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HP Brazil: Journey Towards Industrial Internet of Things Within Industry 4.0 Context

Rebecca Angeles
Univ of New Brunswick Fredericton, angeles.rebecca@gmail.com

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Rebecca Angeles
University of New Brunswick Fredericton, Canada
rangeles@unb.ca

ABSTRACT

This paper features a case study of Hewlett Packard Brazil's deployment of radio frequency identification-enabled Exceler8 platform to support its product assembly using Flextronics in Sorocaba, Sao Paulo and distribution by DHL. The study also identifies the stage HP Brazil belongs to in its journey to being a full smart factory using the framework of Odwazny et al. (2018). The case study and content analysis methods are used in analyzing the concepts prescribed by the Industry 4.0, smart factory, and Industrial Internet of Things (IIOT) frameworks to HP Brazil's RFID system. The Odwazny et al. (2018) framework identifies HP Brazil as being in the maturity stage, with selected attributes of the "smart factory" stage since its Exceler8 platform supports vertical integration in its assembly, distribution, and recycling sites. Hopefully, empirical work will be pursued with vigor in the future to gain an understanding of the actual conditions that support the successful deployment of both Industry 4.0 and IIOT initiatives. Firms interested in applying Industry 4.0 and IIOT concepts within their production environments would be guided by this study. Applying the German Industry 4.0 model, their Industry 4.0 initiative would seek to (1) enable collaboration between humans and machines; (2) produce customized products in small batches; (3) optimize high automation; and (4) deploy devices in flexible and eco-friendly production processes to meet customization requirements.

KEYWORDS: Industrial Internet of Things, Smart Factory, Industry 4.0, radio frequency identification

INTRODUCTION

This study focuses on Hewlett Packard Brazil's (HP Brazil) award-winning industrial Internet of Things (IIOT) radio frequency identification (RFID) deployment in its manufacturing/assembly, distribution, and recycling sites. Using the qualitative methods of content analysis and case study, concepts involved with the Industry 4.0 initiative of Germany, the Internet of Things, "smart factory," and the framework for the stages of transition to the full "smart factory" status will be used to analyze and understand HP Brazil's foray into IIOT.

LITERATURE REVIEW

Hewlett Packard Brazil: Background

Organized in 1967, HP Brazil is a subsidiary of Hewlett Packard North America, a Fortune 100 firm (Rapp, 2018; Pandini, 2007). With business operations in Sorocaba, Sao Paulo, HP Brazil uses contracted manufacturing/assembling with Flextronics to produce servers, laser and inkjet printers, scanners, personal computers, and monitors for the business market.

HP Brazil developed its Exceler8 platform in 2015 in its attempt to deploy IOT and Industry 4.0 concepts in its business operations using RFID (Perin, 2017).

Industry 4.0 Characteristics

Germany launched its High-Technology Strategy 2020 Action Plan, which featured the "Industry 4.0" concept in 2011 (Odwazny et al., 2018; Rapp, 2018). Similar initiatives were introduced in the U.S. (i.e., Industrial Internet Consortium) in 2014, in China (i.e., Internet+), among other countries (Odwasny et al., 2018). The German Industry 4.0 version's objectives are: (1) enable real-time communication and collaboration between humans and machines; (2) produce non-standard, customized product items in small batches, optimizing high automation and efficiencies in a smart factory (Lee et al., 2017); (3) deploy devices in the production process to enable flexible and dynamic systems management to meet specific customer requirements (Prause & Weigand, 2016); (4) promote flexible, efficient, and eco-friendly production processes; and (5) establish a global network of setting value (Frazzon et al., 2013) and "…influencing business models and corporate structure…" (Kagermann et al., 2013, p. 258).

The following are the four key characteristics of Industry 4.0.

1) *Vertical integration of smart production systems*

Undergirding the Industry 4.0 platform are smart factories supported by smart production systems enabled by cyber-physical systems (CPS) designed for production (Gilchrist, 2016). CPSs are "…integrations of computation, networking, and physical processes. Embedded computers and networks monitor and control the physical processes, with feedback loops where physical processes affect computations and vice versa." (Gilchrist, 2016, p. 36). With Industrial IOT, CPSs would be sensor-based applications where RFID tags, RFID readers, antenna nodes, WIFI access points, etc., monitor events like movements of cases and pallets through the physical supply chain. Tags report back tracking information to software stored in other network nodes where processing is conducted to produce information for planning supply chain operations (Gilchrist, 2016).

In a vertically integrated smart factory, networking technologies connect smart production systems within the firm of focus involving internal operations like marketing, production, logistics, and distribution (Gilchrist, 2016).

2) *Horizontal integration through global value chain networks*

Horizontal integration means the interconnection between the firm of focus and its customers, suppliers, and business partners like technology vendors (Gilchrist, 2016).

3) *Through-engineering across the entire value chain*

Through-engineering means taking custody of its products' complete life cycle from the time the raw materials are acquired to the time the product is recycled or completely disposed of (Gilchrist, 2016).

4) *Acceleration of manufacturing*

IT plays a greater role in delivering greater connectivity and interaction between the firm of focus and its trading partners. Notable changes would involve greater modularization of functionalities and use of cloud-based deployments and embedded sensors/devices (Gerbert et al., 2015). Manufacturing will be accelerated if the firm is horizontally integrated with trading partners using automation architectures supported by cloud-based software capabilities for production-related applications and data-driven services (Gerbert et al., 2015). Cyber physical systems (CPS) systems will also accelerate manufacturing systems. CPS systems capture data on physical events such as the printer assembly process, using sensors, networks, embedded systems, etc., and forward the data to software on another networked node that enable interactions between the software and the physical artifacts (Gilchrist, 2016). CPS systems can also be networked with other complementary devices and so they have input/output (I/O) ports as well. Human workers in the assembly process can resolve exception cases after receiving alerts from the system. Alerts are produced when programmed business rules are "fired" when certain conditions are met.

Industry 4.0 Design Principles

Under Industry 4.0, intelligent networks link systems, machines, and work units in a firm's supply chain (Gilchrist, 2016). These same principles apply as well to the design of a "smart factory" (Odwazny et al., 2018). These networks are designed to work independently and yet, be able to control each other autonomously to achieve overall system goals. The Industry 4.0 design principles are: 1) interoperability, 2) virtualization, 3) decentralization, 4) real-time capability, 5) service orientation; and 6) modularity (Gilchrist, 2016; Odwazny et al., 2018; Hermann et al., 2016). *Interoperability* means that the different components of a production environment such as business processes, machines, and workers interact and collaborate during the production process. *Virtualization* means having the capability to create and work with virtual models of products/services/business processes resulting from simulation and sensor data gathered from the physical world. Workers can, then, use virtual models for testing or customizing a physical product before actually executing changes to the physical model in the analog world. *Decentralization* means multiple systems can be independently self determining, yet working towards the overall system's goals. This is important when the production system has to be reconfigured to fulfill customized orders (Odwazny et al., 2018). *Real-time capability* means production processes collect data, monitor systems, and return feedback as events are happening --- thus, in "real time." *Service orientation* means creating services that can be consumed both internally within a firm of focus and externally with its trading partners. *Modularity* means that production systems are designed to be modular so that any of them could be modified quickly as market situations change. Isolated changes can be made to specific modules without disrupting the overall system.

Industry 4.0 Building Blocks

Building blocks already available in the marketplace can create "smart factories" within the Industry 4.0 context (Gilchrist, 2016): 1) big data and analytics, 2) autonomous robots, 3) simulation, 4) vertical and horizontal system integration, 5) the industrial IOT, 6) cybersecurity, 7) cloud computing, 8) additive manufacturing (i.e., method of creating objects using three-dimensional model data, by joining materials layer by layer --- similar to 3D printing) (Wohler's Associates, 2018), and 9) augmented reality (i.e., computer-generated and interactive imagery using graphics, sounds, text, and other effects for enhanced effects improving viewer experience) (Techopedia, 2018).

Framework: Stages of Transition to "Smart Factory"

The framework depicting three stages towards attaining "full" smart factory status has been attempted by Odwazny, Szymanska, and Cyplik (2018) based on extensive literature review and content analysis. Table 1 shows these three stages: aspiration, maturity, and smart factory stages, that were based on three factors/evaluation criteria, which are human resources, technical/organizational resources, and managerial capability.

The "smart factory" status is notable for the following features. Vertical and horizontal integration are assumed, with business operations conducted in real time (Prause & Weigand, 2016; Kagermann et al., 2013). Top-class use of analytics methods by internal expert firm data analysts and IOT-generated data is completely captured and secured as an asset, mostly likely involving cloud computing. Virtualization via extensive simulation modeling drives operational decision making. The management layer is most distinctive, however. The "smart factory" supports decentralized and autonomous business process systems, accelerated with cyber physical systems, designed to meet customized client product/service requirements (Hozdic, 2015; Chien et al., 2017). Demand planning and forecasting increasingly focuses on smaller batches fulfilling a particular customer's specifications.

Table 1. Three-Stage Movement to "Smart Factory"

Implementation Stage*	Evaluation Area	Feature	Characteristic
Aspiration	Human factor	Staff qualifications	Team has qualified individuals including IT specialists and automatics engineers.
	Technical/ organization	Cooperation, communication skills	Individuals are capable to work in teams.
		Financials	Budget is sufficient for investments into staff and technology.
	Management	Data	Enterprise aspires to aggregate available data effectively.
		Machine park equipment	Sufficient technology is available including IT solutions.

		Tools and technologies	Automation and robotics of single processes. Part of the machine park is equipped in PLC steering.
		Vertical integration	Readiness to cooperate with other departments, within enterprise.
Maturity	Human factor	Staff qualifications	Operational employees have analytic skills and operate with available IT software.
		Cooperation, communication skills	Teams gain autonomy and can easily cooperate with others.
	Technical/ organizational	Data	Software and systems are fully integrated data wise. Enterprise is implementing Big Data concept.
		Tools and technologies	-Internet of Things is implemented gradually. More elements are included in the net. -Simulation models are used in decision process and production steering. -RFID (or similar technology) is widely used in the factory for track and trace. -Monitoring and cooperation is built within machine park.
	Management	Vertical integration	Full cooperation between departments.
		Horizontal integration	Readiness to cooperate with other companies in the supply chain and potential co-operators.
	Human factor	Staff	No operational employees in the machine park. Staff consists of [experts]. Employees are controlling the process and react to system warnings if necessary.

Smart Factory	Technical/ organizational	Data and its correctness	-World class in aggregation, analysis, and data interpretation. -Aggregated data is effectively stored. Data is valid, up to date and allows sufficient production steering.
		Tools and technologies	Full integration of all installed tools and technologies.
		Research and development	-Big investment pressure in research and development area. -Staff is being moved to such departments from the shop floor if possible (skills and knowledge wise).
		Virtualization	Simulation models used for all decision required processes.
		Real-Time Capability	Monitoring of current state and real-time capability.
		Safety	Database is fully secured.
		Horizontal and End-to-End Integration	Factory as an integral element of a supply chain cooperating with companies within the branch and also outside.
	Management	Client	High level of integration with clients. Products highly customized according to market demand.
		Organizational structure	High level of autonomy and decentralization.
		Control	Demand driven planning according to single clients' orders.

SOURCE: Odwazny et al., 2018.

NOTE: *Original wording was "Implementation Phase" changed to "Implementation Stage".

Internet of Things Platform

The Industrial IOT (IIOT) specifically refers to industry systems in the manufacturing, transportation, energy, health care, and public sectors (Gilchrist, 2016). IOT, on the other hand, is broader and includes consumer, industry, enterprise, and commercial applications. Industrial systems under the IIOT umbrella deploy digital technologies such as sensors, actuators, logic components, and networks to capture operational data from connected devices and transfer it to enterprise systems. The availability of cloud- based data storage and data analytics software via software as a service will facilitate descriptive, predictive, and prescriptive data analyses to optimize business operations.

The Industrial Internet Consortium (IIC) recognized the need for an architectural framework that is standards based, open, and applicable to a wide range of industries/business applications. The resulting reference architecture is a high-level common framework designed to separate the conceptual architecture from technical specifics of available information technologies. The IIC used the ISO/IEC/IEEE 42010:2011 standard in developing the three-tier topology of its Industrial Internet Architecture Framework (IIAF), which address three core areas (Gilchrist, 2016): the edge tier, platform tier, and enterprise tier.

Data from all connected devices, objects, end nodes, etc., is collected by the edge tier, which includes functions for the control domain (Gilchrist, 2016). Nearby networks collect, aggregate, and transmit the data to a border gateway. Data may have to be translated and the interfaces integrated at the hubs, remote input/output devices, or protocol converters, depending on the technologies and protocols used in the edge tier. Data is, then, processed and transformed in the platform tier, the tier responsible for functions covered by the information and operations domains (Gilchrist, 2016). This tier also manages control over data that flows from the enterprise to the edge tiers.

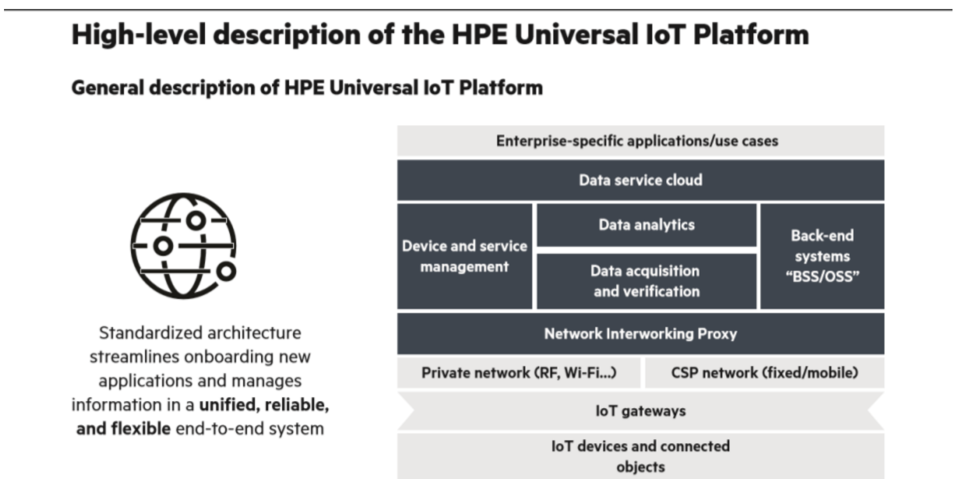
The enterprise tier deploys the logic behind business application software that supports decision support systems, enterprisewide systems, and end user interfaces for operations specialists (Gilchrist, 2016).

Hewlett Packard Enterprise Universal IOT Platform 1.4

Hewlett Packard Enterprise offers an IOT platform service called the HPE Universal IOT Platform 1.4 (Hewlett Packard Enterprise, 2016-2017). This platform matches the three-tier topology of the IIC architectural framework previously discussed.

Figure 1 clearly depicts the elements that go into each layer of the three-tier topology. The following elements comprise what would be the platform tier in the IIC three-tier topology: device and service management; network interworking proxy; data acquisition and verification; data analytics; back-end systems "BSS/OSS"; and data service cloud.

Figure 1. HPE Universal IOT Platform 1.4



Source: Hewlett Packard Enterprise, 2016-2017

Device and service management (DSM)

In delivering IOT services, the DSM is the critical module that manages the gateways, devices, sensors, etc., and expose device capabilities to business applications that subscribe to notifications. Corporate end users can use a Web-based graphical user interface (GUI) to subscribe to and consume IOT services. In the meantime, the DSM oversees the service registration on the platform to allow business applications to subscribe to machine-to-machine resources with its supporting gateways and sensors.

Network interworking proxy (NIP)

Different devices that need to communicate with each other over heterogeneous underlying networks and a variety of gateways are managed by the NIP component. With this component, the HPE Universal IOT platform is designed to enable heterogeneous systems to be interoperable and exchange data/information. This component is based on the "Distributed Message Queue" architecture in order to manage the volume, variety, and velocity of “big” IOT data.

Data acquisition and verification (DAV)

Cloud-based IOT business applications and IOT gateways and devices exchange data and communicate bi-directionally via the DAV component which uses the underlying NIP component. The uniform data model used in the DAV component is agnostic with respect to devices and business applications, thus, enabling flexibility and extensibility. IOT-based business applications are able to discover, access, and use resources through the use of HTTP REST (hypertext transfer protocol representational state transfer) interface that relies on a stateless, client server, cacheable communications protocol.

Data analytics (DA)

Data collected from connected devices, objects, and business applications is analyzed by HPE’s Vertica technology that enables “complex events processing” of batch and real-time data. Vertica provides a visualization tool to display processed and analyzed data in graphical form.

Operations and business support systems (OSS/BSS)

End-to-end user views of devices, gateways, and network information are provided primarily by the OSS/BSS component for IOT operators. IOT operators are able to automate and prioritize operational tasks, reduce downtime by quickly resolving IT infrastructure problems, and improve service quality.

Data service cloud (DSC)

The DSC component makes available the application program interfaces (APIs) from the DAV component to the firm’s partners, customers, and internal developers. APIs are a set of tools, routines, and protocols used to develop business application software. These APIs make it possible to develop IOT micro services via reusable components, thus, cutting both the costs and time-to-market involved for IOT-based business processes and applications. The DSC component also combines IOT data from both internal and external systems, thus, lending more insight even to end users outside the immediate IOT ecosystems. This encourages the monetization of such information.

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RESEARCH METHOD

This study uses the case study approach in aligning the concepts prescribed by frameworks defining Industry 4.0, smart factory, and Industrial Internet of Things to the RFID system of HP Brazil. The case study is an appropriate methodology in testing the application of a conceptual framework to a real firm. Primary data consists of the transcription of the annual RFID Journal Live! conference presentations in 2018, 2017, 2014, 2012, and 2007 of a number of executives from HP Brazil: Rafael Rapp, Business Operations Manager, Latin America Supply Chain Operations (2018, 2017); Armando Lucrecio, RFID Center of Excellence Manager, RFID Center of Excellence, Flextronics Institute of Technology (2014); and Marcelo Pandini, Manager, RFID and Business Development, HP Brazil (2012, 2007). Videos from HP Brazil's Center of Excellence on Exceler8 were also analyzed. In addition, secondary data sources from academic and trade articles were content analyzed using key concepts in the concept frameworks. The following are accepted definitions of content analysis:

Content analysis is any research technique for making inferences by systematically and objectively identifying specified characteristics within text. (Stone et al., 1966, p. 5).

Content analysis is a research technique for making replicable and valid inferences from data to their context. (Krippendorff, 2004).

Content analysis is a research method that uses a set of procedures to make valid inferences from text. (Weber, 1990, p. 9).

In this study, the concepts used for content analysis were derived from the concept frameworks of Industry 4.0, smart factory, and Internet of Things. These concept frameworks form the "context" of the content analysis method as applied to RFID system of HP Brazil. Secondary data was analyzed within the context provided by the same frameworks, which is considered the "prior theory." "Analytical constructs operationalize what the content analyst knows about the context, specifically the network of correlations that are assumed to explain how available text are connected to the possible answers to the analyst's questions and the conditions under which these correlations could change….analytical constructs ensure that an analysis of given texts models the texts' context of use…" (Krippendorff, 2004, p. 34).

The following key conceptual elements of the content analysis method as stipulated by Krippendorf (2004) were used in this study: (1) body of text selected for the analysis; (2) research question that needed to be addressed; (3) a context of analysis within which interpretations will be made; (4) analytical constructs that operationalize what the analyst knows about the context; and (5) inferences that will be arrived at to address the research question.

Table 2. HP Brazil Executives: Work Experience Relevant to Supply Chain Management, IIOT, and Industry 4.0

NAME & CURRENT TITLE	***RELEVANT ACCUMULATED WORK EXPERIENCE:***
Rafael Rapp, Business Operations Manager, Latin America Supply Chain Operations (2018)	***IIOT Experience:*** + Evaluated and planned for the deployment of Industry 4.0 and IIOT concepts that apply to HP Brazil's supply chain --- this would have a broad range coverage of business applications involved in manufacturing, inbound & outbound logistics, distribution center operations, sales & marketing & planning, after sales services, and recycling center operations. + Educated and trained in Industry 4.0 and IIOT concepts and attended industry conferences and events related to these initiatives, including those conducted in Germany. Originated seminal concepts that would eventually be used in the planning and deployment of HP Brazil's Digital Supply Chain. + Planned and oversaw the implementation of RFID tagging of imaging and printing products and the corresponding revisions in the business processes involving production and quality management, consistent with the envisioned digital supply chain and IIOT capabilities. For targeted revenue generation projects involving HP products, he was strongly involved in the early systems development life cycle stage that required performing technical, cost, and feasibility analysis in the systems analysis/design phases. Later on during the implementation phase itself, he was involved in the deployment of the new manufacturing operations and had specific expertise in the engineering area.

	+ As an HP Engineer, worked in collaboration with EPCGlobal Inc. on RFID standards development. ***Types of Business Applications Overseen*** Business applications involved in manufacturing, inbound & outbound logistics, distribution center operations, sales & marketing & planning, after sales services, and recycling center operations. ***Functions of IIOT Applications*** All the business applications listed above cover all the functions involved in HP Brazil's internal supply chain business operations.
Armando Lucrecio, RFID Center of Excellence Manager, RFID Center of Excellence, Flextronics Institute of Technology	***IIOT Experience:*** + As New Technologies Manager, exhibited leadership and strategic planning capabilities in developing the Flextronics Worldwide Technology Roadmap. Acted as a major contributor to the documentation on applying "Industrial Internet of Things" concepts through the use of different technologies in an advanced manufacturing environment. + As a member of the Advanced Manufacturing Group of Brazil's IOT Forum, designed a strategy for the implementation of Industry 4.0 to mobile manufacturing environments. + Assumed a leadership position in creating teams focused on technology and product development for robotics, automation and control systems, electronics manufacture, printed electronics, RFID, cloud computing, hardware and product certification. These are all elements that are needed in configuring some level of efficacy as an IIOT-based smart factory. These team initiatives resulted in significant process improvements in test, assembly, and packing solutions using RFID, leading to increased productivity, reduced assembly time, and product quality improvements.

	+ Led an R&D team of 23 members and using both hardware and software products, delivered the first RFID as a Service system. This system was created based on all the supply chain business processes of HP covering --- manufacturing, inbound and outbound logistics, warehouse/distribution center operations, sales and marketing, after sales service, and recycling center operations. The RFIDaaS services that support all supply chain business operations are now offered to client firms on behalf of HP and the Center of Excellence. + Led a Robotics/Automation team of 50 members to create a state-of-the-art laboratory for mobile manufacturing improvements for Motorola mobile products. The mobility aspect is part of the IIOT vision for HP. ***Types of Business Applications Overseen*** Business applications involved in manufacturing, inbound & outbound logistics, distribution center operations, sales & marketing & planning, after sales services, and recycling center operations. ***Functions of IIOT Applications*** All the business applications listed above cover all the functions involved in HP Brazil's internal supply chain business operations.
Marcelo Pandini, Manager, RFID and Business Development, HP Brazil	***IIOT Experience:*** + He has been responsible for HP Brazil's manufacturing supply chain program management, business process management, quality management systems, and manufacturing system. He also led the business planning and analysis phases of the systems development life cycle of such projects as the supply chain network development and more specifically, projects involving inkjet and laserjet printers. He participated in both the early and later phases of RFID tagging printers starting with the manufacturing process and tracking them in their movements through warehouses/distribution centers, outbound logistics/shipping to customers, and closed loop operations in the recycling centers.

	+ He participated in the execution of the factory direct program and was also involved in operations controls and putting together the manufacturing plan of records. ***Types of Business Applications Overseen*** Business applications involved in manufacturing, inbound & outbound logistics, distribution center operations, sales & marketing & planning, after sales services, and recycling center operations. ***Functions of IIOT Applications*** All the business applications listed above cover all the functions involved in HP Brazil's internal supply chain business operations.

NOTE: Sources of information: transcripts of talks and curriculum vita of executives.

Table 3. HP Brazil Executives: Results of content analysis of transcripts and depth of contribution to study's findings

TOPIC	RAPP	LUCRECIO	PANDINI
NOTE: ***Extensively discussed; **discussed moderately; *briefly covered.			
HP Brazil firm background	*** (2018) *** (2017)	** (2014)	** (2007)
HP Brazil firm & supply chain capabilities	*** (2018) *** (2017)	*** (2014)	*** (2007)
Industry 4.0 concept & smart supply chain	*** (2018) *** (2017)	*** (2014)	
Industrial IOT concept	*** (2018) *** (2017)	*** (2014)	
Digital supply chain	*** (2018) *** (2017)	*** (2014)	*** (2007)

HP RFID Center of Excellence Services	** (2018) *** (2017)	*** (2014)	** (2007)
Justification for RFID use in HP Brazil	*** (2018) *** (2017)	*** (2014)	*** (2007)
RFID tag application in HP internal business operations & its supply chain	*** (2018) *** (2017)	*** (2014)	*** (2007)
RFID's role in recycling operations	*** (2018) *** (2017)	*** (2014)	
RFID's role in IOT	*** (2018) *** (2017)	*** (2014)	*** (2007)
Benefits attained From RFID in supply chain	*** (2018) *** (2017)	*** (2014)	
RFID as a Service via the Center of Excellence	*** (2018)	*** (2014)	
Additive manufacturing: 3-D printing of RFID tags	*** (2018) *** (2017)	*** (2014)	
Smart factory	*** (2018) *** (2017)		
Robotics	*** (2018) ** (2017)		
Factory automation	*** (2018) ** (2017)	*** (2014)	
Exceler8 Platform	*** (2018) *** (2017)		
Mobile app (working with Exceler8 platform)	*** (2018) *** (2017)		
Information visibility at all firm levels, resulting from mobile app	*** (2018) *** (2017)		
RFID-enabled internal operations	*** (2018) *** (2017)	** (2014)	

& supply chain performance metrics			
RFID & cost issues	*** (2018) *** (2017)		
EPCGlobal member & participant		*** (2014)	** (2007)
Plans for future improvements at HP Brazil	*** (2018) *** (2017)	** (2014)	
Participation in the IOT Forum In Brazil		** (2014)	

FINDINGS

HP Brazil's Exceler8 platform supporting its RFID-enabled IT infrastructure oversees the work conducted in the Flextronics manufacturing/assembly site, DHL distribution site, and Oxcil and Sinctronics recycling centers.

HP Brazil RFID Infrastructure: Exceler8 Platform

The current RFID infrastructure in HP Brazil is supported by the Exceler8 platform, which is a product of the evolutionary growth of the firm's RFID infrastructure since 2005 (Rapp, 2018, 2017; Lucrecio, 2014). Table 4 shows how the different elements that constitute the Industrial Internet Architecture Framework (IIAF) has equivalent layers in the HPE Universal IOT platform template model (see section on "Hewlett Packard Enterprise Universal IOT Platform 1.4"). Table 5 shows the different elements that constitute the Exceler8 platform.

Table 4: Equivalence of IIC Framework and HPE Universal Platform 1.4

IIC (Industrial Internet Consortium)	***Hewlett Packard Universal IOT Platform 1.4*** Enterprise-specific business applications/use cases

<table>
<tr><td>Industrial Internet Architecture Framework (IIAF))

ENTERPRISE TIER</td><td colspan="3"></td></tr>
<tr><td rowspan="3">PLATFORM TIER</td><td colspan="3">Data-service cloud</td></tr>
<tr><td rowspan="2">Device and service management</td><td>Data Analytics</td><td rowspan="2">Back-end systems</td></tr>
<tr><td>Data acquisition and verification</td></tr>
<tr><td rowspan="4">EDGE TIER</td><td colspan="3">Network Internetworking Proxy</td></tr>
<tr><td colspan="3">Private network CSP network (fixed/mobile)</td></tr>
<tr><td colspan="3">IOT gateways</td></tr>
<tr><td colspan="3">IOT devices and connected objects</td></tr>
</table>

Table 5. HP Brazil Exceler8 Platform

Enterprise-specific business applications/use cases
-business use cases: order management; manufacturing process; manufactured goods receiving; manufacturing packing process; distribution warehouse receiving; storage; distribution warehouse rework pallet; distribution warehouse outbound; customer management; -*recycling operations:* collection center shipping; recycling center receiving; recycling process; disposal process -enterprise resource planning (Flextronics)/SAP -enterprise resource planning (DHL)/Baan -mobile app used by HP end users to view dashboards
Data-service cloud
-HP Brazil started using cloud-based databases in 2013

<table>
<tr>
<td rowspan="2">Device and service management

-product flow control systems software used in assembly line
-GS1/EPCIS-based software used
-HP-developed data collection software to be used by Mercury5 RFID readers in Oxcil recycling facility</td>
<td>Data Analytics

-HP used T3Ci for analytics services & reporting
-business intelligence</td>
<td rowspan="2">Back-end systems

-EPCIS database
- OATSystem's OAT Foundation Suite 5.0 software
-OATSystems asset tracking and work-in-progress solution
-manufacturing product database integrated with business intelligence software to process recycled HP product information
-SmartWaste software solution</td>
</tr>
<tr>
<td>Data acquisition and verification</td>
</tr>
<tr>
<td colspan="3">Network Internetworking Proxy</td>
</tr>
<tr>
<td colspan="2">Private network</td>
<td>CSP network (fixed/mobile)</td>
</tr>
<tr>
<td colspan="3">IOT gateways</td>
</tr>
</table>

RFID went live for full production in August 2006. Product assembly activities are undertaken by HP Brazil's partner, Flextronics in Sorocaba, Sao Paulo, while distribution is managed by DHL (Gambon, 2007).

At Flextronics, RFID tag is attached at the bottom of the printer's chassis (Lucrecio, 2014; Pandini, 2007). During assembly, three different RFID interrogators at each production line record manufacturing operations information on the tag, thus commissioning the EPC tag. Printers being assembled are tracked throughout all the steps in the production lines. There are temporary storage areas where interrogators embedded in three portals track the movement of printers transported in and out of storage areas.

After storage, the printers are sent to the packing lines (Pandini, 2007). Again, interrogators installed in the packing line areas re-commission the EPC tag as a fully assembled printer and is assigned a new stock keeping unit (SKU) code. These interrogators also record information which is, then, stored in the tag, and track printer movements in the packing lines. Printers ready to be shipped pass through the outbound portals where embedded readers capture tag information that is, then, forwarded to DHL. The ThingMagic Mercury 5 readers in the outbound portals of

Flextronics have been able to read 100 percent of the tags passing through them (Roberti, 2008).

Once the printers reach the DHL, the printers' tags are read at the receiving area, at the pallet preparation area, and finally, at the outbound doors when the pallets are moved to the DHL trucks for delivery (Lucrecio, 2014; Pandini, 2007).

Each printer's RFID tag is its "DNA" and stores the following data elements: electronic product code (EPC) number, the printer's serial number, and its part information (Pandini, 2007; Roberti, 2006). Additional memory in the RFID tag is used to store important "DNA" type information such as test results for the printer and destination information (Pandini, 2007). Test results information helps screen out printers that pass quality control tests and can proceed to the packing and shipping stages. In the shipping process, EPC information of finished printers is compared with those shown in purchase orders to ensure that the right order is fulfilled correctly. The printer's serial number is important when the products are sent back by customers for repair under warranty agreements (Pandini, 2007). In this case, the RFID tag is also used to record the nature of the repairs done to the product and track the progress of repair activities. Tag information is used when customers return HP products in order to track where in the supply chain to send back the products and for later quality control analysis.

OATSystem's OAT Foundation Suite 5.0 software acts as the RFID data management platform and middleware that sends RFID data to the SAP system at Flextronics and Baan System at DHL. Data from the tags are also stored in the Flextronics and DHL databases, and then, transferred to HP Brazil's databases. HP Brazil currently also uses OATSystems asset tracking and work-in- progress (WIP) solution, which helps configure how its RFID systems need to track materials throughout all business processes involved in manufacturing, assembly, and distribution (Bacheldor, 2007).

The WIP software includes a Web-based graphical user interface (GUI) used by factory workers to define and enact programmed business rules. So, for instance, during laserjet printer assembly, workers can do the following using the GUI : (1) identify points in the assembly line where RFID interrogators need to capture RFID tag data from laserjet printer raw materials; (2) define attributes of raw materials, parts, and products; (3) link unique RFID tag ID numbers with parts they are associated with; and (4) write a business logic that would trigger an alert if, say, a specific operation on a printer part is exceeding a reasonable time threshold. The WIP software can send alerts to workers using email, smartphone text messages, and flashing lights on light stacks, with specific light colors indicating what should be done --- green lights to keep the assembly line running, or red lights to stop the conveyor belt (Bacheldor, 2007).

Cloud-Based Rotating Reader Portal

HP Brazil Center of Excellence developed the cloud-based RFID reader portal which is a freestanding metallic framework outfitted with a strong rotating arm supporting a reader antenna at its tip (Lucrecio, 2014; Swedberg, 2014; HP Brazil Center of Excellence, 2014). This rotating portal is designed to read the RFID tags on assembled HP products being prepared to move to the DHL, and address technical challenges involved in having high metallic content in HP products. Reader antennas needed to be oriented at a certain angle to ensure complete capture of tag information. Captured RFID tag information is transferred to a business application software running from a server that associates the tag ID numbers with information specific to the product read and the corresponding shipping order. Total read time for one pallet dropped from 60 seconds to 37 seconds using the rotating arm.

Another reader designed was the "tunnel reader" intended to read the tags of all other items in the boxed printer --- instructional CDs, brochures, cartridges, etc.

The DHL distribution center uses "smart shelves" that store HP printer cartridges in the warehouse and use RFID readers to capture data from cartridges shipped to customers. Captured data is, then, uploaded to the cloud and then, in a couple of seconds, product information is shown in dashboard format on a customer's tablet computer (Roberti, 2013; HP Brazil Center of Excellence, 2013). HP Brazil plans to develop an app that would allow a customer to create a shipping application that compares order information against actual RFID tag read information and send alerts to HP Brazil if the order information does not sync up with the tag read information.

Self-service smart kiosks could also be used in retail outlets where customers purchase printer cartridges (HP Brazil Center of Excellence, 2013). Data from these smart kiosks is uploaded to the cloud and then, made available to all HP personnel involved in retail operations, sales and marketing activities, planning, and distribution.

HP Brazil's Recycling Center

When HP Brazil applied RFID for recycling its inkjet printers in July 2011, it designated drop-off centers for used printer cartridges, which were collected and processed in the Oxil recycling facility (Rapp, 2018, 2017; Lucrecio, 2014; Angeles, 2013). Currently, HP Brazil is also conducting recycling activities at the Sinctronics recycling facility that is near the Flextronics assembly plant (Perin, 2016). HP Brazil also uses "smart bins" designed to collect discarded cartridges customers drop in the bins at designated drop off centers (HP Brazil Center of Excellence, 2013). Height sensors detect the number of discarded ink cartridges collected in the bin. A predefined limit for the volume of disposed cartridges has been programmed in the smart bin and once this is reached, the bin sends a signal to HP Brazil to pick up the container.

After depalletizing, the printers are transferred to a disassembly line where laborers manually separate parts by type of material --- plastic, metal, paper, and electronic components.

For its recycling operations, HP Brazil uses the SmartWaste solution, which captures additional printer information on recyclable materials used in the printers such as acrylonitrile butadiene styrene (ABS), and high-impact polystyrene (HIP) plastics, from the tags and forwarded this to a database (Zaino, 2012). A special data collection software application was written to transfer RFID tag information using the Internet via a wired connection to HP Brazil's business intelligence software that is integrated with its manufacturing product database. The business intelligence software generates decision making information for the environmental business strategic team members who can now view screen dashboards that highlight the amount of recycled materials recovered and the number of products recycled monthly. This information helps in forecasting how much recycled material can be used for future printer production. Brand new HP inkjet printers currently manufactured can contain as much as 40 percent recycled raw materials (Pandini, 2012a).

Industry 4.0 Building Blocks Used by HP Brazil

HP Brazil's Exceler8 platform is supported by cloud-based services that stores RFID data collected from all readers in the Flextronics plant, DHL distribution center, retail outlets that use the smart shelves, and drop-off centers for used HP products. HP Brazil is involved in capturing, storing, processing, and distributing "big data" as it collects at least one terabyte of RFID data daily from 400,000 plus tag readings daily, (Rapp, 2018, 2017), with data streaming from more than 100 RFID readers and 200 RFID antennas. HP Brazil uses up about 25 million RFID tags annually.

Selected HP Brazil end users use data analytics software to analyze RFID data collected from different points of its internal supply chain. The data analytics services of the T3Ci firm was also used since 2007 to help end users analyze the data and create dashboards and reports using a mobile app for front-end data (Rapp, 2018, 2017; Lucrecio, 2014).

HP Brazil also plans to do some type of additive manufacturing by using organic materials to develop RFID antennas and create RFID tags using 3-D printing methods and organic electronic techniques (Rapp, 2018, 2017; Lucrecio, 2014). Less copper will be used using 3-D printing methods, thus, making them more environmentally friendly. HP Brazil's use of EPC standards will facilitate the printing of the organic tags. Overall, this future planned capability will eliminate part of the cost issues involved in the larger scale RFID deployment in HP Brazil. Robots are also used in the Flextronics plant and DHL distribution center in storing and preparing pallets for outbound shipping (HP Brazil Center of Excellence, 2017).

Industry 4.0 Design Principles Used by HP Brazil

Interoperability and real-time capability

An industrial IOT platform undergirds Exceler8 and enables interoperability among the different elements that constitute this platform as shown in Figure 1. The real-time tracking of the raw materials through the assembly and distribution processes enables transparency and visibility into HP Brazil's internal supply chain.

Service orientation

HP Brazil established its Center of Excellence (HP/COE), which is recognized by EPCGlobal, a non-profit organization dedicated to developing standards and best practices for using the electronic product code (EPC) in global supply chains (Lucrecio, 2014). While capitalizing on its actual experience developing the RFID infrastructure for HP/Brazil, HP/COE offers its services to clients through consulting services that cover visioning RFID potentials in the firm, configuration and validation of RFID-related products, using development tools for interfacing RFID-related systems, RFID tests, and RFID simulations (HP Brazil/RFID Center of Excellence, 2018; Lucrecio, 2014).

Industry 4.0 Main Characteristics Observed at HP Brazil

This is how HP Brazil stands with respect to these main Industry 4.0 characteristics (Gilchrist, 2016).

1) Vertical integration of smart production systems

The Exceler8 platform connects and integrates the business operations in the receipt of raw materials from local and foreign suppliers, manufacturing and assembly of HP products at Flextronics, product packaging, raw material and product inventory management, product storage at DHL, management of sales channels, product repair, and finally, product recycling (HP Brazil/RFID Center of Excellence Website, 2018).

HP Brazil COE has piloted the use of smart ink cartridge shelves/kiosks that can be used in selling the products using a self-service approach (HP Brazil Center of Excellence, 2013). These kiosks have touch screens that interact with customers as they pick, choose, and pay for printer cartridges. The kiosks store sales transaction information that is transferred to the cloud and then, forwarded to the HP's sales and marketing teams, who, use the information for demand planning and forecasting purposes and eventually, procurement of raw materials from suppliers. Use of these smart kiosks in retail outlets ensures the reliable and timely supply of printer cartridges resulting from the constant automatic replenishment from the distribution centers.

2) Horizontal integration through global value networks

There is no horizontal integration as yet in HP Brazil's supply chain. Exceler8 only covers HP Brazil's internal supply chain that include Flextronics, DHL, recycling centers, and retail outlets where smart kiosks/bins are used. Ideally, the RFID system should cover HP Brazil's suppliers and corporate customers as well. This should not be too difficult in the future as HP Brazil's Exceler8 platform is cloud based and observes the EPCIS standards, which should facilitate data/information exchange between the firm and its current and future trading partners.

3) Through-engineering across the entire value chain

HP Brazil is practicing the concepts behind "through-engineering across the entire value chain" through the recycling and recovery of reusable raw materials for the production of new products (See section on "HP Brazil's Recycling Center").

4) Acceleration of manufacturing

Manufacturing and logistics have accelerated at HP Brazil because of a host of factors, the main one being the deployment of cyber-physical systems (CPSs). So, for instance, if alerts are sent out to indicate certain printers failing quality control tests, further analysis can be done to review what went wrong. Also, humans can ensure that these printers are properly removed from the assembly line and not forwarded to packaging. Although humans are overseeing the process, the automated assembly line physically removes substandard printers from the assembly line.

Other factors that contribute to accelerated manufacturing include the use of: cloud computing, real time information exchanges, big data and analytics, and robotics. HP Brazil's adoption of GS1's standards for RFID infrastructure deployment has also streamlined and speeded up the exchange of data/information in key business processes of its internal supply chain (GS1.org, 2010).

Changes Observed in Manufacturing and Supply Chain after IIOT Deployment

The business operations in HP Brazil's manufacturing and supply chain environment certainly experienced significant changes after the deployment of its RFID-enabled initiative (Rapp, 2018): order management metrics noticeably improved; warehouse management costs were reduced by 50 percent; both logistics and inventory costs were cut by 20 percent; turnaround time for outbound shipments registered a 19-day improvement; turnaround time for inbound shipments registered a 16-day improvement; and annual growth overall went up by 13 percent. Because of the significant supply chain visibility achieved, HP Brazil is now able to re-route end customer product shipments through the closest distribution centers, which has resulted in remarkable savings to the firm.

Business operations activities in HP Brazil also increased as reflected in the following performance statistics (Rapp, 2018): managed over 1,000 different stock keeping units (SKUs); more that 25 million RFID tags have been used per year; more than 200 interaction points involving RFID antennas, robots, etc.; more than 400,000 product readings per day; more than 6,400 customer orders automatically processed per year; over 600 gigabytes of data captured from the deployment of mobile apps; and more than one terabyte of product data captured per day.

As HP Brazil gained more experience in deploying IIOT in its Sorocaba site, the Center of Excellence progressively gained expertise and was able to offer its clients a range of cloud-based services. Lucrecio (2014) noted the four key advantages that HP Brazil derived from the deployment of IIOT in manufacturing: intelligence, mobility, connectivity, and collaboration. In terms of its Center of Excellence, HP Brazil benefits both itself and the center's clients through the three services it provides based on RFID technology (Lucrecio, 2014). The first service is

"RFIDaaS Architecture," which offers an RFID-based platform that interconnects hardware resources via the cloud. Potential Center of Excellence clients can connect with any of its supply chain partners throughout the world using this architecture using a customized RFID powered system. The second service is "RFIDaaS Middleware" which is compliant with the EPCGlobal standards and is supported by middleware that will support virtually any type of RFID reader and device supporting data matrix, bar codes, etc., sold in the market. This means the "plug-and-play" method can be deployed as well, and the management of the hardware is facilitated by a Web browser-based system that provides clients the desired level of control over the devices. In addition, this service makes it easy for supply chain trading partners to control devices that are communicating with each other and exchanging data without having to involve the IT departments of the supply chain partners. The "RFIDaaS Processes" service offers support for all 36 business processes that the EPCGlobal supports such as commissioning, picking, packing, transfers, outbound logistics, among others, for supply chain participants. This service also supports GS1-supported technologies like different types of barcodes such as the EAN/UPC barcode used with consumer goods; GS1 data matrix used with healthcare products, and the GS1-128, GS1 databar, and GS1 QR (i.e., quick response) code. The data captured from the readers are stored in the cloud and the platform maintains a 1.5 second refresh rate in uploading data to the servers supporting the cloud in both Brazil and the U.S. The benefits gained by the Center of Excellence clients are quite apparent: cost savings from the use of the three cloud-based solutions delivered as services; ease of deploying RFID-based services with supply chain trading partners located anywhere; the center is in compliance with EPCGlobal and GS1 standards for deploying supply chain-based solutions; using a Web browser, clients can access their control dashboards for customizing the settings for their required services using multiplatform options --- desktops, laptops, tablets, or smartphones; the end user interface for the services is easy to understand and use; and tight security measures are provided for cloud-stored data both at rest and in motion from point to point (Lucrecio, 2014).

Rapp (2018, 2017) articulated a number of points suggesting that HP Brazil is well on its way to attaining some indicators of the "smart factory" stage in the framework of Odwazny et al. (2018). Rapp touches on the following attributes: staff, data and its correctness, [data] safety, organizational structure, and control (see Table 1). In terms of its staff, Rapp (2018) strongly expressed the need to ramp up their human resource pool to include candidates with special skills in data design, development, analytics, and data security. These special skills address the expertise to promote data correctness and safety especially during this time when HP Brazil is gathering "big data."

In terms of organizational structure, he said that employing both hardware- and software-enabled robots in an increasingly automated factory site should allow HP Brazil to set up smaller autonomous production sites, decentralized all over the world. Furthermore, a higher level of automation should liberate HP Brazil from costs associated with its dependence on cheap unskilled labor in Latin America. Lastly, in terms of control, decentralized and agile factories scattered all over the world should allow HP Brazil to pursue demand-driven planning and mass customization more intensively. This is in keeping with the more mature "smart factory" stage of the Industry 4.0 framework. Rapp (2018) also expressed that HP is investigating the potential use cases, required financial budget, and expected benefits from deploying blockchain technology in combination with RFID in their supply chain.

HP Brazil's longer term future plan revolves around its original RFID-enabled digital supply chain, but is branching out toward related directions that are natural consequences of its earlier RFID initiatives. HP is investigating the use of machine learning and artificial intelligence to be able to graduate from having mere supply chain visibility to having prediction capabilities. With these capabilities, Rapp (2018) would like HP executives and workers to receive alerts in their smartphones via an enhanced mobile app that informs them of the consequences of the state of certain business processes and events in their supply chain and the effects of these on their ability to reach sales goal targets.

CONCLUSIONS

The framework of Odwazny et al. (2018) gives a more accurate picture of where HP Brazil is in terms of becoming a smart factory according to the Industry 4.0 vision. It appears that HP Brazil is mainly in the maturity stage, with selected attributes of the "smart factory" stage. The key attribute that pegs HP Brazil in the maturity stage is the fact that its Exceler8 platform supports vertical integration in its assembly, distribution, and recycling sites. The firm has for years intended to include key suppliers but has not yet done so at the time of the research (Gambon, 2007). There was no mention of integrating valued organizational customers as well. Thus, horizontal integration is missing. Workers at HP Brazil are already familiar with the data analytics software provided by T3Ci firm but their proficiency levels and self-sufficiency with their analytics skills are unclear. HP Brazil, though, is using the cloud to collect "big data" captured from RFID tags. There are some attributes that more appropriately belong to the "smart factory" stage. For instance, HP Brazil is using additive manufacturing methods like 3-D printing to create RFID tags made from organic materials (Lucrecio, 2014). The Exceler8 platform has enabled real-time visibility in HP Brazil's internal supply chain. The use of the "smart bins" for printer cartridges generates customer purchase data used in interactive, real-time demand planning and forecasting.

Future Possibilities for HP Brazil on the IIOT Trail

The following are speculative improvements that HP Brazil could conceivably consider for its future plans as well. Continued use of sensors could also upgrade all the maintenance responsibilities of parties offering printer leasing services --- this could be HP or other third party firms. RFID data collected from HP printers will provide a continuous stream of data indicating the status of the printers and issue alerts if their performance is about to degrade. HP Brazil could also increase the level of virtualization and simulations used in their business operations. The RFID based data collected from the printers could be used to create a "digital" twin or clone of the physical printer, which can be used by design engineers for simulated testing purposes to improve on existing printers and/or develop new printer models. Also, design engineers can use the recommendations generated by data analytics engines to test virtual clones of printers before working on the physical printers in the actual production process. HP Brazil workers could also use augmented reality tools like Google Glass Enterprise Edition to give them interactive instructions while doing their work whatever it may be, while freeing up their hands to do other things (Abraham & Annunziata, 2017). These suggestions could advance HP Brazil more fully into the "smart factory" stage.

REFERENCES

Abraham, M., and Annunziata, M. (2017). Augmented Reality Is Already Improving Worker Performance. *Harvard Business Review*, March 13, 2-5.

Angeles, R. (2013). Using the Technology-Organization-Environment Framework and Zuboff's Concepts for Understanding Environmental Sustainability and RFID: Two Case Studies. *World Academy of Science, Engineering and Technology International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering*, Vol. 7 No. 11, pp. 2878-2887.

Bacheldor, B. (2007, September 18). OAT Launches RFID Software for Tracking Work-in- Progress. RFID Journal. Retrieved February 5, 2018, from https://www.rfidjournal.com/articles/view?3619/2

Chien C., Hong T., and Guo H. (2017). An empirical study for smart production for TFT- LCD to empower Industry 3.5. *Journal of the Chinese Institute of Engineers*, Vol. 40 No. 7, 552-561.

Frazzon E. M., Hartmann J., Makuschewitz T., an d Scholz- Reiter B. (2013). Towards socio- cyber-physical systems in production networks. *Procedia CIRP*, Vol. 7, 49-54.

Gambon, J. (2007, June 1). Best RFID Implementation: Keeping Tabs on Printers. RFID Journal. Retrieved May 2, 2018, from https://www.rfidjournal.com/purchase-access?type=Article&id=3374&r=%2Farticles%2Fview%3F3374

Gerbert, P., Lorenz, M. Rubmann, M., Waldner, M., Justus, J., Engel, P., and Harnisch, M. (2015, April 9). Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries. Retrieved March 1, 2018, from https://www.bcg.com/publications/2015/engineered_products_project_business_industry_4_future_productivity_growth_manufacturing_industries.aspx

Gilchrist, A. (2016). *Industry 4.0 The Industrial Internet of Things*, APress, New York, NY.

GS1.org (2018). HP Brazil RFID CoE --- Center of Excellence. Available at available at https://www.gs1.org/docs/epc/HP_Brazil_RFID_CoE_FACT_SHEET_6_09_compversion_Final V02_3_.pdf

GS1.org (May 2010). Implementation Guide for the Use of GS1 EPC Global Standards in the Consumer Electronics Supply Chain. Available at https://www.gs1.org/sites/default/files/docs/epc/Implementation_Guide_for_the_use_of_GS1_EPCglobal_Standards_in_the_Consumer_Electronics_Supply_Chain_-_May_2010.pdf

HP Brazil Center of Excellence. (2017, May 16). Transcript of Video entitled, Exceler8 --- RFID operations control [Powered by HP. Available at https://www.youtube.com/watch?v=LYkRpSnm_eA

HP Brazil Center of Excellence. (2013, August 6). Transcript of Video entitled, Smart Shelf. Available at https://www.youtube.com/watch?v=hc0NMZw2sn8

HP Brazil Center of Excellence. (2014, September 9). Transcript of Video entitled, RFID Real Time Reading (RFID Rotating Cloud Portal). Available at https://www.youtube.com/watch?v=mbW8ALp6Emw

HP Brazil/RFID Center of Excellence Website. (2018). RFID for the Future. Available at http://www.rfid-coe.com/rfid-center-of-excellence

Hewlett Packard Enterprise. (2016-2017). *Delivering on the IOT customer experience: The HPE Universal IOT Platform 1.4*, Hewlett Packard, Palo Alto, CA.

Hermann M., Pentek T., and Otto B., (2016). Design Principles for Industrie 4.0 Scenarios. *49th Hawaii International Conference on System Sciences (HICSS),* Koloa, HI, pp. 3928-3937.

Hozdic, E. (2015). Smart Factory for Industry 4.0: A review. *International Journal of Modern Manufacturing Technologies,* Vol. VII No. 1, January, 2067-3604.

Kagermann, H., Wahlster, W., and Helbring, J. (2013). *Securing the Future of German Manufacturing Industry: Recommendations for Implementing The Strategic Initiative Industrie 4.0 Final report of the Industrie4.0 Working Group.* Retrieved April 5, 2018, from http://www.acatech.de/fileadmin/user_upload/Baumstruktur_nach_Website/Acatech/root/de/Material_fuer_Sonderseiten/Industrie_4.0/Final_report_Industrie_4.0_accessible.pdf

Krippendorff, K. (2004). Reliability in content analysis. *Human communication research*, *30*(3), 411-433.

Lee J., Jin C., and Bagheri B. (2017). Cyber physical systems for predictive production systems. *Production Engineering*, April, Vol. 11 No. 2, 155–165.

Lucrecio, A. (2014). Transcript of talk entitled, RFID Center of Excellence: HP and Flextronics Drive End-to-End RFID Developments in

Brazil. Delivered at RFID Journal Live! 2014 Conference, April 8-10, 2014, Orlando, Florida.

Odwazny, F., Szymanska, O., and Cyplik, P. (2018). Smart Factory: The Requirements for Implementation of the Industry 4.0 Solutions in FMCG Environment --- Case Study. *Log Forum Scientific Journal of Logistics*,Vol. 14 No. 2, 257-267.

Pandini, M. (2012a). Transcript of session entitled, RFID Journal Award 2012: Green Award Parts 1 and 2. RFID Journal Live! 2012 Conference, April 3-5, 2012, Orlando, Florida.

Pandini, M. (2012b). Transcript of talk entitled, Achieving Manufacturing Excellence with RFID. Delivered at RFID Journal Live! 2012 Conference, April 3-5, 2012, Orlando, Florida.

Pandini, M. (2007). Transcript of talk entitled, Best RFID Implementation: Hewlett Packard. Delivered at RFID Journal Live! 2007 Conference, May 30-April 4, 2007, Orlando, Florida.

Perin, E. (2017, August 27). Hewlett-Packard Factory Showcases Internet of things Advances in Brazil. RFID Journal. Retrieved April 15, 2018, from https://www.rfidjournal.com/purchase-access?type=Article&id=16525&r=%2Farticles%2Fview%3F16525

Perin, E. (2016, September 30). RFID Platform Tracks HP Brazil's Manufacturing, Distribution. RFID Journal. Retrieved April 17, 2018, from http://www.rfidjournal.com/articles/view?15013

Prause M., and Weigand J. (2016). Industry 4.0 and Object-Oriented Development: Incremental and Architectural Change. *Journal of Technology Management & Innovation*, Vol. 11 No. 2, 104-110.

Rapp, R. (2018). Transcript of talk entitled, HP LATAM Uses Digital Supply Chain Program to Improve Efficiency. Delivered at RFID Journal Live! 2018 Conference, April 10-12, 2018, Orlando, Florida.

Rapp, R. (2018). Transcript of talk entitled, HP LATAM Uses Digital Supply Chain Program to Improve Efficiency. Delivered at RFID Journal Live! 2018 Conference, April 10-12, 2018, Orlando, Florida.

Rapp, R. (2017). Transcript of talk entitled, How Cloud Analytics Gives HP Brazil New Supply Chain Insights. Delivered at RFID Journal Live! 2017 Conference, May 9-11, 2017, Phoeniz, Arizona.

Roberti, M. (2013, November 11). Insights from RFID Journal LIVE! Brasil 2013. RFID Journal. Retrieved May 5, 2018, from http://www.rfidjournal.com/articles/view?11171

Roberti, M. (2008, October 28). HP Optimizes RFID System at Printer Plant. RFID Journal. Retrieved May 7, 2018, from http://www.rfidjournal.com/articles/view?4420

Roberti, M. (2006, February 28). HP Takes RFID End to End. RFID Journal. Retrieved May 9, 2018, from http://www.rfidjournal.com/articles/view?2172

Stone, P.J., Dunphy, D.C., Smith, M.S., and Ogilvie, D.M. (1966). *The General Inquirer: A Computer Approach to Content Analysis*. MIT Press, Cambridge, MA.

Swedberg, C. (2014, April 8). HP's RFID Center of Excellence to Market Cloud-based Rotating RFID Portal. RFID Journal. Retrieved May 15, 2018, from http://www.rfidjournal.com/articles/view?11659

Techopedia (2018). Augmented Reality. Available at https://www.techopedia.com/definition/4776/augmented-reality-ar

Stone, P.J., Dunphy, D.C., Smith, M.S., and Ogilvie, D.M. (1966). *The General Inquirer: A Computer Approach to Content Analysis*. MIT Press, Cambridge, MA.

Weber, R.P. (1990). *Basic Content Analysis, 2nd edition*. Sage Publications, Newbury Park, CA.

Weick, K. (1979). *The Social Psychology of Organizing*, Addison-Wesley, Reading, MA.

Wohler's Associates (2018). What is Additive Manufacturing? Available at: https://wohlersassociates.com/additive-manufacturing.html

Zaino, J. (2009, June 8). A Guide to RFID WIP Solutions for Discrete Manufacturers. RFID Journal. Retrieved March 15, 2018, from https://www.rfidjournal.com/purchase-access?type=Article&id=4958&r=%2Farticles%2Fview%3F4958

Zaino, J. (2012, July 30). Extracting New Value from Old Printers. RFID Journal. Retrieved March 20, 2018, from http://www.rfidjournal.com/articles/view?9754