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REVIEW: MANUFACTURING SYSTEMS AND INDUSTRY 4.0

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ABSTRACT

Although Lean manufacturing techniques are not yet in place in every shop floor production, the so-called Smart Factory with the very promising label "Industry 4.0" is already making its tour. This Paper represents the review of conventional manufacturing Systems and Industry 4.0. This new digital industrial revolution holds the promise of increased flexibility in manufacturing, mass customisation, increased speed, better quality and improved productivity. However to capture these benefits, enterprises will need to invest in equipment, information and communication technologies (ICTs) and data analysis as well as the integration of data flows throughout the global value chain.

Keywords: Manufacturing Systems, Industry 4.0, Circular Economy.

I.INTRODUCTION

A system in which raw materials are processed from one form into another, known as a product, gaining a higher or added value in the process and thus creating wealth in the form of a profit. There is no one concept that will cover all industries in detail. However, there are numerous detailed definitions of what represents a manufacturing system. One such definition that is particularly appropriate is that of Lucas Engineering and Systems. It defines "A manufacturing system is an integrated combination of processes, machine systems, people, organizational structures, information flows, control systems and computers whose purpose is to achieve economic product manufacture and internationally competitive performance."[1]

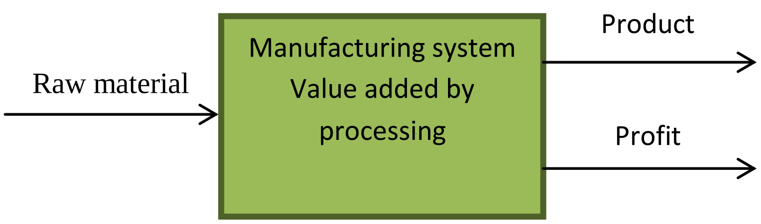

Fig 1. Basic process of a Manufacturing System

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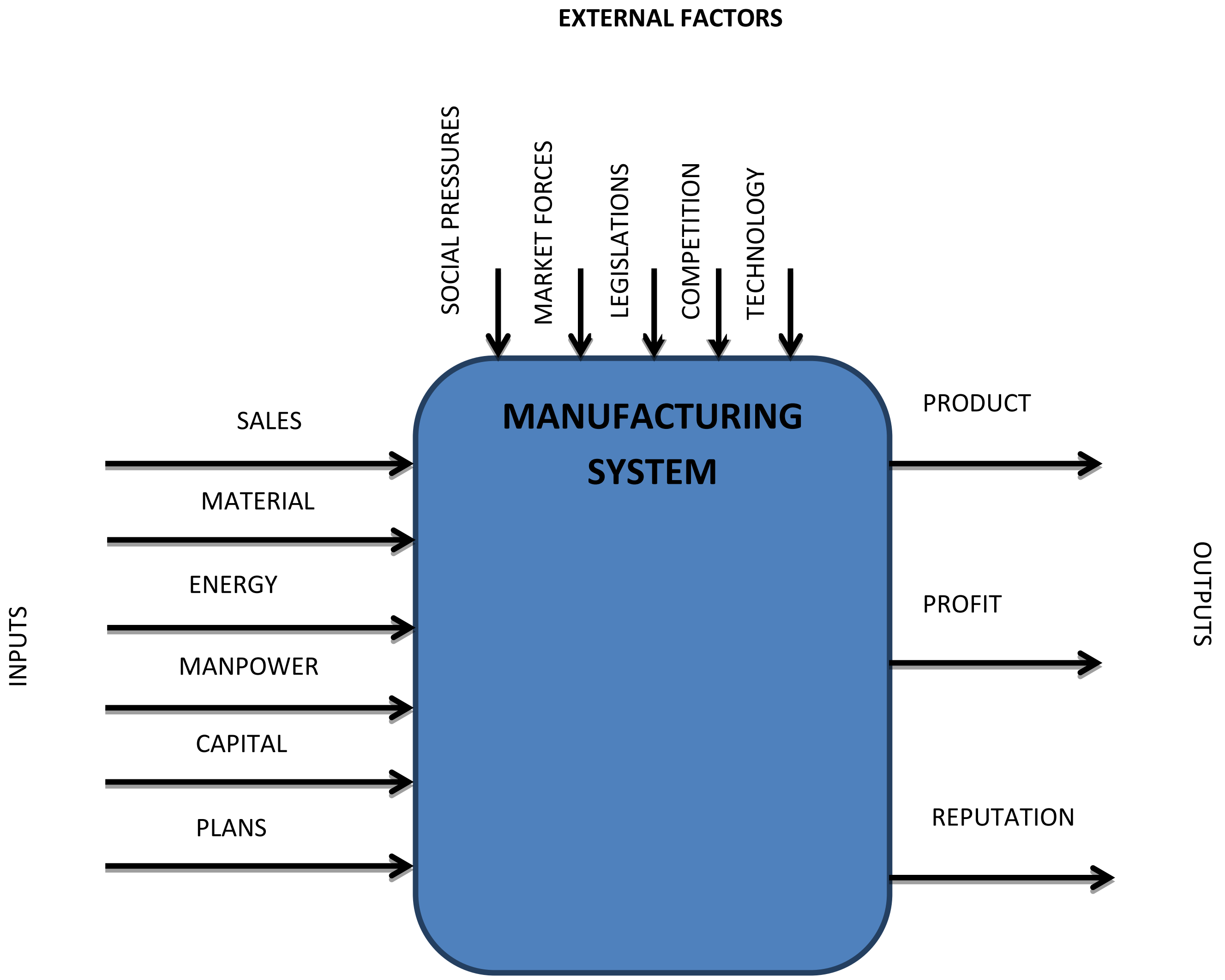

Fig 2. Detailed Process of Manufacturing System

II.MANUFACTURING ORGANIZATIONAL STRUCTURES

Every manufacturing organization is unique in some respect, there are six broad functions that can be identified in almost any manufacturing organization. These are sales and marketing, engineering, manufacturing, human resources, finance and accounts and purchasing. The general responsibilities of these functions are as follows:

Sales and marketing – This part of the organization provides the interface with the market. The main responsibilities of this function are to ensure a steady flow of orders and consolidate and expand the organizations share of the market. Typical sub-functions might include sales forecasting, order processing, market research, servicing and distribution. Engineering – typically under this functional heading the sub-functions would include product design, research and development (R&D) and the setting of specifications and standards. The level to which R&D is carried out will depend on the product. For example, in high-tech products, R&D will play a major role in determining the use of materials and processes and future product design.

Manufacturing – The diversification of the manufacturing function will depend very much on the size of the organization. Typical sub-functions might include: Production planning with responsibility for producing manufacturing plans such as the master production schedule (MPS) and the materials requirements plan (MRP). Quality assurance whose job it is to ensure that products are being made to the required specification. Plant maintenance with the responsibility of ensuring that all equipment and machinery is maintained at an appropriate level for its use. Industrial engineering whose responsibilities include the determination of work methods and standards, plant layouts and cost estimates. Manufacturing engineering's responsibilities includes manufacturing systems development, process development, process evaluation and process planning.

Human resources – It includes sub-functions such as recruitment, training and development, labour relations, job evaluations and wages. **Finance and accounts** – the main responsibilities of finance include capital financing, budget setting and investment analysis. Accounts generally deal with the keeping of financial records including cost accounting, financial reporting and data processing. **Purchasing** – this primarily involves the acquisition of materials, equipment and services. They must ensure that the above support the manufacturing capabilities by satisfying their supply need. They must also ensure the quality and quantity of supplies through vendor rating.[2]

III.TYPES OF MANUFACTURING SYSTEMS

The manufacturing systems differ in structure or physical arrangement. According to the physical arrangement, there are four kinds of classical manufacturing systems and two modern manufacturing systems that is rapidly gaining acceptance in industries.

The classical systems are as follows:

1) Job shop
2) Group Technology
3) Project shop
4) Continuous process

The modern manufacturing systems are

1) Linked cell system (Cellular manufacturing system)
2) Flexible manufacturing system (FMS)

A. **JOB SHOP -** To produce a large variety of products will require a number of different machinery. When similar machines are grouped together into different departments within a plant layout the arrangement is classified as a JS operation. In producing a part it is sequenced through the various departments depending on the manufacturing operations required. When dissimilar parts are required to be manufacture utilizing the same machines considerable time is utilized in set-up. Further delays are encountered through material handling between departments, since different types of machines required for processing the part are in different department at a distance apart. The JS arrangement allows manufacturers the flexibility to produce small quantities of different products that the customer requires. It also allows the manufactures the flexibility to adapt to changes in customers requirement; to quickly adjust to the manufacturing of new products and to cushion oneself when product have become obsolete.

B. **GROUP TECHNOLOGY (GT) -** An improvement of the JS operation utilizes GT. GT is simply the classification and coding of similarities between parts into families of parts. However, considerable time is required to develop. Upon classifying the families; the tools, fixtures and machinery required to produce a family of parts are grouped together into cells within close proximity. These cells consist of functionally dissimilar machines. This arrangement facilitates a reduction in time for process planning in terms of sequence of operations.

C. **CELLULAR MANUFACTURING SYSTEM (CMS) -** CMS can be defined as an application of GT where the families of parts that require a similar set of operations are produced within a cell utilizing all or most of the machinery in the cell. A product can be processed progressively from one workstation to another within the cell without having to wait for a batch to be completed. Cells may be dedicated to a process, a sub-component, or an entire product. Since only similar parts that require a similar set of operations are produced in the cell the set-up time for producing the product will be zero or a limited amount resulting in reduction work-in-process (WIP) inventory and throughout times, increased worker satisfaction and productivity of the shop. However, it requires the physical reconfiguration of the machines within the JS to a cellular layout at considerable cost. On the other hand, when new products manufacturing are required if they do not fit into the existing cell then the whole manufacturing setup needs to be restructured.

D. **VIRTUAL CELLULAR MANUFACTURING (VCM)**: The new concept of CM utilizes the existing JS layout. VCM utilizes the JS layout in direct conjunction with GT. When different families of parts are required to be manufactured the cells are reconfigured based on the operations requirement. It exists within the minds of the workers where the physical layouts of the machines are not rearranged but remain in their respective departments. This reformatting of cells facilitates quick changes in customer’s requirement at relatively no cost to the manufacture in terms of plant layout. With the traditional JS operation the products are not group into families, as compared with CM where the application of GT is utilized. However, with VCM since it follows on from the concept of CM, the products are grouped into families.

E. **FLEXIBLE MANUFACTURING SYSTEM:** Flexibility is an attribute that allows a mixed mode manufacturing system to cope up with a certain level of variation in part or product cycle, without any interruption in production due to change over’s between model and hence FMS is called flexible due to the reason that it is capable of processing a variety of different part styles simultaneously at the workstation and quantities of production can be adjusted in response to changing demand patterns. The different type of flexibility that's exhibited by manufacturing system are given below

Machine Flexibility - It is the capability to adapt a given machine in the system to a wide range of production operations and part styles. The greater the range of operations and part styles the greater will be the machine flexibility.

Production Flexibility - It is the range of part styles that can be produced on the systems. The range of part styles that can be produced by a manufacturing system at moderate cost and time is determined by the process envelope.

Mix Flexibility - It is defined as the ability to change the product mix while maintaining the same total production quantity that is, producing the same parts only in different proportions. It is also known as process flexibility. Mix flexibility provides protection against market variability by accommodating changes in product mix due to the use of shared resources. However, high mix variations may result in requirements for a greater number of tools, fixtures, and other resources.

Product Flexibility - It refers to ability to change over to a new set of products economically and quickly in response to the changing market requirements. The change over time includes the time for designing, planning, tooling, and fixturing of new products introduced in the manufacturing line-up.

Routing Flexibility - It can define as capacity to produce parts on alternative workstation in case of equipment breakdowns, tool failure, and other interruptions at any particular station. It helps in increasing throughput, in the presence of external changes such as product mix, engineering changes, or New product introductions.

Volume Flexibility - It is the ability of the system to vary the production volumes of different products to accommodate changes in demand while remaining profitable. It can also be termed as capacity flexibility.

Expansion Flexibility - It is defined as the ease with which the system can be expanded to foster total production volume.

IV.INDUSTRY 4.0

Industry 4.0 is a term applied to a group of rapid transformations in the design, manufacture, operation and service of manufacturing systems and products. The 4.0 designation signifies that this is the world's fourth industrial revolution, the successor to three earlier industrial revolutions that caused quantum leaps in productivity and changed the lives of people throughout the world. In the other words, Industry4.0 is the comprehensive transformation of the whole sphere of industrial production through the merging of digital technology and the internet with conventional industry. In short, everything in and around a manufacturing operation (suppliers, the plant, distributors, even the product itself) is digitally connected, providing a highly integrated value chain. The term Industry 4.0 may variously be labelled: Smart factories, the Industrial Internet of Things, Smart industry, or advanced manufacturing.

Industry 4.0 depends on a number of new and innovative technological developments:

- The application of information and communication technology (ICT) to digitise information and integrate systems at all stages of product creation and use (including logistics and supply),both inside companies and across company boundaries;
- Cyber-physical systems that use ICTs to monitor and control physical processes and systems. These may involve embedded sensors, intelligent robots that can configure themselves to suit the immediate product to be created, or additive manufacturing (3D printing)devices
- Network communications including wireless and internet technologies that serve to link machines, work products, systems and people, both within the manufacturing plant, and with suppliers and distributors
- Simulation, modelling and virtualisation in the design of products and the establishment of manufacturing processes
- Collection of vast quantities of data, and their analysis and exploitation, either immediately on the factory floor, or through big data analysis and cloud computing
- Greater ICT-based support for human workers, including robots, augmented reality and intelligent tools.

V.INDUSTRY 4.0 VALUE DRIVERS

1) RESOURCE /PROCESS

Using resources and optimizing processes. Enabled by the IoT and CPSs. It is possible to observe processes in real-time. The interconnection of machines, products and humans and the omnipresent information about everything makes it possible to react in a very fast, efficient and fully automated way to every circumstance during production. If everything gets traceable also the consumption of resources gets increasingly transparent within these advanced manufacturing processes.

The observation of state and location of valuable materials (e.g. rare metals used in electronic parts) by using RFID-technology will reduce waste and will increase the reuse of these scarce resources. This will enable or at least ease to hold technical nutrients within their cycles.

The observation of process conditions in real-time holds not only for the consumption of classical input materials. It also makes it possible to trace for example energy and water consumption during each step of production. In addition to optimization of the production time does not only save time, but shorter production processes typically consume less resource like energy. Within Industry 4.0 processes will be able to monitor, to be aware, to predict, to optimize and to configure themselves. Consequently processes can be designed more sustainable and ease to establish an economy according to CE (Circular Economy) principles and this improvement of manufacturing processes including the optimization of material consumption will drive value and will make it possible to increase productivity.

2) ASSET UTILIZATION

Within most factories manufacturing equipment is a capital good with a long use phase up to 20 or more years. Retrofitting of assets enables an easy way of upgrading existing manufacturing equipment with sensor and actuator systems as well as with the related control logics. This is a cost-efficient way to use Industry 4.0 technologies and make assets “intelligent”. Similarly retrofitting enables the realization of CPS throughout a value creation module, such as a factory, with already existing manufacturing equipment. Through the use of Industry 4.0 technologies knowledge about the assets, location, condition and availability can be collected. The information about the location and availability of an asset is especially important for businesses that have mobile assets and will enable them to use their assets more effectively. It is an important facilitator of sharing models, which contribute to a sustainable use of resources. The collection of data to monitor an asset´s condition will enable users to define thresholds or rules to initiate actions or notifications that allow condition based reactions. This will make predictive maintenance and replacement of failing components (prior to asset failure) possible and will enable to minimize downtimes. Therefore the use of Industry 4.0 technologies enables to extend the use phase and facilitates the application of manufacturing equipment in a new use phase according to CE principles.

3) LABOUR

Within Industry 4.0 humans will still be the organizers of value creation. Nevertheless the needs for skills will change and different competences will be important. Routine jobs will cease to exist and through an accelerating digitization new functions will get more complex and new occupational areas will arise. To cope with the social challenge of Industry 4.0 in a sustainable way the training efficiency of workers can be improved by combining new information and communication technologies (ICT).

4) INVENTORIES

Industry 4.0 applications definitely ease the management of inventories. Through real-time data about stock levels it is possible to reduce waiting times, inventory costs and storage space. This hides a lot of potential also with regard to sustainable economic activities, because too much inventory leads not only to great capital costs, but also to unused and excess resources. Additionally, Industry 4.0 technologies can minimize unreliable demand planning and overproduction. An intelligent system, which automatically reorders if the minimum fill level is reached will avoid surplus materials and will lead to a real-time optimization of the supply chain. Such reductions of inventory levels lead to decreased energy needs for the proper storage of the inventory as well as less waste created by materials turning old or out-dated due to technical progress. Consequently optimal manufacturing component utilization can be achieved by using Industry 4.0 applications, leading to ultimate sustainable benefits.

5) QUALITY

Quality improvement of products and processes by using real-time problem solving, advanced process control or real-time error corrections hide also potentials for a more sustainable manufacturing. As described previously, it becomes possible to design manufacturing sequences more resource-efficient regarding to material, water and energy consumption through process optimization. Therefore the consumption of these resources can be minimized through the use of Industry 4.0 technologies. In addition to the optimization of processes, an increased product quality will lead to less rework and less waste during the production process. This will also reduce waste as well as production time.

6) SUPPLY /DEMAND MATCH

As already mentioned within the sub item “Management of inventories”, Industry 4.0 technologies can minimize unreliable demand planning and overproduction. More accurate demand forecasts as enabled by Industry 4.0 applications lead to reductions in waste, because needed input materials could be projected more accurate (which will reduce inventory) and overproduction can be reduced. This will decrease the need for large amounts of raw material within the supply chain and transportation, because only on-demand spare parts are created. Accurate demand forecasts will also ease the implementation of CE principles, because also the reuse and preparation of already used materials can be planned more precise.

7) TIME TO MARKET

New Industry 4.0 technologies enable faster and cheaper R&D processes. This will be possible through procedures like concurrent engineering or rapid prototyping, also called additive manufacturing, by using 3D-printing. Additive manufacturing has the potential to create geometrically complex parts that require a high degree of customization, using less material and producing less waste. In addition to the more sustainable technologies used to realize the reduction of time to market, it also means faster learning if a product or process turns out to be less suitable for a CE(Circular Economy). This means that the continuous improvement cycles are accelerated to the benefit of using the latest technology and practices to implement a CE(Circular Economy).

8) SERVICE AND AFTERSALES

Service and after sales: Through Industry 4.0 new business models will emerge. These models will bring manufacturer or service provider and customer more closely together. There will be models where products or services will be only leased or borrowed instead of being bought. Consequently service and after sales will get more and more important within these models. This also hides potential for sustainable improvements. On the one hand products provided can be kept longer operational by the support through maintenance services and repairs. On the other hand it will be easier for the provider to get back products

VI.CHALLENGES FOR INDUSTRY 4.0

Investment and change:

Building a complex value network that can produce and distribute products in a flexible fashion means business leaders must accept to change and partner with other companies – not only suppliers and distributors of a product, but technology companies and infrastructure suppliers such as telecoms and internet service providers. Companies may even need to cooperate with competitors, e.g. in the establishment and use of standards that allow the transmission and exploitation of large quantities of data.

Data ownership and security:

With the large quantities of data being collected and shared with partners in the value network, businesses need to be clear about who owns what industrial data and to be confident that the data they produce will not be used by competitors or collaborators in ways that they do not approve. In particular, smart services will be based on the data generated by smart devices during their manufacture and use. For example, car-makers are reluctant to share data generated by their cars, for fear of finding their profits being squeezed by digital competitors

Legal issues:

Advanced manufacturing also raises a variety of legal questions including employee supervision, product liability and intellectual property. For example, data from a 'smart glove' that guides and records the movements of workers might be used to monitor or evaluate employees. If an autonomous manufacturing system that links different value networks produces a defective or dangerous product, how should the courts determine who in the network is responsible? If a customer requests an individualised product, who owns the intellectual property (IP) rights to the design?

Standards:

Standards are essential to ensure the exchange of data between machines, systems and software within a networked value chain, as a product moves into and through the 'smart factory' towards completion, as well as to allow robots to be integrated into a manufacturing process through simple 'plug-and-play' techniques. If data and communication protocols are proprietary or only recognised nationally, only the equipment of one company or group of companies will be compatible; competition and trade can be expected to suffer and costs rise. On the other hand, independent, commonly agreed, international standard communication protocols, data formats and interfaces can ensure interoperability across different sectors and different countries, encourage the wide adoption of Industry4.0 technologies, and ensure open markets worldwide for European manufacturers and products.

Employment and skills development:

The nature of manufacturing work has been shifting from largely manual labour to programming and control of high performance machines. Employees with low skill levels risk becoming replaceable unless they are retrained. On the other hand, workers able to make the transition to Industry4.0 may find greater autonomy and more interesting or less arduous work. Employers need personnel with creativity and decision-making skills as well as technical and ICT expertise.

Table 1. Challenges for lean implementation from integration perspective and Solutions provided by Industry 4.0

Dimensions of Lean Manufacturing	Challenges for lean implementation from integration perspective	Solutions provided by Industry 4.0
Supplier feedback	Limited expertise and resources	Collaborative manufacturing
	Difference in business models, operation and data maintenance practices	Better communication mechanisms
		Synchronisation of data
JIT delivery by suppliers	Incomplete goods' shipping status	Item tagging
	Mismatch in quantity of transported goods	Wireless tracking of goods
	Unexpected delays during transportation	Smart reallocation of order
Supplier development	Inadequate resources and expertise	Standardised interfaces
	Equipment compatibility between organisations	Virtual organisations - synergetic cooperation
Customer involvement	Little flexibility for product	Elongated freeze period

	alteration	
	Relationship between needs and functions	Usage analysis
	Acquiring exact customer needs	Large volume QFD
Pull production	Improper track of supplied material quantity	Material replenishment monitoring
	Changes in production schedule	Schedule tracking and kanban updating
Continuous flow	Errors in inventory counting	Real-time inventory tracking
	Capacity shortages	Subcontracting
	Centralised control systems	Decentralised decision making
Setup time reduction	Human experience based process adaptation	Self Optimisation and machine learning
		Workpiece - machine communication
Total productive/preventive maintenance	No control of machine breakdown	Machine worker communication
	Unknown problem solving time	Self maintenance assessment
		Predictive maintenance control systems
Statistical Process control	Ignorance of operators	Workpiece machine communications
	Inability to track process variation	Improved man-machine interface
		Process tracking, integration & management
Employee involvement	Improper feedback mechanism	Smart feedback devices
	Performance evaluation practices	Worker support systems
	Monotony in work	Improved man-machine interface

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