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RFID- Enabled Dynamic Value Stream Mapping

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Abstract

Value Stream Mapping (VSM) is one of the most powerful lean manufacturing tools used for quick analyses of products and information flow through a manufacturing system from door to door. This versatile, powerful method is used to visualize product flows as snapshot; it just describes the production behavior within specific period from the total production time; which some time cause a misleading during lean tools implementation. In this paper a new real-time data collection called Radio Frequency Identification (RFID) system will be integrated in VSM to collect the objects information through a manufacturing system in the production floor. The new integrated RFID-VSM system called Dynamic Value Stream Mapping (DVSM) Provides a real-time data for VSM to be able to interact with the processes, people, material, and any other constraint relevant to the production situation. As time progresses and the operation are "producing", the workers and managers will have the ability to interact live with the animated flow. Queues build up, inventory deplete, people move, etc... Based on the real situation the managers can take the right decision at the right time where the workers will make changes to processing capacity, labor requirements, flow, and cell layout, to optimize and design or develop the future state.

Keywords
Value stream mapping, Radio frequency identification system, Dynamic Value stream mapping, Just-in-Time, KANBAN.

1. Introduction

With the increased customer demand , market fluctuations , and the need for fast information flow within most manufacturing industries today it has become increasingly important to continuously analyze and improve the manufacturing system and the corresponding planning system. The most widely known approach for improvement work performance is lean manufacturing.

The lean concept was defined by (Womack et al. 1990) and (Liker 2004), where the concept of lean manufacturing has been evolved from the early 1930s by Toyota Production System (TPS) in Japan. Within lean there are tools and methods that are used for different purposes in the organizations. Because of many potential benefits of lean manufacturing, much attention has been focused on advancing its tools, techniques, and implementation strategies in recent years. Further discussions can be found in Bozzone (2002), Edwards (1996), Feld (2001), Rother and Shook (2003), and Storch and Lim (1999).

The first step toward lean is VSM; it’s a traditional lean tool used for quick analyses of product flow through a manufacturing system, from door to door. But due to its weakness in covering some issues in the manufacturing facilities, beside that it displays the information for specific period of time from total production time which serves just as snapshot - static - description of the production behavior. Therefor this work tends to improve the VSM abilities by utilizing RFID capabilities in VSM; and it becomes called Dynamic Value Stream Mapping (DVSM). RFID will be integrated in VSM as real-data collection tool to fill the gap between physical flow of products or objects and the corresponding information flow. The DVSM will be used as starting point for implementing lean manufacturing tools like Just-In-Time (JIT) , KANBAN system , Total Productive Maintenance (TPM) , quality issues while after lean implementation its used as continuous real-time production monitoring tool to ensure the consistency of lean tools implementation and for continuous measuring of production performance for further improvement opportunity.

2. Traditional Value Stream Mapping

Value stream mapping is well known as material and information flow mapping. VSM can serves as a starting point for management, engineers, production associates, schedulers, suppliers, and customers to recognize and identify waste and the corresponding causes. The VSM process involves physically mapping the current state while focusing on the desired goals, or the future state map, that can serves as the starting point for other lean improvement strategies. VSM has been discussed in detailed about its application in manufacturing (i.e. physical transformation) in Rother and shook book "learning to see" (2003). while value stream management ties people, lean tools, metrics, and reporting requirements together for a lean enterprise.

Despite VSM benefits but it still has some weaknesses as it is normally used (Solding and Gullander 2009):

- Only the flow of one product or product type is analyzed per VSM analysis.
- The VSM gives only a snapshot of the situation on the production floor at one specific moment.
- The VSM map is a rough simplification of the real situation.
- Fails to factor queuing delays, sequencing rules for multiple orders, capacity constraints, etc.
- Lacks any worthwhile economic measure for "value" (ex. profit, throughput, operating costs, and inventory expenses).

Rother and shook (2003) stated the way of taking the information by walking along the actual pathways of material and information; this means , a general information will be collected rather than the real information; the collected information in this simple way is misleading information for the managers who want to improve the production system or take decisions . From their side this method of collecting the aggregated data is usually more convenient than timing every work piece going through the production line. Therefore, obtaining the time averages of a VSM requires less effort than collecting detailed data from the individual work piece. But the averages are capable of representing just the general conditions of the value stream. However, an average number cannot display the variability of the actual conditions or the enough deeply description of the actual situation. The lost information may contain clues of the actual leanness level and potential improvements. Therefore utilizing an automatic data collection technology (Auto-ID) can serves as accurate and fast automatic data collection for the interacted objects in the production system, which gives the management a detailed description about actual condition of the production line.

3. FRID and its Uses in Production and Supply Chain Management

3.1. RFID Essentials

Although the scope of this paper is not to give a detailed insight into the RFID technology itself, but it is mandatory to have a basic understanding of the underlying technology . RFID is an emerging technology intended to complement or replace traditional barcode technology to identify, track, and trace items automatically. RFID is claimed to add intelligence to and to minimize human intervention in the item

identification process by using electronic tags. The tags are significantly different from printed barcodes in their capacity to hold data, the range at which the tags can be read, and the absence of line-of-sight constraints (Asif and Mandviwalla 2005) .The basic components of RFID system is consist from three components. Note that the exact configuration of a particular deployment depends on the vendor, system integrator, and the application.
An RFID system includes:

- Transponders (Tags) that allow items to be identified.
- Antennas and Readers/writers that allow tags to be interrogated and to respond.
- Software that controls the RFID equipment's, manages the data and interfaces with enterprise applications.

where transponders are the distinguishing feature of an RFID system. Transponders are the 'labels' that are attached to objects (products, operators, machines, etc.) to be identified. Due to their wide-spread uses in supply chain operations, they are commonly known as tags. These microchip-based tags with a tiny antenna attached to them can hold up to 10 Kbits of data. The data stored can include product identification, expiration, warranty, handling and storage instructions, and service history. Instead of visible light used in ordinary bar code labels, these tags use radio waves to communicate with the readers. To produce radio waves tags require some source of energy to power its electronics. Active tags use a tiny battery, a microchip, and a tiny antenna built into them. RFID tags come in many forms, including glass capsules, disks, cylindrical tags, wedge-shaped tags, smart cards, and keychain fobs, and can range from a few square millimeters to up to a few inches long (Asif and Mandviwalla 2005), RFID tags can be as small as a grain of rice, they exist in manifold form factors in dependence upon the application; they can be attached to price tags or be directly implemented into the product.

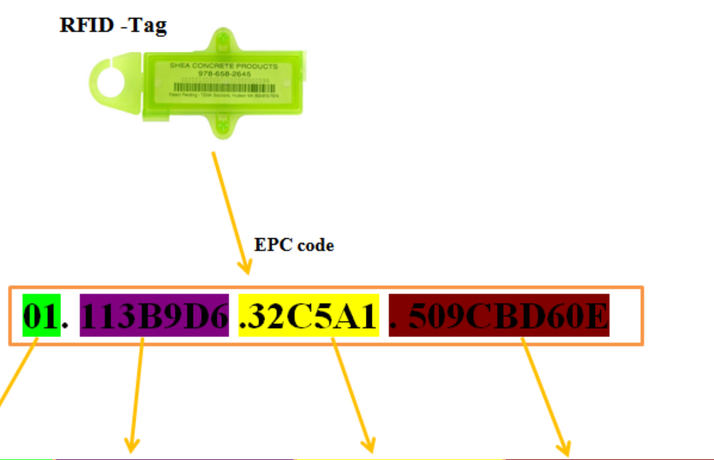
Some readers can write to the tags which mean that data on the read/write tags or so-called active tags may be changed or updated to the real time production situation e.g. updated every workstation a product has passed in the supply chain. This ability may prove helpful in situations where customer needs; business processes and standards may change any time. Read/write tags are reusable which reduces long term operating costs (Asif and Mandviwalla 2005) The used RFID middleware software depends upon the production environment, the software is developed suitably to be compatible with enterprise information system policy and to manage the enormous amount of the data captured by RFID readers taking into account the complexity of the actual RFID system and the complexity of the data processing. In a typical manufacturing scenario, for example, readers will be picking up a continuous stream of tag data, which might contain errors such as duplicate reads and phantom-reads. The job of the software is to filter and manage this data and forward only clean data in order to avoid overwhelming enterprise applications (Asif and Mandviwalla 2005).

3.2. Utilizing RFID Technology in Production and Supply Chain Management

In supply chain and production activities the process starts with orders of raw materials and/or semi-finished parts from suppliers, which are then used by the sequential production processes in the manufacturing plant or product assembly line to make the finished products. These products flow through supply chain from the suppliers passing through production process and then transported to the distributors, then to the retailers, and finally to the end users /customers. But a manual data entry and product identification processes for each single activity are time-consuming processes which delay the critical information necessary to run an efficient manufacturing operation or warehouse/distribution. Small gaps in timing or data entry errors can increase the difficult task of ensuring the right product, at the right time, in the right place.

Building a strong and robust supply chain management system it's needed to develop an effective way of data collection and information exchange especial in large scale enterprise cases. For this reason, the ways of collecting or capturing the information among supply chain and sharing these information in the enterprise or further, and besides how fast and secured is this ways become the most important research issues investigated by the enterprises. Depending of the described abilities of RFID technology which make it an ideal candidate for information capturing throughout the whole supply chain and the best method for data exchange between the supply chain parties . In this manner there are absolutely many areas of the supply chain where RFID technology is utilized very effectively in order to optimize the supply chain process. BMW and Vauxhall decided to utilize RFID technology, where RFID tag is used to enable accurate customization of customer orders, a read/write smart tag is programmed according to the customer order specifications, and then its attached to the car body and travels with it during the production process, this tracking ensure that the car is manufactured with the correct production process at each workstation relating to the customer specifications (Brewer and Landers 1997).

However, as the technical prerequisites of RFID installation in the supply chain have discussed above ; it still needed to identify how RFID-based supply chain can be realized , this mean firstly we have to use identification system for each product, machine, labor, material handling system or other objects upon a system requests, secondly the system should define the type of information which will be captured and when, thirdly , the criteria of data processing and analyzing must be defined and where will be stored , fourthly decide who has a permission to use this information . These fundamentals have been addressed by the EPC global. The EPC global has its beginnings in an academic research center based at the MIT called the Auto-ID Center (Hunt et al. 2007) , the key component of the EPCglobal model is the Electronic Product Code or EPC. EPCglobal has specified three standards (EPC Tag Data Specifications, Object Name Service (ONS) ,and Physical Markup Language (PML)) which can be used to establish architecture in an RFID system that is comparable to the Internet, where every object in the production facility can be identified by its unique Electronic Product Code (EPC) which is similar to the bar code standard (Hunt et al. 2007).and Each tag contains a unique EPC which is a 96-bit code proposed as a successor to Uniform Product Code or UPC. The structure of the Electronic Product Code defined by Auto-ID Center is illustrated in figure 1.



01	113B9D6	32C5A1	509CBD60E
8 bits	28 bits	24 bits	36 bits
Version of EPC	Manufacturer Identifier	Product Identifier	Item Serial Number
	More than 268 million unique IDs possible	More than 16 million unique IDs	More than 68 billion unique IDs

Figure 1: The structure of the 96-bit PECglobal.

The reading of the RFID tag depends on the type of the attached tag itself , mostly the tag reading began where the antenna enables the chip to transmit the object's identification information as radio waves to the RFID reader installed at predetermined point corresponding to specific production area , The RFID reader will converts the received radio waves into digital information through a middleware software in the enterprise system, then this information are available for use according to the permission given from the enterprise to different department in the enterprise like production, purchasing, sales, maintenance, finance department and others.

4. Integration RFID Technology in Value Stream Mapping

The basic idea of utilizing lean manufacturing concepts in any enterprise is to eliminate the waste in all activities in all phases especially in production phases to improve the productivity, reactivity of production to different external or internal fluctuation, quality and total performance of the enterprise, Therefore, the implementation of lean tools and principles start by drawing the VSM which is considered the most powerful lean tool and the best starting point to implement other lean concepts due to its ability to visualize the current situation of the production and identifies not just the wastes but also the source of the wastes in value stream. It has the ability also to tie together lean concepts, techniques, people and methods during the transformation from current to future VSM, figure 2 shows this through lean building blocks where VSM considered as a stairs to the house of other lean tools and concepts.

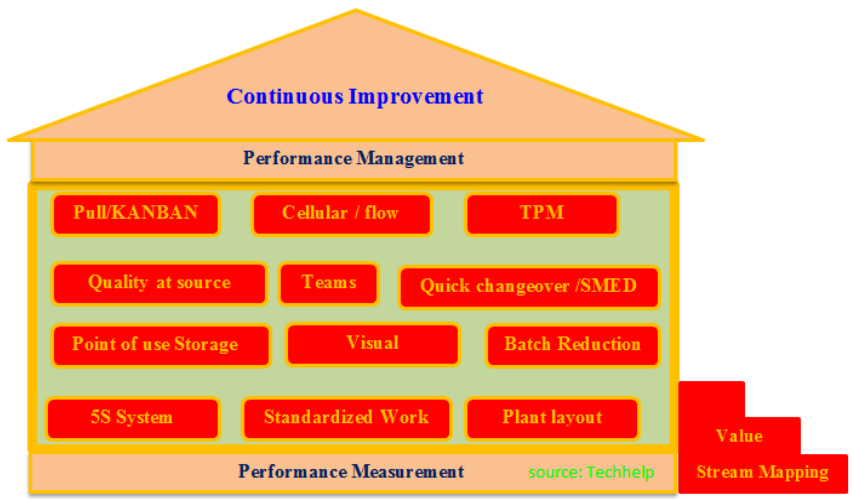


Figure 2: Lean building blocks

4.1 Dynamic Value Stream Mapping as Continuous Real - Time Production Monitoring Tool

Extensive studies were performed on various subjects related to VSM; but most of them didn't focus on the dynamic behavior of VSM just Solding and Gullander (2009) tried to build a dynamic values stream mapping based on the simulation software called Simulation-Based Values Stream Mapping (SBVSM), also this work doesn't represent the actual situation of production and doesn't give a real information describing the production floor activities to improve the ability to react against different sudden changes or to avoid them at the right time.

Although many organizations implement lean concepts but they don't know how to keep and ensure them implemented on the production floor for long-term. Normally after the implementation of lean tools and measuring the achieved results its needed a continuous monitoring system to display the performance consistency of the production system, moreover to check and ensure the continuous implementation of lean tools to avoid degradation in implemented lean tools and to measure the discrepancies and deviation between the actual and target process which is called process compared to the Standard Work-in-Process (SWIP) required within the process.

In this paper it is proposed that the real-time continuous monitoring process of production performance can be performed through DVSM, meanwhile RFID will give a real-time information from the production floor to the already built VSM of the production floor , referring to the study of (Fauple et al. 2008) the integration of FRID in VSM to develop the new tool DVSM will improve the performance level of the enterprise in three effecting level ; they are Automation , Informatization and Transformation and they are leading to support the deployment process of lean manufacturing tools and concepts .

4.2 Integration Development of RFID in VSM

4.2.1 Framework Development of DVSM

The integration of RFID in VSM will be built as general as possible, so it can be easily adapted in any manufacturing environment with the same steps and configurations, these steps are mentioned and explained below:, where figure 3 and figure 4 explain the integration idea and the impact of this integration on lean tools and waste .

First step: attach each object in the production floor with RFID - Tag either passive or active or chip - less or sensor tag depending on the object tracking target. So every single object will be tagged and become so called smart-object in order to react with the real-time continuous monitoring and controlling system while flowing in the production stream. Table 1 contains a proposal of RFID objects tag structure.

Table 1: RFID objects tag structure.

Object type	Auto-ID content	Purpose of RFID utilizing	Type of RFID-Tag
Workstations operators staff	Staff -ID	Attendance, location, time of coming and leaving, moving area.	The Type of RFID – Tag depends on the specific target and production environ-ment
Logistics operators staff	Staff -ID	Attendance, location, time of coming and leaving, moving area.	
Workstation’s Machines	M -ID	Sum the uptime and Idle period, downtime period, cycle time for each product arrival-departure of the products ,and condition update	
Material handling systems and equipment	MH -ID	Sum the uptime and Idle time, downtime Period, capacity of product handling.	
Supporting equipment and tools	SE/T-ID	Usage time , condition updating	
Semi-finished , subassemblies and finished products	P-ID	Tracking, Tracing, Monitoring, Counting, Processing time, Waiting, Status updating, quality issues	
Containers , boxes ,pallets and others	C/B/P - ID	Tracking, Tracing, Monitoring, Counting, Waiting	
Other objects	--------	-------------	

Second step: define the added value activities executed through value stream to produce the needed products according to customer specifications in order to build a standard production template.

Third step: program the RFID-Tag attached to the semi-finished product with the defined added value activities as standard operations and processing instructions.

Fourth step: determine the quality inspection point though value stream to inspect if the semi-finished products meet customer specifications and production standards as well as to reduce the response time to changes in customers specifications during manufacturing if it not in advanced production stages and can be adjusted.

Fifth step: build the needed middleware - software in order to analyzing and filtering the captured information corresponded to each object with ability to forward this information to farther departments through information system like XML or any information and communication network infrastructure.

Sixth step: divide the production areas in the production floor to Manufacturing cells or unit and define them with specific code number; to facilitate that, the manufacturing unit can be defined with respect to the main workstation exist at each production area.

Seventh step: assign the objects located and operators working to their corresponding Manufacturing unit, (the objects are used may be by the main workstation in that area or may be in the same area, the idea behind this step is to support the lean tool 5S).

Eighth step: define the type of information which will be collected or updated at each manufacturing unit for each object.

4.2.2 The Principles of DVSM-Framework

The structure of the framework is generally illustrated in figure 3, the flow stream of value steam mapping is taken from Rother and shook book "learning to see" (2003), the working principles are summarized in the following steps:

First step: the working principle of the framework begin by building the value stream mapping depending on the collected information from the tagged objects in the existed value stream in different time intervals under different manufacturing condition, this will representing an actual situation of the production through specific time intervals. Longer time intervals give high accurate representation of the actual production behavioral. This step classified under automation and Informatization according to (Fauple et al. 2008).

Second step: use the built VSM as starting point to realize lean tools and concepts to improve the existed value stream and then re-engineer the value stream or make the transformation process according to those lean tools and concepts with the help of real-time information to improve the performance of the value stream.

Third step: after the implementation of re-engineering process, the new value stream need RFID as continuous monitoring system which utilized for managing, supporting and ensuring the lean tools and concepts like: managing JIT and KANBAN system, Quality system, maintenance system, supporting 5S concepts, work standardization, visual system, line balancing, production smoothing, continuous improvement, small lot production and continuous flow. The description of how RFID manage or support each one of these tools will be discussed later in farther separated research papers.

Forth step: using RFID system as continuous improvement supporting tool, utilized to catch the often occurring errors, happening problems and use these information as a feedback for build a solutions to avoid the occurrence of these errors and problems, which lead us also to find a new technologies in order to be utilized in our production systems for further performance improvements.

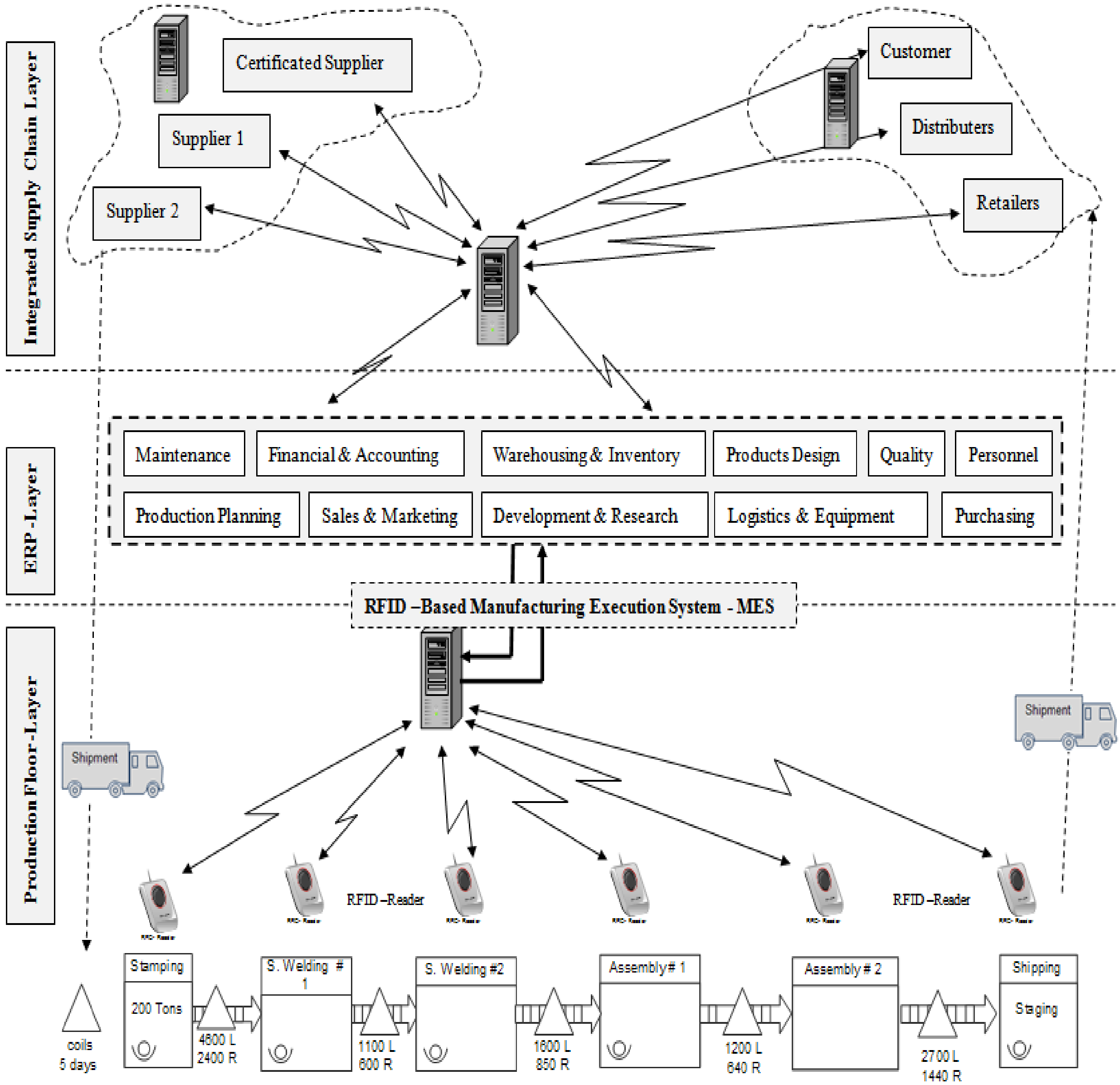
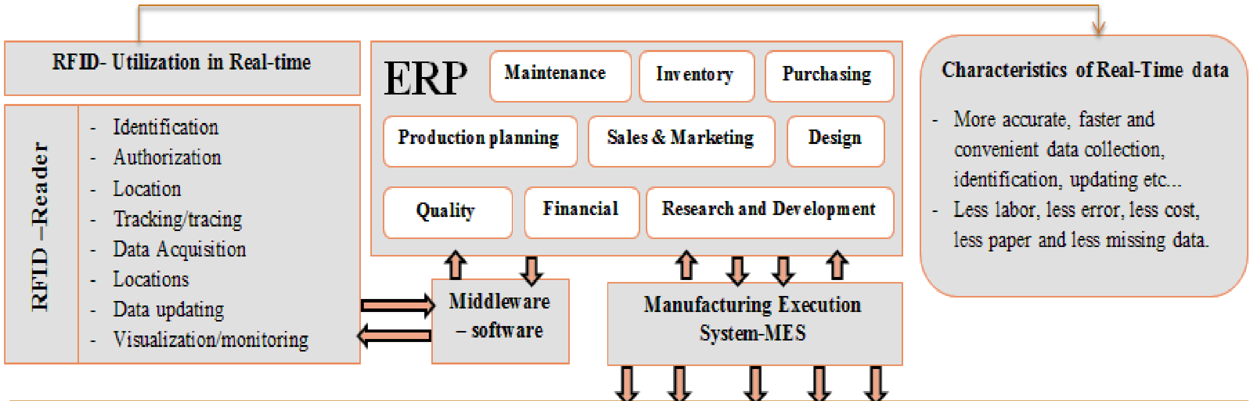


Figure 3: The Framework of DVSM.

4.2.3 The Impact of the DVSM on Lean Tool Implementation and Waste Elimination

The DVSM has an important impact on lean manufacturing implementation and contribution in waste elimination; and how DVSM lead to real time interaction between other departments and the current production situation in the production floor. Figure 4 shows a proposed live interaction of ERP with RFID profitability through VSM to contribute in faster, easier, and cheaper waste elimination.



Monitored Lean tools	Proposed Profitability from RFID	Type of eliminated Waste						
		Over-production	Motion	Waiting	Inventory	Rework	Transp-ortation	Over-processing
Quality Tools	Improve Customer Orders deliveries				✓			
	Improve Quality inspection					✓		✓
	Reduction the production downtime	✓		✓	✓			
	Supporting Maintenance system	✓		✓	✓			
	Improve defects/scrap/rework tracking					✓		
	Improve Quick customer response					✓		✓
	Improve resources Supplying	✓			✓			
Production Process Tools	Capacity / Utilization measuring and monitoring	✓	✓	✓	✓	✓	✓	✓
	KANBAN managing	✓		✓	✓		✓	
	Minimizing production variability	✓		✓			✓	
	Facilitating Labor guidance during production		✓				✓	✓
	Monitoring WIP Inventory, warehousing system			✓	✓			
	Improve Line balancing/production mix	✓		✓	✓		✓	✓
	Improve communication possibilities	✓	✓	✓			✓	
Lean Methods Tools	Improve work standardization					✓		✓
	Improve cost accounting system							✓
	Monitoring Supportive tools and equipment						✓	
	Continuous Visualization /monitoring	✓	✓	✓			✓	
	Reduction in theft				✓			
	Reduction of paper work error and the needed time	✓		✓				✓

Figure 4: The impacts of using RFID on waste elimination and deploying lean manufacturing tools.

5. Conclusion and Future Work

Due to the importance of value stream mapping in lean manufacturing, which is used as starting point, identification tool and roadmap to use the needed lean manufacturing tools and principle in the production system , In this work the effectiveness of this powerful tool was improved and developed through integrating RFID system in VSM as real-time data collecting technology , the real-time data enables VSM to represents the exact situation in the production floor, the exact representation for the production floor will help the value stream manager to make the right decisions during and after lean implementation process , the new developed system called DVSM will helps the companies after adopting lean to ensure the implementation of each planned and scheduled process as well as measure the discrepancies and deviation between the actual and standard process . The continuous real-time collected data are forwarded to different departments for different purposes as mentioned above. DVSM supports real-time manufacturing intelligence; where manufacturers can achieve high levels of performance. For further research in this topic we will try to build a general framework showing how DVSM will manage many areas in the companies like KANABAN, Bullwhip effects, TPM, supporting cost accounting and other areas.

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