the header section related to the content.
2) "0000A89" identifies a manufacture number.
3) "00016F" is a group of products or product.
4) "000169DC0" is a product serial number. It can be included a device like a laptop or any material else.

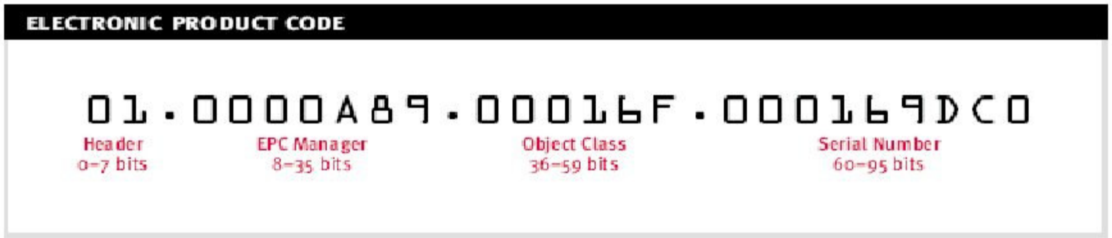

Figure 7: The EPC layout contains of 96 bits in length [37]

3.4 Comparison of RFID System and Barcode Technology

This section illustrates the comparison of RFID technology and barcode device and investigates how RFID overcomes barcode in many areas by demonstrating its ability. Both RFID and barcode scanner identify items based on ID number. At beginning, items are scanned and identified by devices and next, data would be monitored in the host computer for further process. However, it is not affordable RFID can be replaced completely instead of barcode technology according to cost increasing.

The significant differences between RFID and barcodes are explained as follows:

- Barcode scanner is usually mounted at the position and requires a light of sight to scan the identification number. On the contrary, RFID technology detects objects without any direct contact by using radio waves captured by the reader or antenna.
- RFID system identifies tagged items at wider distances, while barcode devices need to read the tag's ID number less than approximate fifteen feet.
- The rate of parts tracking by RFID system, which processes more than dozens of tags at a time, is much faster than barcode, so barcode scanner is ineffectual in many applications that instant traceability is needed due to time-consuming.
- Barcode readers do not provide to write/read data in tag's memory. Conversely, data can be smoothly updated in the RFID tags as much as needed by the interrogator.
- Barcodes need to obtain the product's information one after another notwithstanding the fact that RFID traces multiple tagged items simultaneously.

- RFID may be successfully applied to harsh environment, but barcodes cannot be exposed in such case. Therefore, it withstands against of rough situations including humidity, high pressure, dust or extraordinary temperature.

Chapter 4

INTEGRATION OF RFID IN DISTRIBUTED MANUFACTURING INTELLIGENCE SYSTEM

4.1 Introduction

This chapter will investigate the employment of RFID system for the distributed intelligence system in manufacturing. Firstly, a brief explanation about manufacturing types will be described in conformity with system flexibility. Secondly, the infrastructure of manufacturing intelligence and a reference model with integrating RFID system will be proposed. Finally, the impact of RFID will be elaborated for system monitoring.

4.2 Distributed Manufacturing Intelligence System

A distributed manufacturing intelligence system is defined as an automated manufacturing system to capture and deliver amount of data simultaneously and automatically by use of wireless or wired communications among the system. It provides variety of processors and devices which are integrated one another or operated independently. The real time performance of each manufacturing cell can be observed so that implementers determine inconsistency concerning equipment in the shop floor. Manufacturing intelligence is also used for smart devices such as wireless sensor networks or even RFID system to monitor the status and movement of objects in places or terminals. It may be divided into two segments including production and assembly systems.

A flexible system involves flexible manufacturing machines and devices such as robots, CNC machines and automated storage and retrieval system (ASRS) which have the ability to integrate together in order to operate different functions.

A production system is composed of manufacturing devices or equipment whereby raw materials are going to be produced and sequential process, which are considered for each manufacturing cell, executes required commands. Furthermore, there are wide varieties of operations including chemical or mechanical operations allocated to corresponding parts.

An assembly system is a set of organized treatments and consists of assembly equipment for performing the last manufacturing operation on the materials. Products are categorized and determined which ones can be added to other parts in terms of producing final parts. In the interim, simultaneous works are carried out by automated systems along the assembly line.

4.3 IT Infrastructure of Manufacturing Intelligence System

Intelligent manufacturing system consists of four main layers as shown in Figure 8. They refer to physical layer, middleware layer, application software layer, and also backend enterprise application layer.

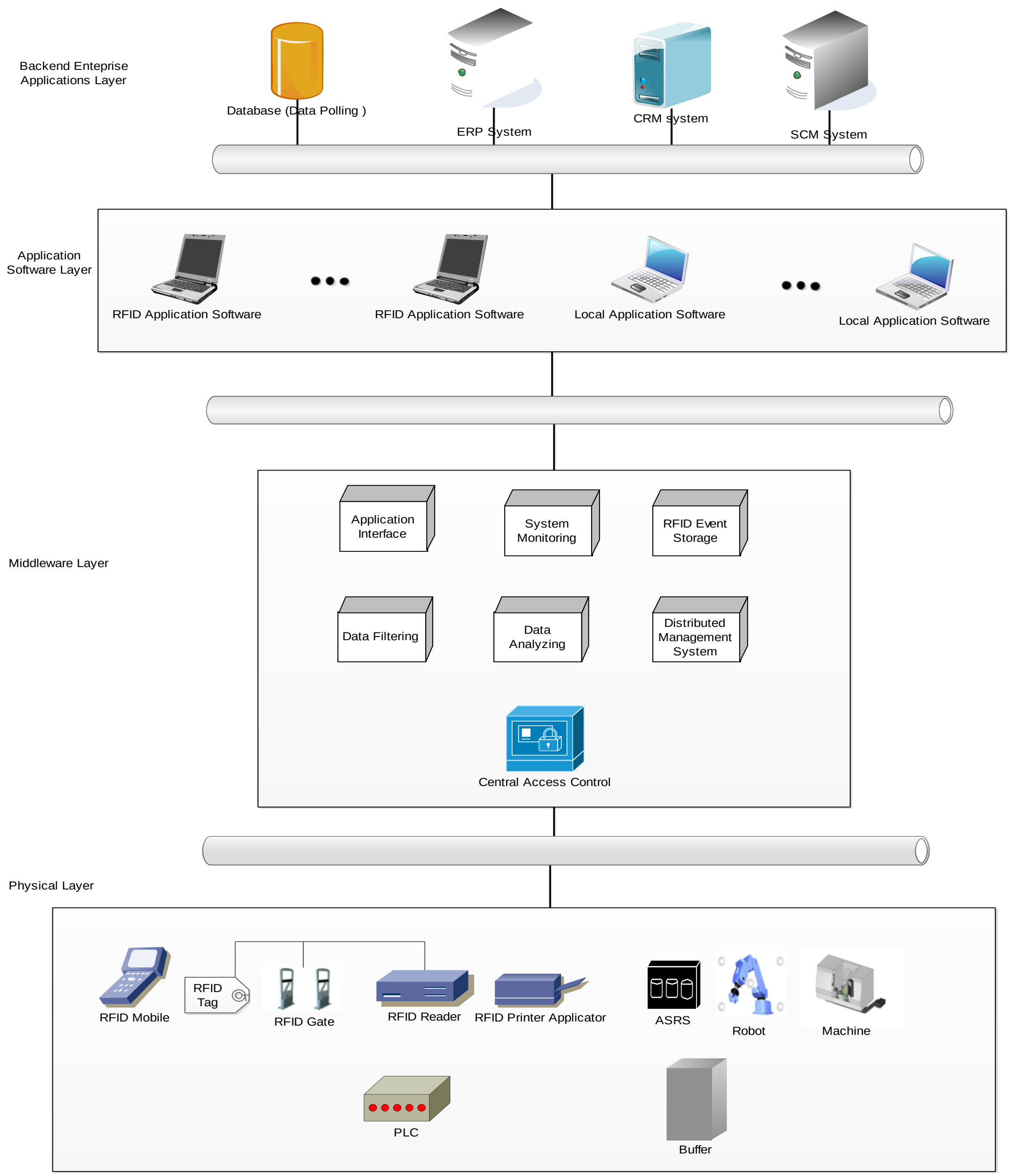

Figure 8: Architecture of manufacturing intelligence system

4.3.1 Physical Layer

A physical layer includes a wide diversity of devices which have the ability to correspond together and perform multiple tasks and also, they may have own computing functionality. Integration of such devices in the shop floor cerates the flexible manufacturing system.

In this layer, wireless communication should be provided for receiving signal along RFID system or any smart devices.

Physical Layer Components:

These devices are described as follows:

1) A programmable logic controller (PLC)
2) An automated storage retrieval system (ASRS)
3) Different type of manufacturing machines and buffers
4) An RFID system which consists of RFID tags, reader (handheld or fixed), gate and printer
5) Robots

A PLC, which is a digital device, is connected to robots and other machines to control them when appropriate decisions are made. An ASRS is a kind of automated storage system that has an own robot to pick the part and place it at the particular location based on instructions. It can be integrated with RFID to determine the exact place of each tagged part. There are different types of manufacturing machines to accomplish operations on products with regard to their abilities. In this study, flexible types of machines are considered that they can be reconfigured and integrated along manufacturing devices to perform processing. As the RFID system was utterly elaborated throughout the third chapter, a typical RFID system is composed of tags, reader and gate that gate and reader are connected to each other to receive signal through RFID tags. At the end, RFID printer applicator can label tags' properties on the products.

4.3.2 Middleware Layer

Overall, a middleware layer encompasses of software or devices that take place among application software layer and physical layer to develop better communication. It supports hardware and establishes an interface in order to manage information coming from hardware and transfers data to the upper layer.

Middleware Components:

The middleware layer contains the following components:

- Data filtering: It classifies and filters raw data captured through devices in the physical layer to relevant applications software in terms of preventing to transfer redundant data.
- Data analyzing: Processing raw data is performed by the analysis of data section. It is responsible to highlight useful information for other parts of manufacturing sections.
- Application interface: application interface is generally used to communicate along software in which data is going to be delivered. It also makes essential requests from upper level by associating of the application software layer with the middleware layer.

- Local data storage: This place stores necessary information related to the physical devices or RFID system.
- System monitoring: It can be integrated to the local data storage that collects information entire the distributed system. System monitoring makes possibility to show the status of system or objects as well.
- Distributed management system: It collects data and controls full resources in the distribution system to determine various functions for different hardware devices via control system.
- Central Access Control: It is a kind of control system that interacts with different sources in order to be carried out the command which is required for devices.

4.3.3 Application Software Layer

An application software layer provides autonomous software for the physical devices to cater data which is needed for any kinds of sources. It may be generally divided to two categories including local application software of devices and RFID application software.

The vital tasks or functions are assigned to each application software when they can be executed at specified time. The RFID application software adopts to fulfill instructions which are considered for each type of tags class. Once data is transmitted to this part, RFID software not only delivers appropriate data to the backend application layer, but also writes new information on the tag's memory by integration with the middleware.

4.3.4 Backend Application layer

A backend application layer refers to servers or corporate systems in which input is entered to the system by implementers or requests are made by other sections of manufacturing infrastructure in order to be processed or monitored. The main goal of backend system is to align disparate systems.

Components of Backend Application Layer:

This layer can be comprised of enterprise database system (EDS), enterprise resource planning (ERP), customer relation management (CRM), and supply chain management (SCM).

1) Enterprise database system (EDS): An EDS is the central storage system on the enterprise layer where the whole information can be stored and organized. It then permits users to manage, modify or achieve information inside the database system.
2) Enterprise resource planning (ERP): An ERP system is defined as a management system which can be integrated with the software to supervise flow data. In addition, it allows employees to control many aspects associated to manufacturing orders, human resources, sales and etc. In fact, it facilitates to gather the whole information of departments into an enterprise.
3) Customer relation management (CRM): It generally provides the organization for interacting essential information among the company, clients and sales aiming to enhance profitability, quality and efficiency and to reduce costs in the company. A CRM system receives and analyses pertinent data through the organization and dispatches it to the relevant destinations.

4) Supply chain management (SCM): An SCM system strives to cover all activities of raw materials and final products across the supply chain by establishing a management network.

4.4 Process of RFID System

RFID system process may be classified into four steps as depicted in Figure 9. Firstly, the data collection is performed by stationary RFID readers (portal readers) through the tagged objects or devices. Secondly, collected ID data can be filtered which means to prevent from storing the redundant data received from the vast number of tags on the database and next, corresponding data is processed and analyzed by the RFID middleware in order to monitor the objects status as well as performing the logical process. Thirdly, appropriate decisions are made and finally, events are generated in order to run appropriate commands.

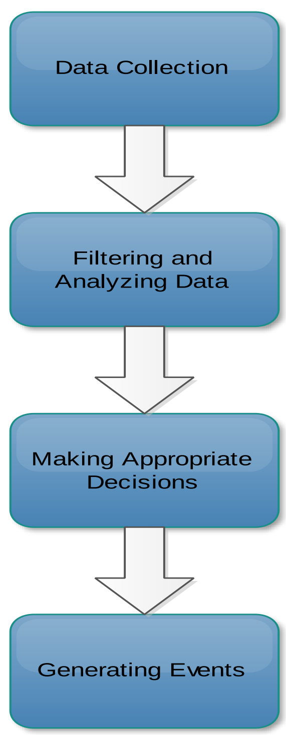

Figure 9: RFID system process

4.5 Integration of RFID System in Manufacturing Reference Model

The reference model is proposed to handle different jobs in the complex production and assembly systems with integrating of RFID system. The aim of current model is to use distributor control system technique based on RFID in order to mitigate bottlenecks or follow the instructions which can be determined by users throughout the system and enhance the flexibility of the system.

Figure 10 and 11 indicate the whole components of manufacturing reference model in both assembly and production areas. Initial buffers are places where different types of raw materials can be accumulated. RFID gates are installed beside machines, stations as well as decision making points. Interim buffers and kinds of machining devices, which has the flexibility to be integrated with the system, may be considered at workstations. Flexible machineries support multiple functions and they are also capable to be reconfigured to process on different products kinds. All workstations can be integrated with RFID antennas in order to specify status of stations. Furthermore, at the end of production cycle, an automated storage system is placed to store completed products. At the assembly stage, assembly stations are assigned to assemble different products types transferring through the production line. In addition, output and temporary buffers also retain number of products in order to be carried to the assembly station.

4.5.1 Procedure of Manufacturing Reference Model

Cumulative different types of tagged products, which are located on the initial buffers, are going to be distributed to the workstations in accord with detecting routs' levels defined to the system. RFID system operates to adjust the number of parts dispatching to the destinations by processing raw data acquired from stationary RFID gates. It then prevents from any interruption in conjunction points. Afterwards, Products are transferred through the distributor systems in order to be processed by further stations. The operation of machining by workstations may occur in different steps. Interim buffers are placed beside each work stations to hold products which may overstep of certain routs' levels.

After parts prepared through production stage, they are stored on the automated storage system or can be transported to the assembly area. This process is performed by means of RFID based on logical process. In this step, RFID system identifies the status of each part in order to be sent to the selected workstation. In addition, the distributor system as a decision making point, which an RFID gate is mounted, is considered to enable products to be transferred.

In several assembly cases, some products, classified in the same type, will be divided into several specified cells. As an illustration, the number of products type A are conveyed to the assembly station No.1 and the rest of products with the similar type are taken by assembly station No. 2. In this occasion, the RFID system detects the queue length of products throughout the buffers to arrive at assembly places according to workstations operation time. Thereupon, decision making point is enabled to distribute products to the convenient assembly lines.

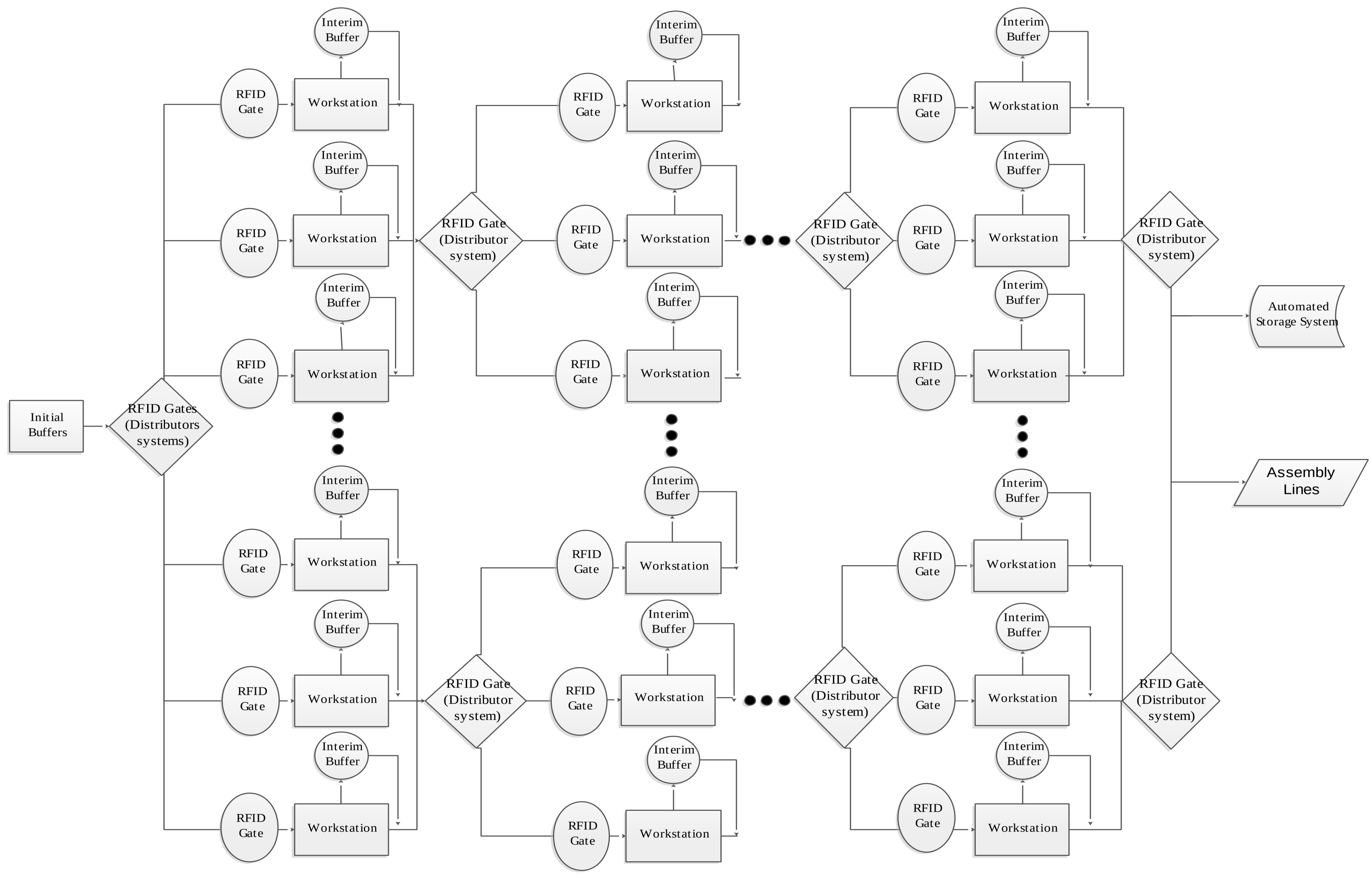

Figure 10: Components of production system

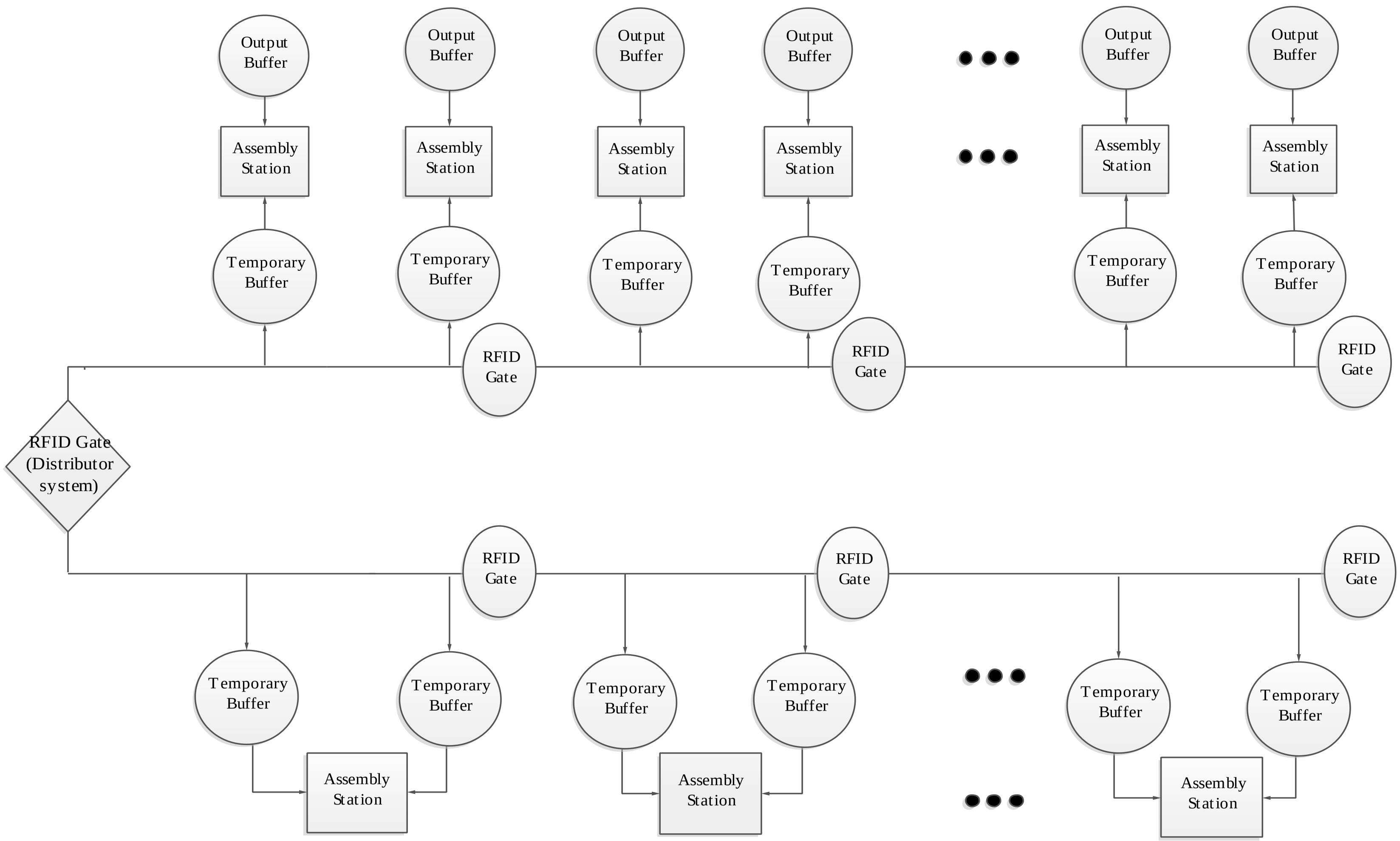

Figure 11: Components of assembly system

Figure 12 depicts the algorithm which RFID reader conforms (among workstations and initial buffers). After distributing a part, a reader collects the required data captured by the RFID gate. Allocated parts are identified by corresponding gates according to their sorts. Thereupon, a reader computes the number of parts placed on the path. It then compares all routs connected to the workstations throughout the transportation lines as long as the routs' levels would be satisfied regarding the priority. The appropriate rout can be detected in order to be selected the conforming part.

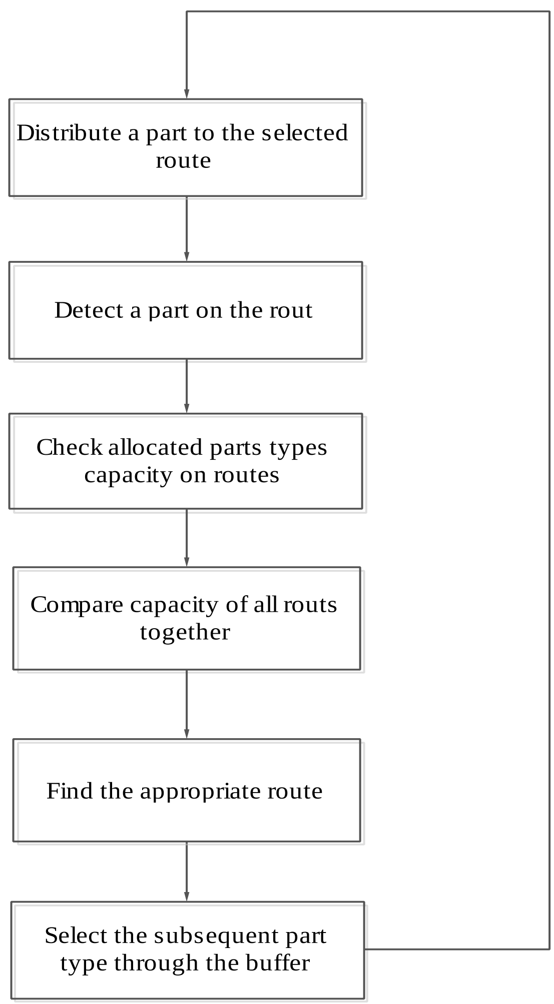

Figure 12: RFID algorithm for the first step distributors

The procedure of dealing data in the distributor control system for each step among workstations, containing flexible machines, is explained in Figure 13. A Part, conveying to the decision making point, is going to be distributed to the related lines. Therefore, an RFID reader functions to identify the classified products which are available on each path and checks routes on the basis of the parts types capacity. If the number of parts satisfies the routs' levels, products will be piled over workstations buffers unless the subsequent part is chosen in order to fill the capacity of transportation lines. Once products are placed in buffers, the quantity of parts again are determined if parts capacity is provided, parts would be selected through interim buffers.

4.5.2 Products Distribution Mode

Two types for distributing products are considered in the manufacturing reference model as follows:

4.5.2.1 Controlling Bottleneck Rate

In this case, the main aim of RFID system is to adjust rate of bottleneck in the temporary buffers which have met products congestion at production or assembly systems. RFID system can recognize the most occupied buffers by means of RFID reader to determine which one can continue parts upon the conjunction points.

In several manufacturing applications, the number of manufactured products types is not much significant. In this way, RFID control system attempts to recognize the buffer which may encounter with higher risk of becoming bottleneck. Thus, the selected buffer can be chosen where products are going to be dispatched.

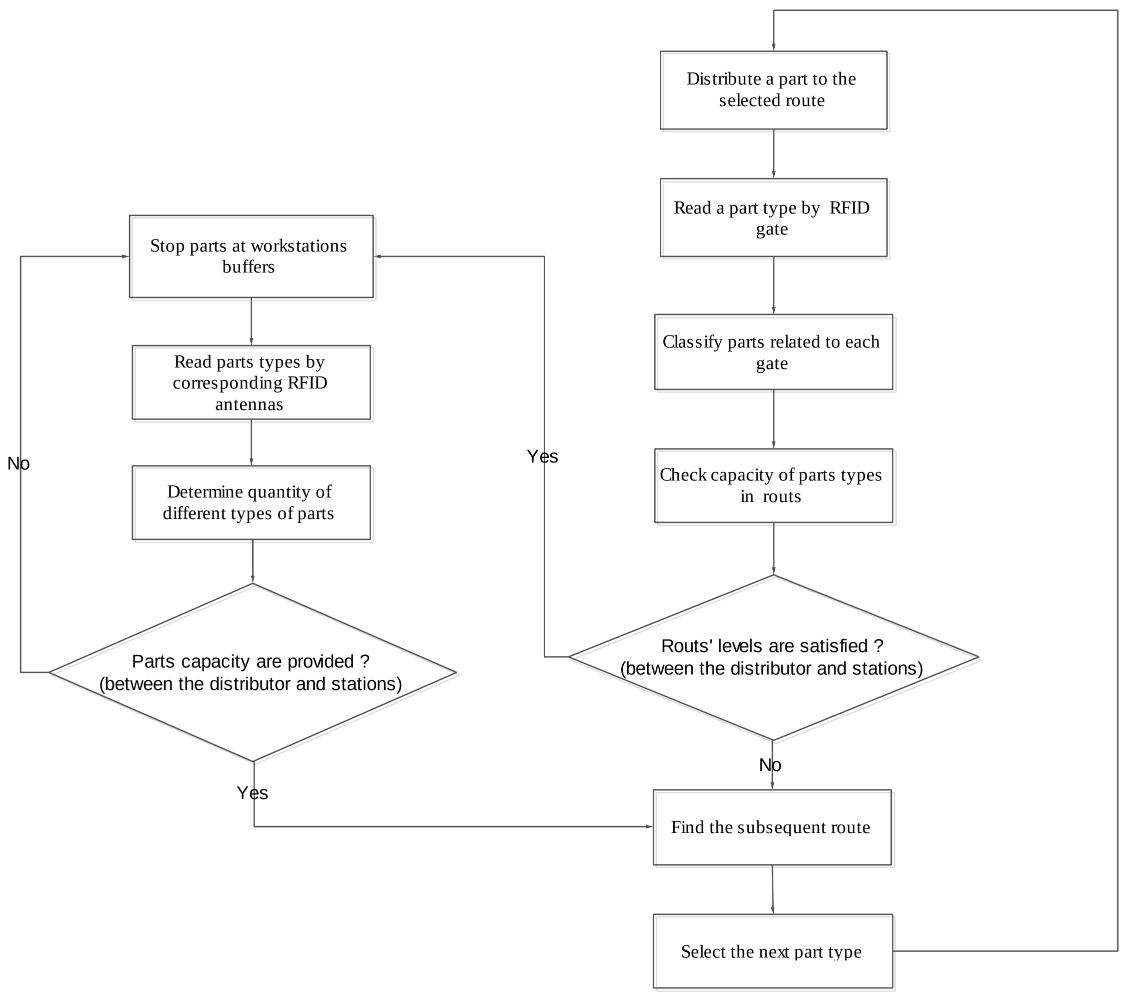

Figure 13: RFID algorithm for the distributor among workstations

4.5.2.2 User-Defined Instruction

In this case, RFID strives to manage various orders defined by implementers to select required products transferring through stations. Instructions are set and characterized to the RFID application software respectively. Since parts are lined up at temporary buffers, they have to be selected regarding the capacity of parts types in the lines.

In different applications, products should be provided at the definite level. This is because of either the certain parts, which are held in the assemble cells, are going to be assembled with the produced products, or the number of specified parts are going to be produced at the production stage.

4.6 RFID System Monitoring Using Traceability:

One of the most significant features of RFID system is to provide real time data monitoring to investigate variety kinds of parameters during the processing along the manufacturing systems. It also inspects the status of tagged items to identify and verify them once they arrive at terminals.

4.6.1 Manufacturing Process Monitoring based on RFID System

Instructions as well as information concerning products are written on tags in order to be retrieved in the following step. After the operation is performed at each stage, any further information or instructions may be updated on the tags. In this case, RFID readers/writers are integrated with workstations. RFID system then writes the related data on the tags as a successful or defective processing. If the prior operation was performed incompletely on the products, they travel to the subsequent workstations without being processed and they continue to attain to the repair station.

4.6.2 Tag Information Modeling

The ability of RFID system is to track thousands of tags and monitor many indices which are indispensable for objects. Tag information modeling can be divided into four subclasses including critical parameters, properties, time expended and status of products where a variety of parameters is sorted. All parameters concerning the information of tag modeling are depicted in Figure 14.

Environmental sensors may be integrated with RFID tags to sense and monitor critical parameters involving speed, pressure, temperature, humidity and vibration. As the functionality of RFID system was emphasized by the third chapter, memory unite is inserted in tags in order to record data retrieved or modified at desired time.

Products properties stored on tags can be presented by a reader thus, it is feasible to recognize which product number or class exists on the place. Product number is summarized to numeric characters and also, product class is depicted by alphanumeric characters.

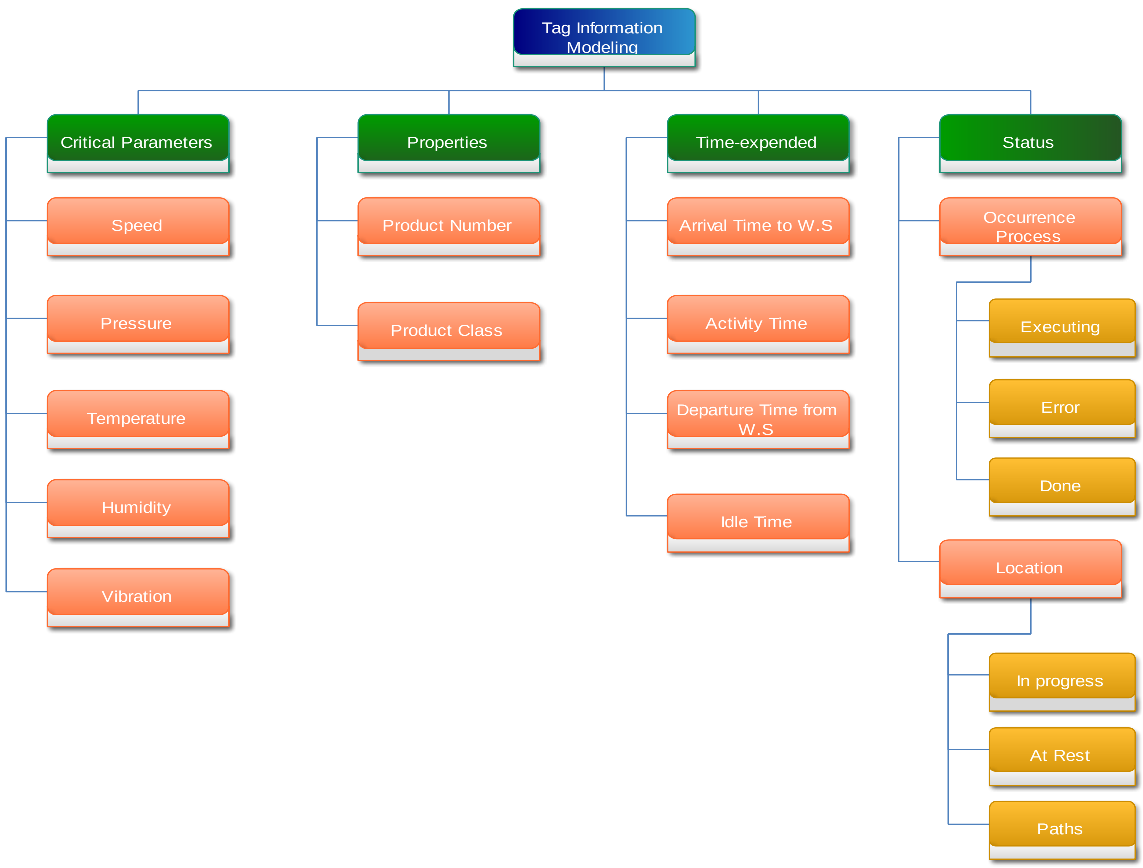

Figure 14: Tag information modeling

Time expended about tags can be obtained by RFID system communication. By attaching tags to objects, arrival time, departure time, idle time and activity time are recorded on the enterprise database. Arrival time and departure time display the time taking for tagged objects to come and departure through places respectively. Furthermore, activity time and idle time show how long objects are being used and they are waiting for the next work respectively.

Status of each RFID tag is investigated to be found out where tags are transferred as for occurrence process. For instance, tags are located on paths as long as they can approach to the destinations or they are in idle status and wait for the further response. Besides, as it was mentioned earlier, occurrence process is evaluated in order to emerge any error during the operation.

Chapter 5

CASE STUDIES

5.1 Introduction

This chapter will describe three case studies simulated in the MATLAB programming Petri Net toolbox representing the potential role of RFID system in the manufacturing system. First, the integration of RFID system with the production and assembly lines will be demonstrated on the basis of flexibility and intelligence in the distributed system. Thereupon, the significant difference of RFID system and barcode scanner will be evaluated. The aim of this step is to show the logical process performed by applying RFID instead of barcode to decrease wasting time. Finally, applications of wireless sensor networks and RFID system will be compared in order that characteristics of both of them can be determined.

5.2 Petri Net Toolbox

The Petri Net is a toolbox which provides mathematical and graphical tools to simulate and analyze a discrete event system (DES) in the MATLAB's environment. The aforementioned program is comprised of four sorts of objects including transitions, places, tokens, and arcs which can make connection between places and transitions [39].A number of manufacturing devices such as robots, conveyors, machines, and storage systems may be applied in the Petri Net environment. It, therefore, can measure the performance of manufacturing system and opens possibility to appear punctual results for each places and transitions by analyzing various factors.

5.2.1 Classes of Models in Petri Net

Several classes of modes are presented by the Petri Net toolbox. These are subsumed into five classes: the untimed Petri Net that transitions are fired to depart tokens without spending time at places and transitions; the T-timed Petri Net that time period is allocated to the transitions once tokens are going to be transmitted throughout the distributed system; the P-timed Petri Net which treats similar to T-timed, however, the time duration is set for the places; Stochastic Petri Net, which is known SPN model, enables the transition between conflicting lines with detecting the shortest time length; Generalized Stochastic Petri Net which works like SPN, whereas it provides timed and instant transitions [40].

5.2.2 Petri Net Global Statistics

Global statistics of Petri Net toolbox involves two types of indices related to places and transitions.

The throughput sum and arrival sum indices mean the total number of products leaving and entering in each source. The throughput rate and arrival rate display the mean frequency of products departures and arrivals. The service time index explains the operation time units per part takes to leave a source. The mean value of material, which queue to arrive at places, is shown by the queue length index. Utilization index also illustrates the status of sources which have been used. Throughput distance shows the average value of distance for output products [41].

5.3 Integration of RFID System in the Mixed Mode Manufacturing System

The current case study applies RFID system in the mixed production and assembly system, and the remarkable role of this technology is investigated in which variety of lots will be produced. In the present application, procedure of parts producing is fulfilled in two phases. Firstly, parts are manufactured in the production line and secondly, they travel to the assembly area in order to be completed as a final product.

5.3.1 Components of Production System

The first step, in the production line, an initial buffer is considered to deliver raw materials to the conveyor. Furthermore, seven workstations (W.S.) containing types of machines, interim buffers and arm robots are assumed that each machine performs machining just for one part at a time. Eleven RFID gates, which can capture amount of different data received through the tagged objects, are installed in the required points where logical process has to be defined so that products are sent to the appropriate places. They carry radio waves and monitor target objects in the software (asset master) as parts tracing as well. These gates are then connected to the RFID application software which executes various functions via readers. In addition, four decision making points, known as distributor systems, are designed on the conveyor to identify products by means of relevant RFID gates and readers. An ASRS, located ahead of seventh workstation, stores products to the determined spot.

5.3.2 Components of Assembly System

In the assembly area and the second phase, four assembly stations as well as six temporary buffers are positioned in the shop floor that lots can be located over temporary buffers and then, they are prepared for the assembly job. Six RFID gates also are fixed at the particular points to detect the parts classes with regard to logical process. In the final step, the shipment packaging and RFID printer are placed to launch products into the specified parcels in order of locating them on the storage system.

Figure 15 and 16 denote the sketch of manufacturing system in the present case study.

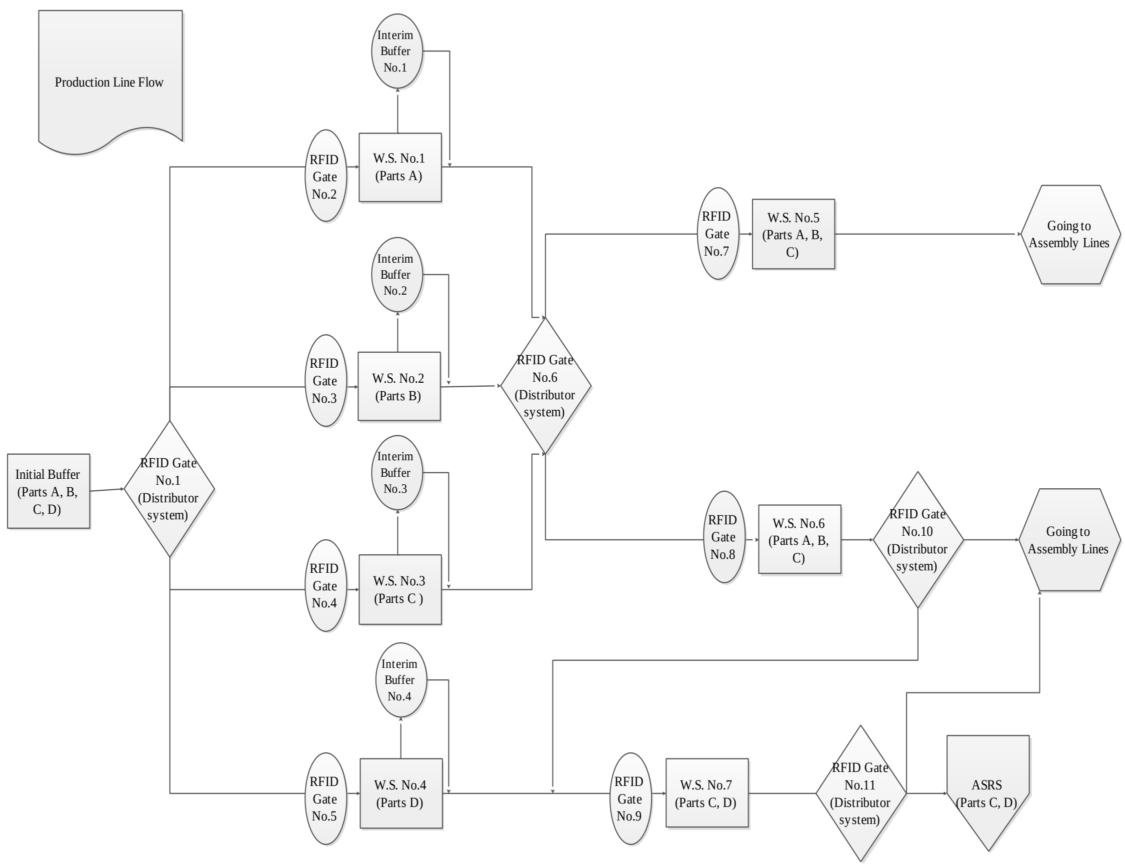

Figure 15: manufacturing production system layout

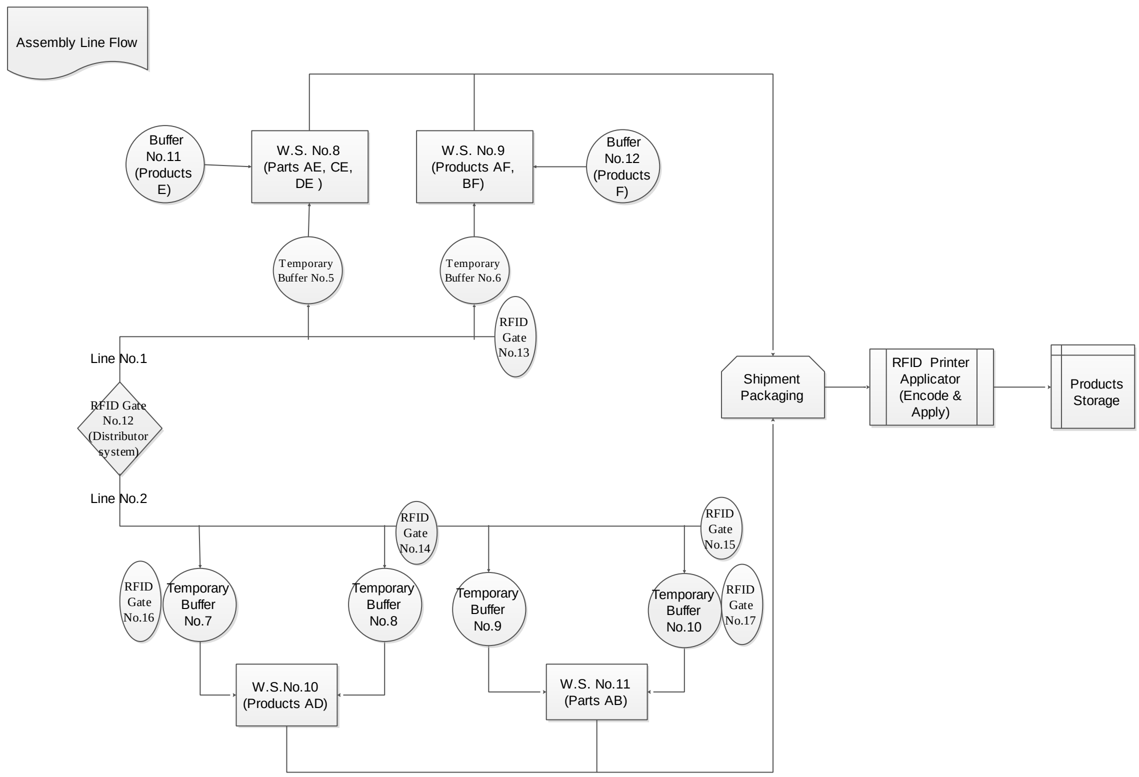

Figure 16: manufacturing assembly system layout

5.3.3 Process of System

First of all, different tagged products types, namely, products A, B, C, and D, are accumulated in the initial buffer that each one has a distinct route processing. After Products A, B, and C are processed thorough workstations No. 1, 2, and 3 respectively, they are mixed together and divided in both lines connected to fifth and sixth workstations. They are then prepared for the assembly step excluding products C transported to the workstation No. 7 in order to be stored in the ASRS. In addition, the identical processing is performed by workstations No. 5 and 6. In this procedure, products D are carried to the forth workstation and then, they are processed by the workstation No. 7. It is noted that the operation time differs for workstations. Status of each product type is updated at each workstation. In brief, Table 1 indicates how products types are distributed to the workstations respectively.

Table 1: Products' routs in the production line

Types	W.S. 1	W.S. 2	W.S. 3	W.S.4	W.S.5	W.S. 6	W.S. 7
Products A	✓	-	-	-	✓	✓	-
Products B	-	✓	-	-	✓	✓	-
Products C	-	-	✓	-	✓	✓	✓
Products D	-	-	-	✓	-	-	✓

When products get ready and travel to the assembly stage, they are going to be distributed to the specified assembly places for the final job. In this way, products A, B, C, and D are transported to related workstations. Finally, Products AE, CE, AF, BF, AD, DE and AB are obtained by different assembly workstations. Table 2 denotes how products are distributed to the different places and from which workstations they are forwarded in the production line.

Table 2: Products' routs in the assembly line

Products Type	Workstation 8	Workstation 9	Workstation 10	Workstation 11
Products A	Forwarded by W.S. 5	Forwarded by W.S. 6	Forwarded by W.S. 5	Forwarded by W.S. 6
Products B	-	Forwarded by W.S. 6	-	Forwarded by W.S. 5
Products C	Forwarded by W.S. 5	-	-	-
Products D	Forwarded by W.S. 7	-	Forwarded by W.S. 7	-
Products E	Forwarded by buffer 11	-	-	-
Products F	-	Forwarded by buffer 12	-	-

5.3.4 Process control of RFID in the distributed manufacturing system

As the control system was proposed for the RFID in the manufacturing distributed system, different types of products can be dispatched to the destinations based on the user defined instruction. The first RFID gate, which is installed on the distributor system, detects how products types are spread regarding capturing data by gates No.2, 3, 4 and 5. The role of RFID reader is to collect required data through corresponding gates and analyze it to command to the distributor system for delivering products classes by three to each workstation route.

Once lots are processed in primary workstations, they are determined either can continue going to the subsequent workstations or should be accumulated in the interim buffers. In light of this issue, the distributor system, integrated with RFID gate No.6, plays a substantial role to manage different lots which are going to enter to workstations No.5 and 6. Gates No.7 and 8 are associated to those products types placed downside of workstations No.5 and 6. They identify products according to routs' levels assigned for both lines. In this case, totally six kinds of products can be positioned at each path. The line, which is connected to the workstation No.6, consists of three products A, one product C, and two products B whose priorities are depicted by Figure 17.

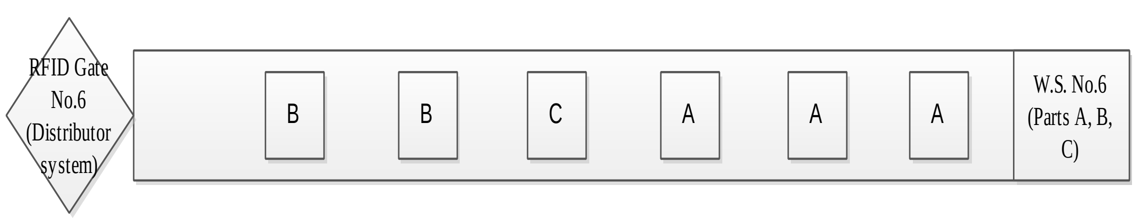

Figure 17: Products places for the W.S. 6

On the contrary, the next line, which joins the distributor to the workstation No.5, is comprised of two products B, three products A, and also one product C. Figure 19 shows the distributed products types to the current line.

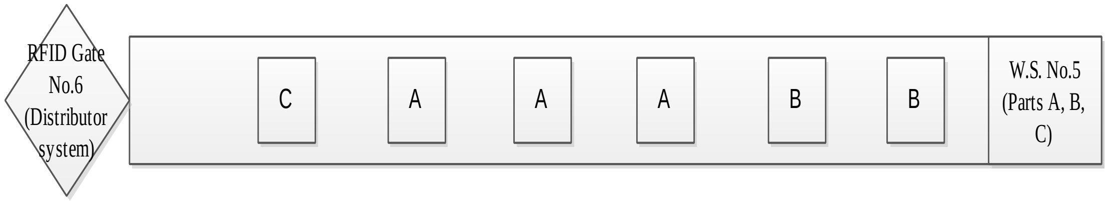

Figure 18: Products places for the W.S. 5

Since those lines capacities are completed, the controller, works based on RFID system, corresponds to primitive workstations as long as the rest of products are temporarily stored in the buffer. In this step, integration of workstations with RFID antennas benefits from specifying locations of different kinds of products in the interim buffers. Thus, accumulated products can be returned to the related paths after the transportation lines capacity is provided. Furthermore, gate No.10 distributes products A and B to the assembly cells and products C to the final workstation.

Gate No.9 allocates to support increments of counting products up to four lots behind the workstation No.7. Otherwise, they have to be kept in the fourth station buffer and wait for the further response. Finally, RFID gate No.11 identifies products C as well as selective products D loaded in the ASRS and lets other products D transport to the assembly lines.

At the assembly stage, RFID gates collaborate with each other via reader to choose the irregular products, entering to the assembly area, to the target destinations as for the stations condition. Distributing similar lots can be performed based on specific instruction. Gate No.12 is inserted in the assembly distributor system that makes communication with other gates throughout the assembly cells. Moreover, the distributor system displays the condition of products at the assembly entrance with the purpose of separating similar manufactured products type which crossed among diverse stations.

Gates, embedded on the conveyor, select different types of lots in order to be loaded in the certain buffers. Gate No.13 detects those specific types A, B, C and D which are forwarded by different stations to the eighth and ninth workstations and also, Gate No.14 selects types A and D processed by stations No.5 and 7, however, Gate No.15 identifies types A and B processed by stations No.6 and 5 as depicted over the Table 2 with their sequences.

In addition, gates No.16 and 17 are able to make logical process to determine the number of products placed in the temporary buffers. After detecting a product by gate No.16 which covers both buffers linked to the workstation No.10, it allows to the assembly distributor system to conduct other products to the eighth station. Therefore, once a product leaves these buffers (No.7 and 8), this gate lets the distributor send the related products to the current buffers. Once orders are completed for first and second assembly cells, other products can be placed in the tenth workstation buffers. The similar process can occur for the temporary buffer No.10 by gate No.17 despite the fact that totally types B, sent by W.S. No.5, are accumulated in the buffer No.9. At the end, after completed products will be transferred for packaging and labeling, they are stored at the particular places.

The goal of defining these logistic processes is to prevent workstations' machines from being kept in standby mode. In other words, if more products stay to arrive to both last stations, it leads lots put in a long queue at buffers due to high time operations and rest of machines remain idle at work without processing on a product.

5.3.5 Performance Measurement

The present case study is applied and simulated in the Petri Net which follows the mathematical modeling to come up with the performance of the system (See Appendix A).

Table 3 and Table 4 demonstrate all indices obtained by the Petri Net Toolbox model at production and assembly stages. This system was run for 225 products types and these tables represent how they are distributed to the workstations regarding specific operation time. Moreover, two service times are allocated for the seventh workstation because of different processing for types C and D. Based on the algorithm elaborated before, as can be seen, utilization of whole workstations reaches above 90% which is induced due to distributing appropriate products to the target destinations to gain the minimum idle time of system. Another benefit driven by RFID system is to control transportation line queue length not to exceed certain rate with regard to arriving various types of products to call or stop them on the path.

Table 3: Performance measurement of production system

Sources	Throughput sum	Throughput rate	Service time	Queue length	Utilization
Initial Buffer	225	0.011987	-	-	-
W.S. No.1	80	0.0042621	120	0.622	0.98306
W.S. No.2	50	0.0026638	200	0.63266	0.98945
W.S. No.3	30	0.0015983	320	0.60069	0.99371
W.S. No.4	65	0.003463	190	0.76159	0.98625
W.S. No.5	77	0.0041023	130	2.181894	0.94619
W.S. No.6	83	0.0044219	130	2.795946	0.97581
W.S. No.7	81	0.0043154	C200, D220	3.4698	0.94097

Table 4: Performance measurement of assembly system

Sources	Arrival sum	Arrival rate	Throughput sum	Throughput rate	Service time	Utilization
W.S. No.8	100	0.0053276	50	0.0026638	350	0.93245
W.S. No.9	78	0.0041556	39	0.0020778	300	0.95663
W.S.No.10	36	0.00191796	18	0.00095898	590	0.93202
W.S.No.11	56	0.0029834	28	0.0014917	470	0.97123

Table 5 indicates properties of different buffers located at workstations. Throughput sum provides quantity of collected products which enters and departs at different occasions. This table indicates no products temporarily stored at the second buffer, but buffer 4 recorded the most involved buffer with regard to waiting time. Buffers 5 through 10 are the interim buffers placed at the assembly area to keep products manufactured by the production system. Buffers 7 and 8 are allocated for selective types D and A. Buffers 9 and 10 are adopted to keep selective types B and A respectively. Both last buffers exhibit number of allocated parts which are going to enter to the assembly cells once required products become available on the workstations.

Table 5: Buffers properties

Sources	Throughput sum	Throughput rate	Waiting time
Buffer 1	21	0.0011188	78.381
Buffer 2	-	-	-
Buffer 3	13	0.00069259	368.3077
Buffer 4	52	0.0027704	2661.9231
Buffer 5	50	0.0026638	3573.12
Buffer 6	39	0.0020778	1002.1026
Buffer 7	18	0.00095898	403.5556
Buffer8	18	0.00095898	417.2222
Buffer9	28	0.0014917	678.5714
Buffer10	28	0.0014917	1440.9286
Buffer 11	50	0.0026638	9745
Buffer 12	39	0.0020778	6438

Figure 19 represents workstations versus number of products kinds. The first four workstations, recognized as normal stations, can receive a type of products. Among them, the most number of operations belongs to the first one by increasing the productivity up to 80 lots. Workstations 5 and 6 collect different types transferring by the distributor system which works based on RFID system. With regard to using priority defined to the RFID, Station 5 produced larger products B which is 28 parts although station 6 performs processing for greater number of products A up to 45 as compared with previous workstation.

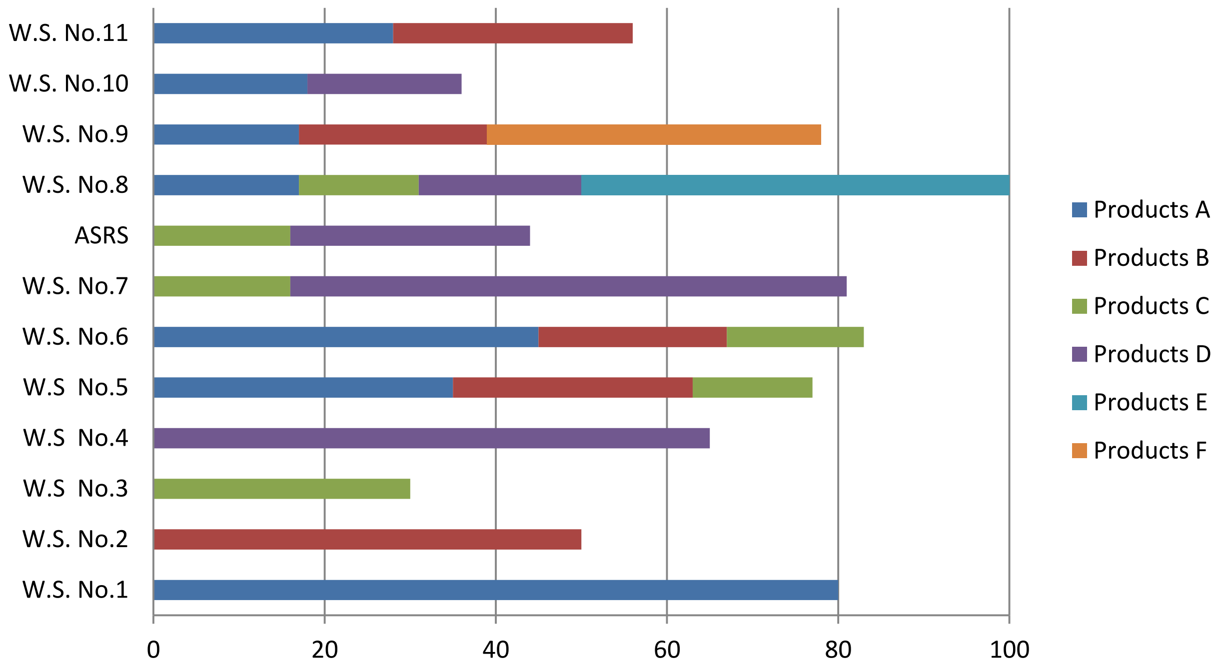

Figure 19: Lots distribution throughout the system

5.4 Comparison of RFID System and Barcode Reader for Manufacturing Processes

The significant role of RFID is investigated whether it can be a beneficial solution in the manufacturing system rather than barcode scanner. This section will elaborate all sequent works.

5.4.1 Case Description

In the present case, First of all, with regard to having prosperous implementation, the whole equipment has to be integrated with the RFID system. Four workstations including several robot arms and machines, whose 3D model is depicted in Figure 20, are considered that each station performs the discrete job. Two lines connected to the last workstation are known as conveyors buffers (temporary buffers). An automated storage and retrieval system (ASRS) is also obtained to remove raw diverse materials and leave them on the transportation line. Moreover, it associates with a computer for treatment and recognizes which material has to be placed respectively. At workstations, local computers (asset master), which are connected to related devices, are located to manage orders. RFID application software manages raw data as well.

All workstations are integrated with RFID antennas to retrieve new process on tags and to identify products waiting on the workstations. Furthermore, six RFID gates are inserted at particular places that each of them has an antenna which can correspond to the reader. They may detect the number of either inputs or outputs of parts to or from locations and send the data to the reader to communicate with the related controller in each workstation.

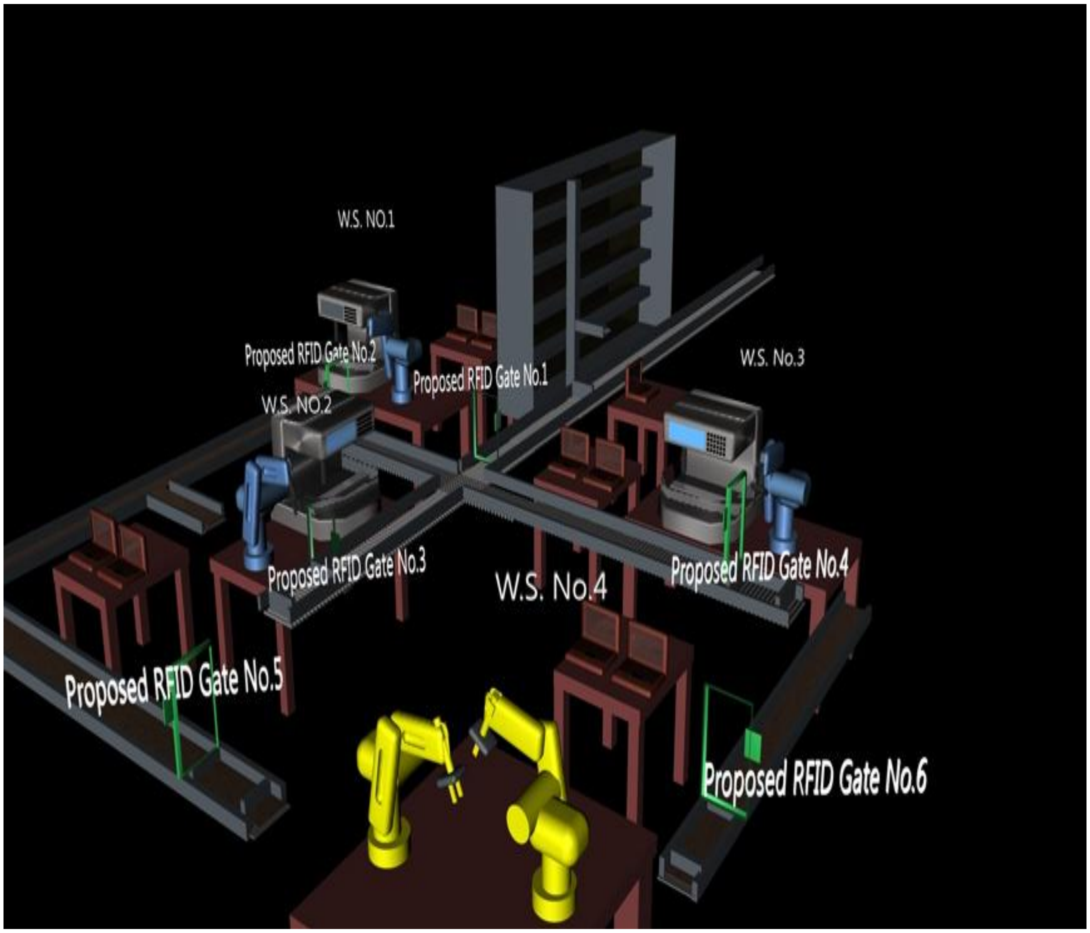

Figure 20: 3D model of production line based on RFID system

In the assumed scenario, two sorts of raw materials, namely, A and B, are going to be machined by three different machines in order to be prepared by the assembly cell (W.S. No.4). Unique tags are embedded on products after they are transferred to the manufacturing area. In addition, all products types should be discerned to the RFID system until parts can be carried to the appropriate places. There are three distinct routs that parts A taken to the workstations No.1 and 2 and parts B conveyed to the third workstation.

According to the capacity of conveyors buffers, the maximum numbers of products, which may temporarily stay on each conveyor, are seven. Products type A, staying in a queue line before assembly cell, are divided by 4 parts being processed by the first workstation and 3 parts being processed by the second station. It is assumed due to different user defined operations time. As a result, these restrictions buffers can be similarly considered as routs' levels of products for related paths which may differ in time. This logic is assigned owing to preventing products are overloaded in the path.

5.4.2 Process Control of System

At the beginning, when the system starts running, products B as well as A are respectively loaded on the conveyor by the ASRS based on the priority defined to the system. The first RFID gate detects the status of products tags and sends them to the workstations. RFID gates play an important role in departing products through the ASRS. Gate No.4 identifies products B located on the path and gate No.6 then detects products B waiting on the path in order to approach to the assembly station. Both gates and related antenna can detect products B up to reaching seven products. Therefore, RFID system permits to the ASRS to leave a new part B on the conveyor as long as the required capacity is achieved by related gates.

The repetition process has been taken place for other gates. Once the level of each workstation is completed, RFID system calls another product based on the priority from the ASRS in order that the capacity of stations are satisfied. At each workstation, the related robot picks the product and locates it on the machine or the assembly place; furthermore, operations time differs at each workstation. Figure 21 elaborates the entire production line proceeding.

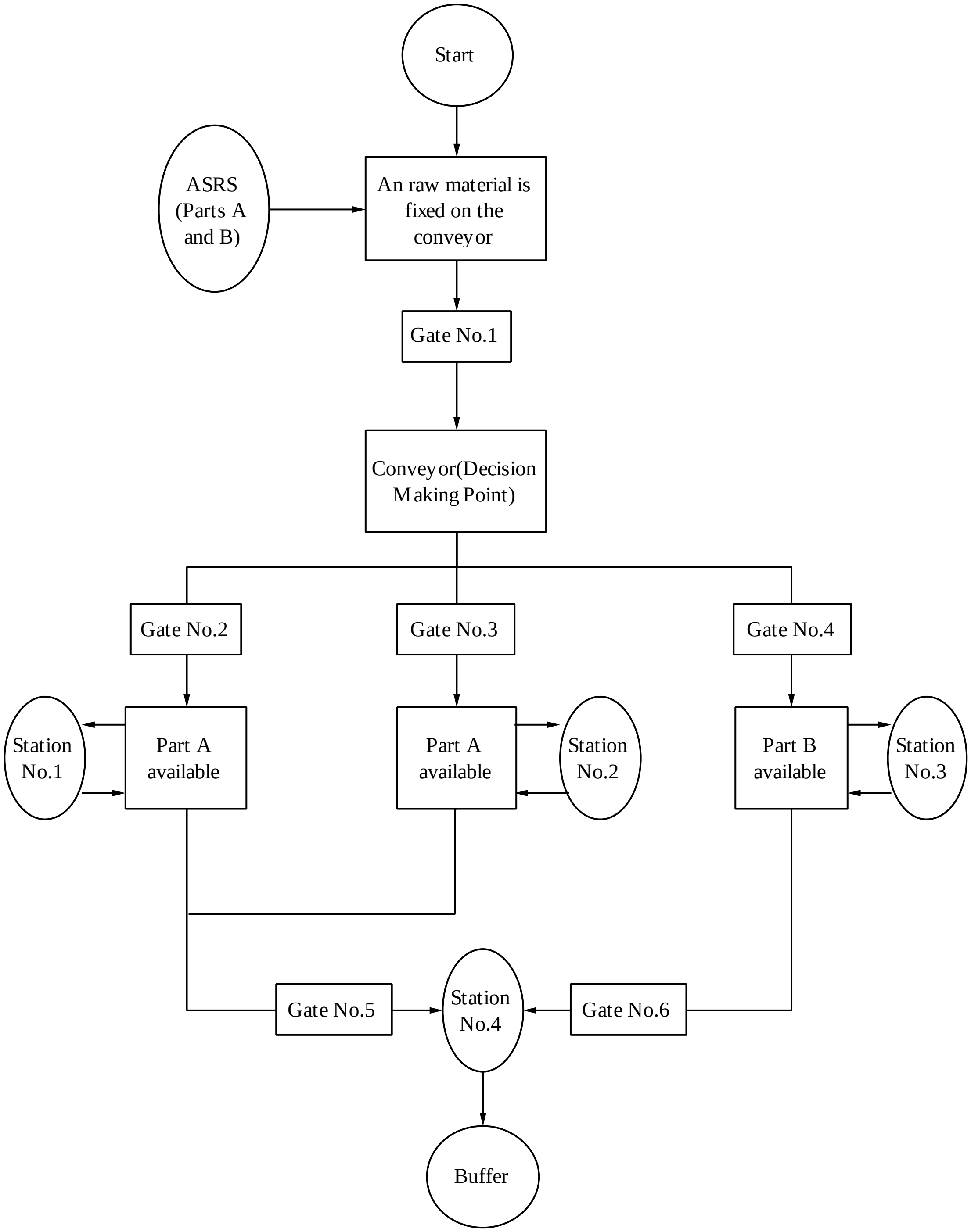

Figure 21: Description of production line proceeding

The logical process has been programmed for the reader to determine which route and part can be distinguished. Figure 22 shows the flow chart of this method among RFID system and ASRS. It explains variety of stages of the process accomplished by the RFID system. Table 6 presents all of the parameters introduced to the RFID system.

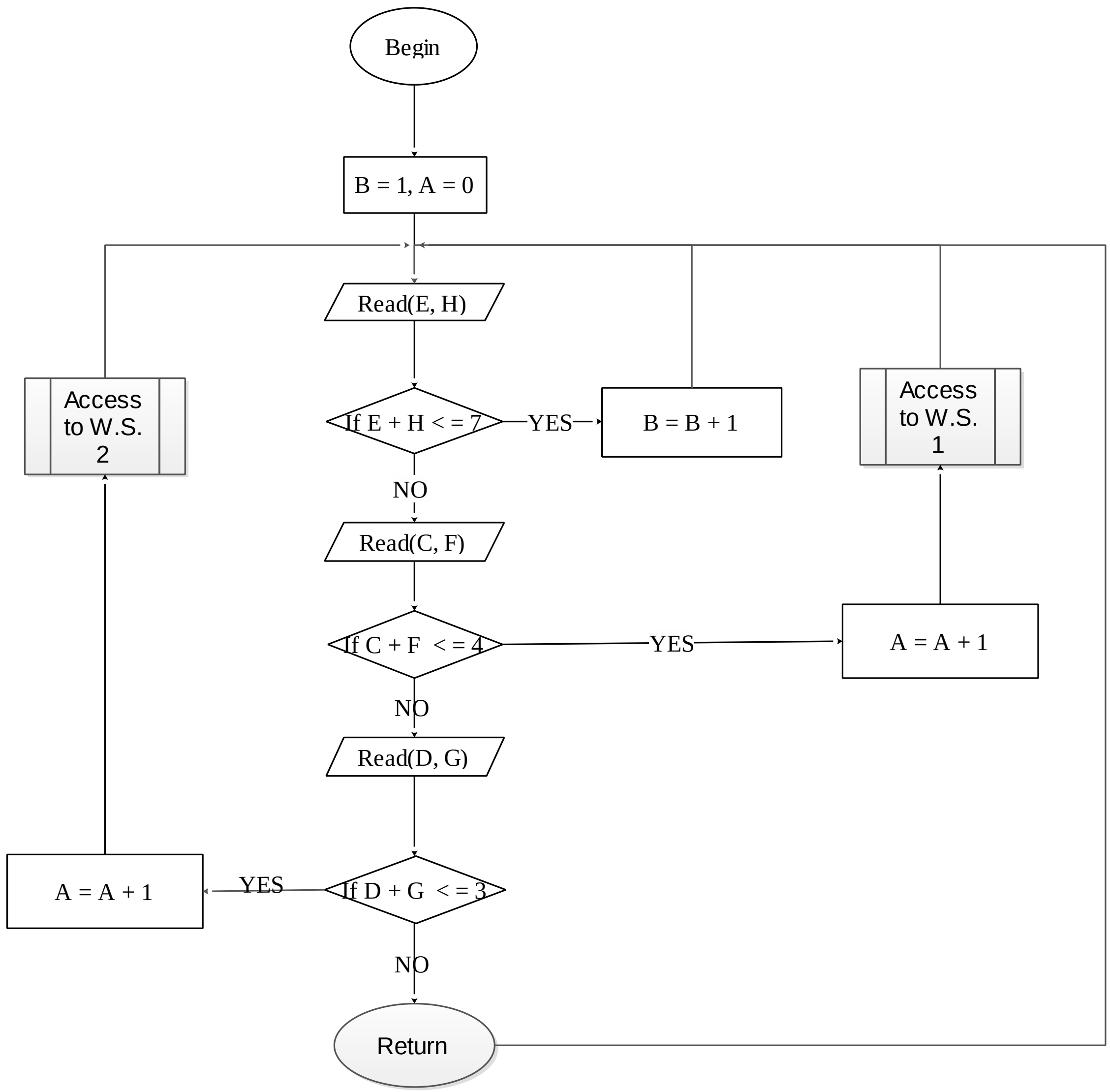

Figure 22: Flowchart of programming for the RFID system

Table 6: Description of Variables

Variables	Description
A, B	represent the number of products types A and B which depart from the ASRS
E, H	number of products which are detected by gates 4 and 6 and related antenna
D, G	number of products which are detected by gates 3 and 5 and related antenna
C, F	number of products which are detected by gate 2 and 5 and related antenna

5.4.3 Process Control of System based on Barcode Reader

In case of barcode scanner, the certain number of barcode devices is applied instead of RFID gates to detect ID number of different products in order to be transported to the related destinations.

The barcode reader, which is installed at the decision making point, identifies the type of product by its barcode number and sends it to the relevant workstation. After detecting a part at the decision point, the controller matches the product type with the related workstation and checks the status of station whether it remains idle or not. Consequently, the product can be transported once the station becomes ready. In addition, the status of assembly cell is determined. When it stands at idle mode, the product can be transferred to the station. Otherwise, it should wait in the current workstation in order that the assembly station ends the job.

5.4.4 Performance Measurement

Two cases were compared by the Petri Net Toolbox in the MATLAB software with the similar situation. Figure 23 and 24 show the RFID and barcode system Petri Net model respectively and Table 7 and 8 describe all places and transitions.

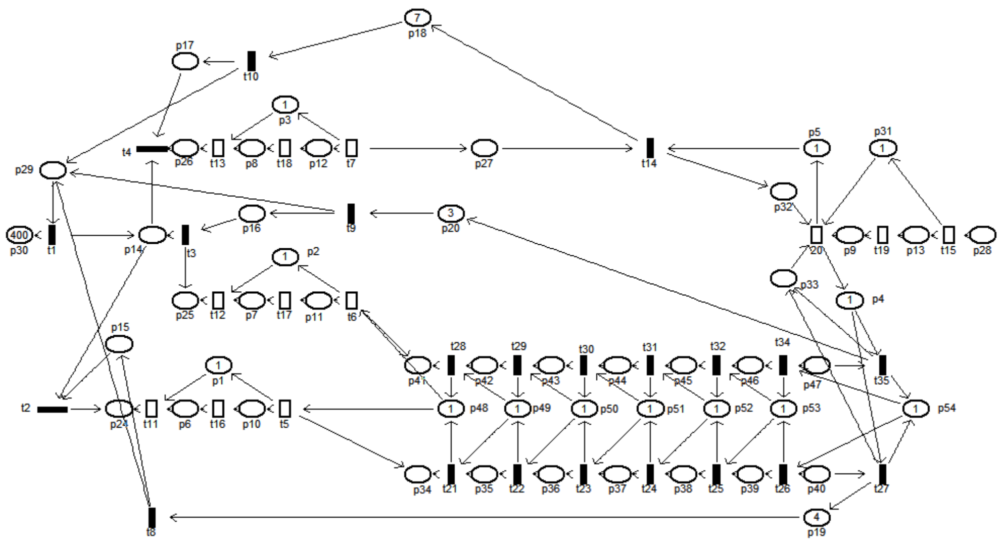

Figure 23: Petri Net model for RFID

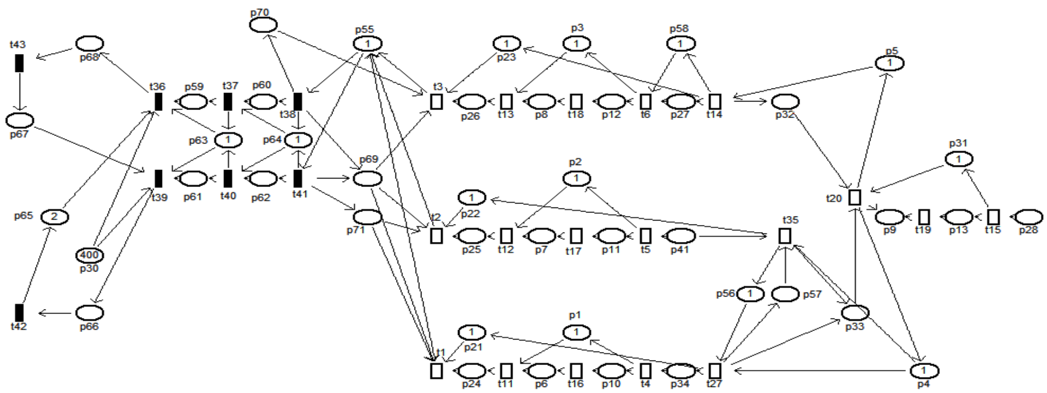

Figure 24: Petri Net model for barcode system

Table 7: Places of Petri Net

Places	Delineation
P1 through 3	Robots at workstations 1, 2, and 3
P4 through 5	Robots at workstation 4
P6 through 8	Machines
P9	Assembly job
P10 through 13	Ready products at workstations
P14 through 18	Gates 1, 2, 3, 4, and 6
P19 through 20	Gate 5 for detecting different types
P21 through 23	Barcode scanners 2,3,4
P24 through 27	products on the path
P28	Sink
P29	Integrating ASRS with RFID
P30	ASRS
P31	Activating assembly workstation
P32 through 33	Available products for entering to the assembly
P34 through 40	products A on the path after being process by the workstation 1
P41 through 47	products A on the path after being process by the workstation 2
P48 through 54	Locating products based on the types capacity
P55	Control of distributor system
P56 through 57	Barcode scanner 5
P58	Barcode scanner 6
P59 through 62	Products on the path
P63 through 64	Places of products before the distributor
P65 through 68	Control system of ASRS
P69	Barcode scanner 1
P70 through 71	Control of barcode scanner 1

Table 8: Transitions of Petri Net

Transitions	Interpretation
T1 through 7	Transitions of products to the path
T8 through 10	RFID system transitions
T11 through 14	Transitions of products to the workstations
T15	Transition of products to the sink
T16 through 19	Time duration of products processing at workstations
T20	Transition of ready products for the assembly job
T21 through 35	Transitions of different products A on the path
T36 through 41	Transitions of products on the path
T42 through 43	Transitions of ASRS control system

In addition, all numerical scales (per time units) concluded in 5000 time units are shown in Table 9. In addition, it depicts how RFID ameliorated the system performance such as throughput distance of workstations as a comparison of barcode application.

Table 9: Performance Comparison of RFID and barcode

Sources	Throughput Sum		Throughput Dist.		Service Time	
	RFID	Barcode	RFID	Barcode	RFID	Barcode
W.S. 1	52	32	96.1682	156.8919	75	75
W.S. 2	40	32	125.0187	156.8919	80 - 110	80 - 110
W.S. 3	86	66	58.1482	76.0688	40 - 70	40 - 70
W.S. 4	85	64	58.8323	78.446	50	50

Sources are included all workstations that first and last ones have the deterministic service time and others follow the service time based on uniform distribution because of products processing monitoring or system maintenance. As can be seen, workstations 1, 2, and 3 perform machining for greater number of products than barcode system. Thus, the number of products, produced by the assembly workstation, reaches to 64 products based on the barcode scanner, whereas RFID system enhanced the productivity by managing higher products up to 85 parts.

Utilization of workstations is illustrated in Figure 25. The maximum rate is adapted to the third workstation by applying RFID, while the minimum utilization rate is approximately 49% for the first workstation based on the barcode reader application.

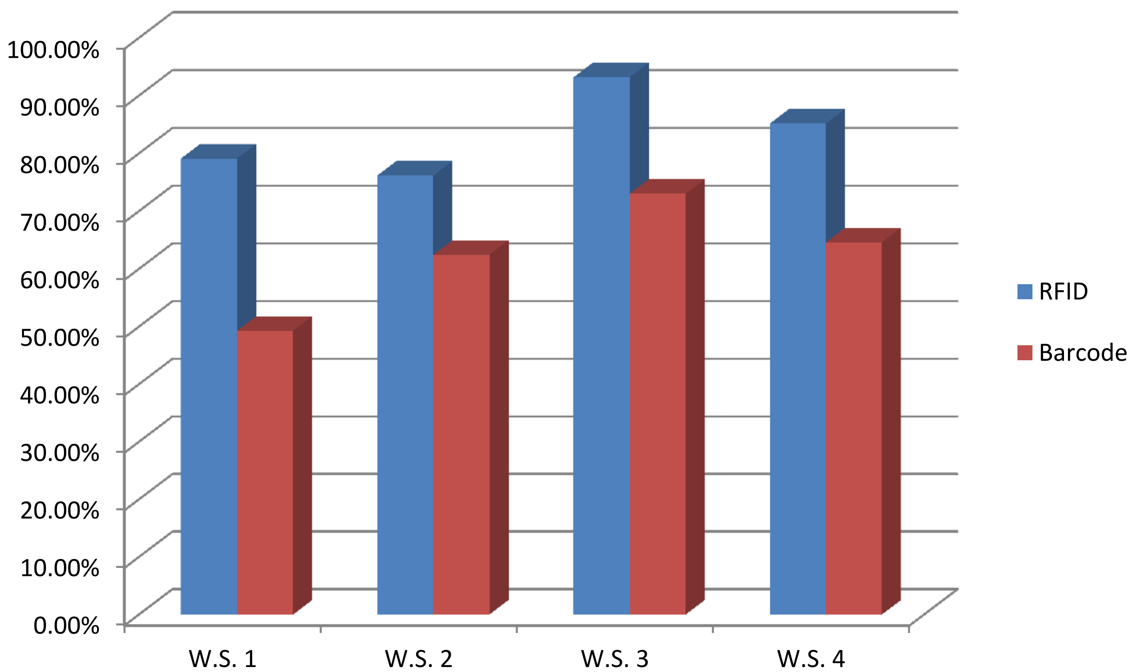

Figure 25: Utilization comparison for both cases

Figure 26 indicates dynamic performance of workstations No.1, 2, and 3 respectively during approximately 1000 time units for the barcode system. The red color shows the global performance index. It attempts to display time duration of workstations once they remain idle or they perform processing on a product. Since the transition becomes 1, the workstation is enabled unless it stands idle.

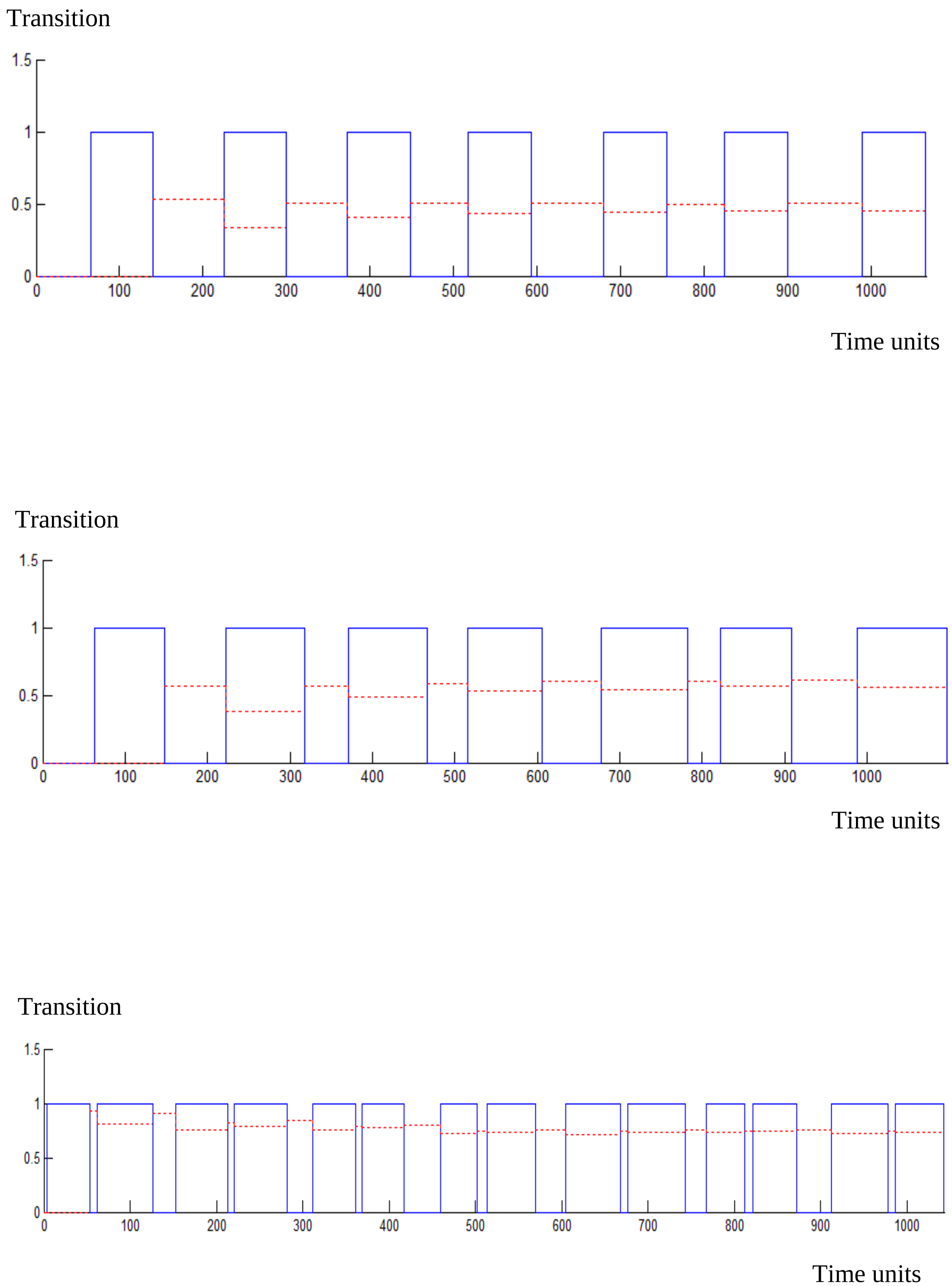

Figure 26: Dynamic performance of barcode system

5.5 Comparison of RFID system and Wireless Sensor Networks for the Distributed System

A comparison between wireless sensor networks (WSN) and RFID for the process control of manufacturing is investigated by this section. As it was mentioned, RFID system can detect numbers of different products in terms of their identification numbers aiming to provide that which products types are available in the range of RFID antenna, while sensor nodes are installed on the devices which are going to communicate one another throughout the network.

5.2.1 Case Description

In the present case study (see Figure 27), three stations including different machines as well as robot arms are placed to perform discrete job. Each station is connected to the local application software by the corresponding computer to manage devices treatment. RFID application software is needed to support the whole RFID gates and process raw data. Moreover, 40 parts types A and B are placed on the ASRS where both of them will be transferred to the stations No.1 and 2 by the automated transportation line and then, they are transported to the station No.3. In addition, several buffers which can retain products are located near stations.

In case of RFID, four RFID gates are installed at the particular places that they trace different tagged objects in order to fulfill logical process based on part detection. First gate, which is located at the decision making point on the conveyor, distinguishes the feasible way for each product.

Furthermore, the next three gates are placed beside stations to identify available parts on the paths. In this way, when products A and B are conveyed to the station No.1, RFID system checks the status of current route if the number of parts increases the specified level defined by three, it communicates to the ASRS robot to pick same types of parts in order to travel to the second station. The maximum three parts can stay among first and third RFID gates. Meanwhile, the cycle process again counts the number of parts for gates No. 1 and 2 in order to enable this line as well. Afterwards, when parts become ready on the machines, they are going to be transferred to the third station. The RFID system sends commands to each station to select the appropriate parts as long as totally, four parts remain in the line unless they retain on the stations buffers and wait for the further response.

In case of WSN, all stations are integrated with the wireless sensor nodes that each of them makes possibility to detect the status of each machine and also, they are able to negotiate together to select suitable lots to the idle station. In this manner, sensor nodes of stations No.1 and 2 call regularly products A and B waiting on the ASRS with regard to detecting idle machines.

After parts machining by these stations, they are maintained on the stations buffers. Henceforth, sensor nod installed on the last station negotiates with the second station to leave the related part on the transportation line for final machining. After the process is performed by the machine, the node then calls the part from second station to the third station. This regular process has been carried out by the negotiation wireless nodes until the last part processing.

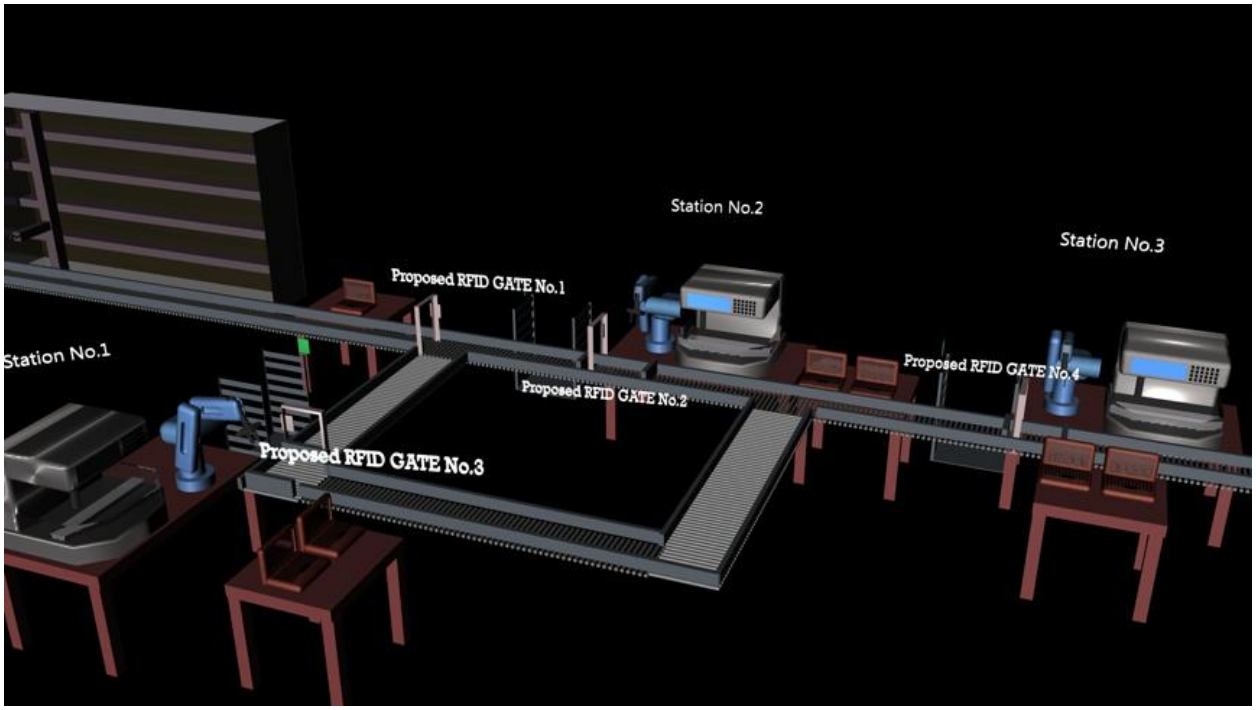

Figure 27: 3D model of manufacturing system

5.2.2 Performance Measurement

Both cases are simulated in the Petri Net Toolbox. Figure 28 and 29 present the Petri Net model developed for the production line equipped with RFID and WSN, respectively. Table 10 and 11 present the places and transitions defined in each Petri net graph.

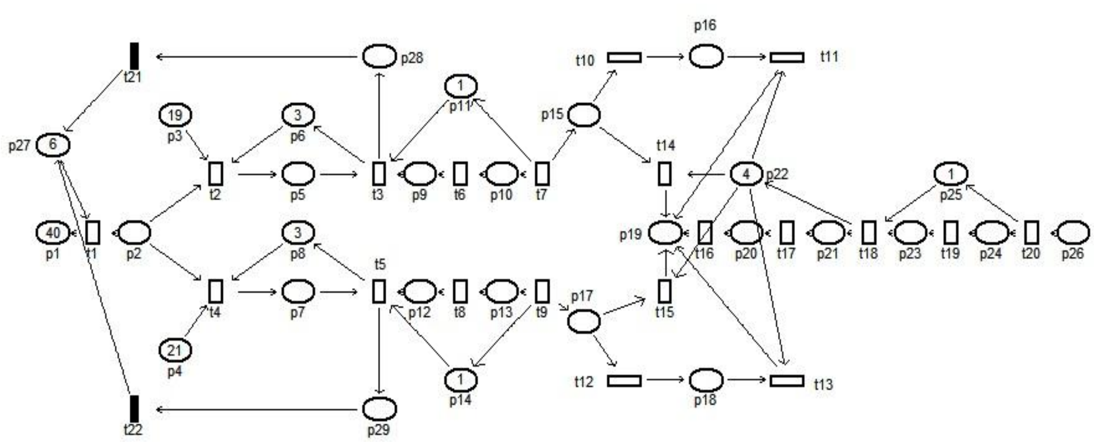

Figure 28: Petri Net model for RFID system

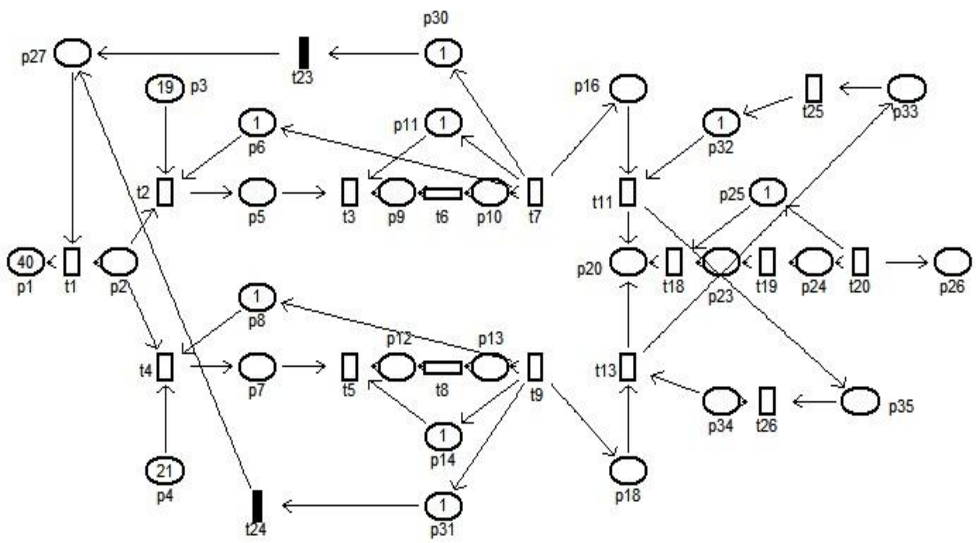

Figure 29: Petri Net model for WSN system

Table 10: Places and the explanations

Places	Delineation
P1	ASRS
P2	RFID gate No.1 and decision making point for WSN model
P28, P29, P19,	RFID gates No.2, 3, and 4 respectively
P3, P4	Associating maximum number of parts crossing at each line
P27	Number of parts removed by ASRS
P5, P7, P20, P21	Available parts on the conveyors before each station
P6, P8, P22	Capacity of conveyors
P9, P12, P23	Machines No.1, 2 and 3
P10, P13, P24	Departure parts from machines
P11, P14, P25	Robots located at stations
P15, P17	Select parts which may be stored in the stations buffers or transported to the conveyors
P16, P18	Stations buffers

Table 10 (continued)

Places	Delineation
P26	Sink
P30, P31	WSN of stations No.1 and 2 respectively
P32, P33, P34, P35	WSN of station No.3

Table 11: Transitions and the explanations

Transitions	Interpretation
t1, t2, t4, t11, t13, t14, t15, t16	Available parts on the conveyors
t3, t5, t18	Robots movements to load parts on the machines
t6, t8, t19	Operation machines
t7, t9, t20	Robots leave parts and return to the initial positions
t10, t12	Parts are taken to the stations buffers
t17, t21, t22	RFID transitions
t23, t24, t25, t26	WSN transitions

Table 12 explains the comparison of RFID system and wireless sensor nodes applications in the production line in 1675 time units. As can be seen, in both situations, the numbers of parts, which are produced by the first and second machines, are the same, but related utilization rates make lower values by using WSN because there is no waiting part behind each station. Therefore, the time is needed for each part in order to be arrived at stations. The significant difference is illustrated by the machine No.3 where 40 parts are machined based on RFID system. On the contrary, 32 parts are produced by the current machine based on wireless sensor nod. In light of this issue, it is worth nothing that the utilization value of final machine is enhanced to around 72 % by applying RFID system. The main benefit driven by WSN is to reduce the queue length on the conveyor as compared with RFID technology due to the fact that products stay on places in order to be conveyed to the destination.

Table 12: Performance comparison of RFID and WSN using Petri net (1675 time units)

Sources	Throughput sum		Throughput rate		Service time		Queue length		Utilization	
	WSN	RFID	WSN	RFID	WSN	RFID	WSN	RFID	WSN	RFID
ASRS	40	40	0.023	0.023	5	5	-	-	0.3552	0.5462
W.S. 1	19	19	0.011	0.011	50	50	0.056	1.740	0.7761	0.8835
W.S. 2	21	21	0.012	0.01253	40	40	0.062	1.603	0.7522	0.8716
W.S. 3	32	40	0.019	0.02388	30	30	0.095	3.011	0.5820	0.7194

Chapter 6

CONCLUSION AND FUTURE WORKS

RFID technology enables a typical automation system to provide abundant functionalities such as objects traceability or systems monitoring by real-time data capturing. It is also capable to be integrated with the distributed manufacturing system in order to establish intelligent system for industrial processes. In addition, the main advantages of substitution RFID system to other automated identification devices refer to high reliability, accuracy, and detection at wide range of environment.

The current study sought to explore the significant employment of RFID system for the distributed manufacturing intelligence system. At the beginning, the IT infrastructure of manufacturing intelligent system was presented with the required components and then, the RFID algorithm for the reference manufacturing model was proposed to manage different instructions as for enhancing the system performance including productivity, efficiency, and sources utilization as well as decreasing idle time.

Moreover, the impact of RFID system has been explored with the purpose of monitoring manufacturing processes. The tag information modeling was then investigated by tags traceability to indicate vital parameters depending on the application type.

Ultimately, several cases have been applied and simulated by the Petri Net Toolbox in MATLAB environment, which provided the mathematical modeling to portray complexity of manufacturing systems in order to come up with the performance of system.

The first case was considered for the integration of RFID system in the mixed manufacturing system in terms of certain quantity of products. It has been illustrated the substantial role of RFID in managing lots types processed through the production and assembly systems. Regarding the performance measurement, all workstations satisfied utilization rate by approximately 90%.

The second case represented the comparison model between RFID and barcode reader system. According to performance of system, RFID enhanced throughput distance and utilization of flexible machines as compared with barcode scanner for different operations. Therefore, the quantity of completed products increased based on RFID controller system at assembly workstation.

The comparison of RFID and WSN was also evaluated for the industrial process in the manufacturing system. It was revealed that WSN affected in reducing the queue length rate of products increasingly before each workstation, whereas RFID created routs' levels by detecting different products kinds. As a result, utilization of machines throughput rate of lots increased based on RFID system.

The present study makes the suggestion for the future research. The integration of RFID and WSN will be recommended to enable negotiation among mechatronic devices and monitor diversity of manufacturing processes the whole time for wider environment. They can refer to crucial parameters concerning the operation including vibration, temperature, and etc.

A smart node, integrated with a device, consists of RFID reader and several sensors. It identifies tagged items and then, transmits allocated data to the base station through network in order to execute appropriate commands. Smart nodes make capability for readers to communicate with each other via multi-hop. This facility reduces number of RFID antennas where objects need to be detected in large scale.

Integrating of RFID and WSN facilitates to determine the exact location of objects by applying known reference tags at particular positions. It can be suggested for manufacturing warehouse management systems in vast space when products are prepared and then, they are going to be collected to a warehouse. Besides, WSN can sense the conditional environment for each tag type detected by reader in order to alert once critical situations are made. It provides to maintain various tagged products in the healthy environment.

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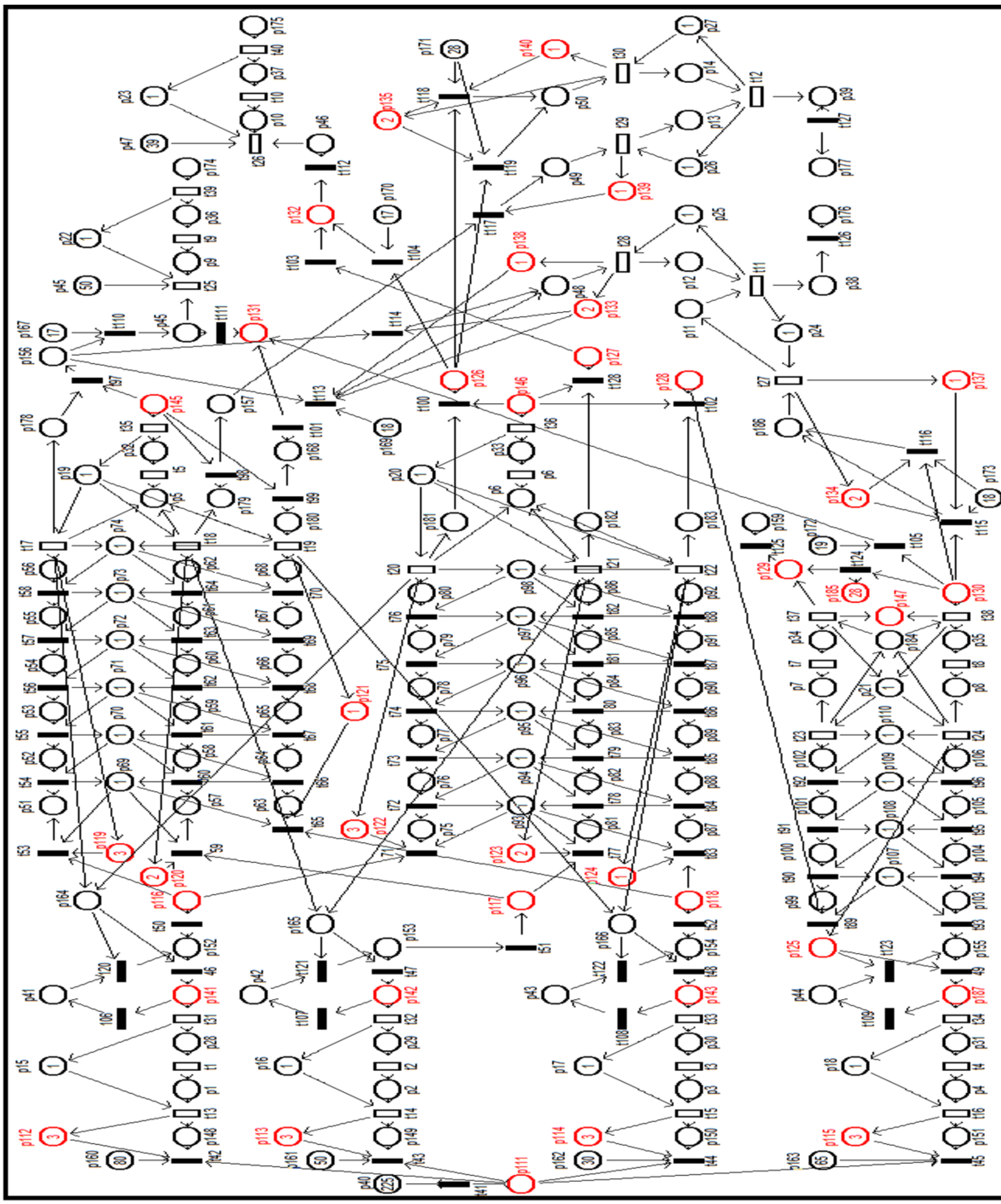
APPENDIX

Appendix A

Simulation of RFID in the Mix Mode Manufacturing System



Places	Delineation
P1 through 6	Machines 1,2,3,4,5, and 6
P7 through 8	Machine 7 for different types which have the distinct operations
P9 through 10	Assembly workstations 8 and 9
P11 through 12	Assembly workstation 10
P13 through 14	Assembly workstation 11
P15 through 23	Robots at workstations 1, 2, 3, 4, 5, 6, 8 and 9
P24 through 25	Robots at workstation 10
P26 through 27	Robots at workstation 11
P28 through 33	Parts are ready to depart at workstations 1, 2, 3, 4, 5, and 6
P34 through 35	Parts are ready to depart at workstation 7
P36 through 39	Parts are ready to depart at assembly workstations 8, 9, 10 and 11
P40	Initial buffer
P41 through 50	Temporary buffers 1 through 10
P51 through 56	Number of parts A waiting to arrive at workstation 5
P57 through 62	Number of parts B waiting to arrive at workstation 5
P63 through 68	Number of parts C waiting to arrive at workstation 5
P69 through 74	Allowing different types sequentially place before workstation 5
P75 through 80	Number of parts A waiting to arrive at workstation 6
P81 through 86	Number of parts B waiting to arrive at workstation 6

(Continued)

Places	Delineation
P87 through 92	Number of parts C waiting to arrive at workstation 6
P93 through 98	Allowing different types sequentially place before workstation 6
P99 through 102	Number of parts C waiting to arrive at workstation 7
P103 through 106	Number of parts D waiting to arrive at workstation 7
P107 through 110	Allowing different types sequentially place before workstation 7
P111 through 115	Gates 1, 2, 3, 4, and 5
P116 through 118	Gate 6 for detecting different types
P119 through 121	Gate 7 for detecting different types
P122 through 124	Gate 8 for detecting different types
P125	Gate 9
P126 through 128	Gate 10 for detecting different types
P129 through 130	Gates 11 and 12
P131 through 132	Gate 13
P133 trough 134	Gate 14
P135 through 136	Gate 15
P137 through 138	Gate 16
P139 through 140	Gate 17
P141 through 147	RFID antennas at workstations
P148 through 158	Places of parts on different paths

Places	Delineation
P159	ASRS
P160 through 173	Associating Total parts arrived at places based on the order
P174 through 177	Final parts are ready in order to be prepare for packaging
P178 through 183	Recognizing which types are under processing
P184	Showing utilization of workstation 7
P185	Associating Total parts arrived at places based on the order
P186	Temporary buffer
P187	RFID antenna at workstation

Transitions	Interpretation
T1 through 10	Operation time of workstations sources
T11 through 12	Operation time of workstations and robots return the home positions
T13 through 30	Robots load a part to sources
T31 through 40	Robots unload a part from sources
T41 through 105	Transitions of parts on the different paths
T106 through 119	Transitions of parts to buffers
T120 through 123	Transitions of parts from buffers
T124 through 125	Transitions of parts to the ASRS
T126 through 127	Transitions of parts from workstations
T128	Transitions of parts on the different paths