

# Use of Value Mapping Tools for Manufacturing Systems Redesign

Romero D. *IAENG Member*, Chávez Z. *IAENG Member*

**Abstract**—Researchers and practitioners have found that focusing on mapping value is a key issue. Several mapping tools have been used for improving and redesigning manufacturing systems making them to become more competitive, flexible and efficient in order to face market economic challenges in their manufacturing environment. This paper analyzes mapping techniques their evolution, strengths, weaknesses, key aspects to consider and how they have been adapted to real environments with different characteristics.

**Index Terms**—VSM, manufacturing systems, re-engineering, lean tools.

## I. INTRODUCTION

Nowadays, the success of the manufacturing industry is largely determined by its ability to rapidly respond to market changes and to immediately adjust to customer needs. This has resulted in an increasing demand for deployment of systems that can cope with agility and efficiency to these demands [1]. Companies must respond with product designs or completely new products, modifying production processes while seeking lower times and more flexibility in their production systems. It has been studied by several authors that, in order to respond to customer's requirements, flexible systems imply studies about the quickness with which these systems can be modified, the required new configuration should turn the flow to become more agile, in such a way that the production systems will technically be viable and suitable for different purposes.

Law and Mak [1] underline the need for an effective tool in order to develop a manufacturing system or to modify an existing system for a specific requirement at a reasonable time frame and cost. There have been developed several tools that presumed to support those actions such as: process mapping based on flow maps, IDEFO, GRAI, material and flows' modeling and simulation software, mapping techniques based on Toyota production system defects and Value stream mapping.

VSM has been defined by Rother and Shook [2] as a powerful tool that not only highlights process inefficiencies,

transactional and communication mismatches but also provides guides about the improvement and redesign of manufacturing environments. Such useful tool has been evolving through its different applications, under many cases of study, under different environments and contexts.

This paper is an ongoing research to obtain a master degree, which focuses in the analysis of mapping techniques and in showing how these have been used for redesigning manufacturing systems. An existing gap in the literature review has been identified, where a framework is required which may be used as stream mapping support tool to decide which technique is more suitable to the manufacturing environment in which the study is going to be deployed. This may increase or provide more resources that can be used in the same or other tasks.

## II. MANUFACTURING SYSTEMS REDESIGNING TOOLS

There are many redesign and improvement tools and methods that have been used to evaluate productive systems, helping production people to speed up the adjustment of changes, and make materials and information flows more agile [3], among those we found the following ones:

- Process mapping based on flow maps.
- IDEFO.
- GRAI.
- Material and information flows' modeling and simulation software.

Their characteristics have been evaluated and analyzed, but they have been founded to be too generic, they do not work so well to the modeling of manufacturing systems, do not give the value and importance to the numeric data as a manufacturing system requires since most of them are based on business processes and in the case of the last one mentioned the resources that it implies: training, time and effort (that at the end all of them translate to money), make it not so practical and not that used for most companies of any field and size, even the quantitative character of it, risk reduction and potential benefits that it could generate.

There are also 7 mapping tools that Hines and Rich study and present in terms of the seven wastes that are commonly accepted for the Toyota production system (overproduction, waiting, transport, inappropriate processing, unnecessary inventory, unnecessary motion, defects) [4].

- 1) Process activity mapping.

Manuscript received April 15, 2011; revised April 15, 2011. This work was supported in part by CONACYT (Consejo Nacional de Ciencia y Tecnología).

R.D. is with the department of Industrial Engineering at Universidad de Sonora, Blvd. Luis Encinas y Rosales S/N, Col. Centro, 83138 Hermosillo, Son., México. Phone: 52-662-2592283 (Iromero@industrial.uson.mx).

C.Z. is with the national council of science and technology. Graduate student at Universidad de Sonora, Blvd. Luis Encinas y Rosales S/N, Col. Centro, 83138 Hermosillo, Son., México. (zuharachavez@hotmail.com).

- 2) Supply chain response matrix.
- 3) Production variety funnel.
- 4) Quality filter mapping.
- 5) Demand amplification mapping.
- 6) Decision point analysis.
- 7) Physical structure (a) volume (b) value.

The mapping tools mentioned above are drawn from variety of origins including engineering, action research logistics and operation management. According to Hines and Rich [4] the first part of the process on using these tools is to identify the specific value stream to be reviewed in order to choose the proper one for the case we are going to analyze. Second, through a series of preliminary interviews with managers in the value stream, it is necessary to identify the various wastes that exist in the value stream, that managers believe can and should be removed having as reference the seven wastes mentioned earlier. In addition, it is important to gain the views of managers on the importance of understanding the complete industry structure, irrespective of which wastes are to be removed, considering what is the most important for the company at a determined time.

It is also recommended that more than one of these tools is used, when there are several wastes to attack, they should be addressed by tools with which they are highly correlated [4]. This will ensure that each waste/structure is covered adequately in the mapping process. As good as the mapping work with these tools has been found to be very useful, it is important to mention that there is a need of knowing what is critical for the productive system on which we are working so the tool can be the most appropriate and give good results at its application.

### III. VALUE STREAM MAPPING AND ITS EVOLUTION

Value stream mapping (VSM) is a technique relatively recent that gives answer to needs expressed by manufacturers in order to develop value chains more competitive, efficient and flexible; with the ones they can solve their economic difficulties that market changes may bring [5]. Both creators and researchers have found that VSM fills the characteristics and properties needed in a tool to be used to redesign a productive system [2]. Despite success cases of study, there have been generated variants of the original technique of VSM as a result of applications in different environments and contexts, different techniques that at the end what they are looking for is to trace the value stream in a productive environment, allowing them to eliminate what are called non value adding activities.

Unlike traditional process mapping tools, VSM is a mapping tool that maps not only material flows but also information flows that signal and control the material flows. This visual representation facilitates the process of lean implementation by helping to identify the value adding steps

in a value stream and eliminating the non value adding steps, or wastes (muda) [6].

The focus of VSM is on a product “value stream” (all actions required to transform raw materials into a finished product) for a given “product family” (products that follow the same overall production steps). In applying VSM, waste is identified at a high level along the value stream in the form of all elements that prohibit or hamper flow and in the form of inventory (raw materials, work-in-process (WIP) and finished goods). In future state design, major issues that create waste in the process are addressed. The future state map forms the basis for the implementation plan, for focused improvement initiatives (such as set-up reduction) [7].

It has been also evaluated the applicability of the VSM in production environments related to disconnected flow lines [5], the results confirm the practical validity of VSM for the redesign of production systems. The research method adopted consisted of a multiple case study of six companies. It perceives the VSM as a practical tool for the redesign and creation of flexible and efficient production environments, in turn concluded that the VSM is shown valid by itself, to justify the redesign to show the improvements that it would provide at a level of productive performance of the system. It was also tested the hypothesis that VSM is the reference for implementation of the redesigned production system according to the action plans that are created from “future states” and the strengths recognized by the teams in each one of the cases of study analyzed.

VSM has been adopted and evolved to plant situations with complex characteristics [8]-[9] in which demand is random, the number of references is very diverse and have difficult grouping, there are plenty processes, many of them shared with other families and therefore the flows integration become complicated. VSM developers recognize that many production systems have multiple streams coming together that can complicate and increase the time needed for mapping [6].

Despite success stories in the application of VSM, there have been generated variants of the original technique of VSM as a result of applications in different environments and contexts:

- Value stream macro mapping (VSMM).
- Value network mapping (VNM).

In the case of the first mentioned above, Fontanini and Picchi present a practical case where VSM is applied and used for a building construction project [10]. VSMM is an extension of VSM that allows not only to see waste and flow inside a company or what is known “dock to dock” but it allows understanding material and information flows in a full supply chain involving several supply chain companies. One can expect the possibility of lean concepts and techniques application inside of VSMM, aiming the entire flow improvement and not isolated tools application or isolated initiatives with limited results. It allows a guide creation to coordinate all agents along the implementation of changes across the chain, in order to eliminate waste across the supply flow.

VNM was developed to eliminate the limitations imposed on the traditional methodology when “many value streams have multiple flows that merge” [6]. It is able to map the complete network of the flows in a value chain that belongs to a complex product, with complex bill of material and several levels of assembly. Also, it utilizes algorithms for clustering of similar manufacturing routings and design of facility layouts to identify families of similar routings for which a single composite Current State Map could be developed. In addition, these algorithms utilize special data structures that capture the complete assembly structure of the product instead of extracting the key components only, as suggested to be done with VSM. The development and benefits of this approach have been demonstrated using results from a pilot study done in a job shop where the production is made by order. Braglia, Carmignani, and Zammori [9], also tested this approach in a real environment job shop showing satisfactory results.

In the cases where VSM application is analyzed, there have been highlighted the following shortcomings of the original tool, which also match with several statements made by [9], [6]:

- Fails to map multiple products that do not have identical material flow maps.
- Fails to relate transportation and queuing delays, and changes in transfer batch sizes due to poor plant layout and/or material handling, to operating parameters such as machine cycle times and measures of performance such as takt time of the manufacturing system.
- Lacks any worthwhile economic measure for “value” (profit, throughput, operating costs, inventory expenses).
- Lacks the spatial structure of the facility layout, and how that impacts interoperation material handling delays, the sequence in which batches enter the queue formed at each processing step in a stream, container sizes, trip frequencies between operations, etc.
- It is based on manufacturing systems with low variety and high volume.

There is also a need to show the impact that the inefficiencies: product travelling long distances, not integrated flows, lack of independency in a process, lack or fail of communication between parts that integrate the complete manufacturing system (because of a none existing protocol or not following an existing one) have on creating bigger amounts of WIP, operation expenses, downtime and leisure (to mention the ones seem to be the most commonly seen in manufacturing systems).

The other need not less important is detect situations where the ergonomic aspect is poor or exist potential improvements to be done in this matter, since it also may create an impact on employee’s productivity by reducing the efficiency on creating value during a formal job shift. It has not been found any paper or study that links ergonomic aspects to creating value, ergonomics is normally seen as a parallel aspect. Analyzing the situation with a different perspective we find that work force is still a must in most

manufacturing systems, its performance have a direct impact on the system performance, that is why it cannot be inherent to the system, therefore should not be excluded from the re design or development of a manufacturing system.

Table I below, shows a comparison between the different mapping tools mentioned above, analyzing certain aspects founded as key on the literature review, such comparison pretend to enhance strengths and weaknesses on each one of the tools.

#### IV. CONTEXT FACING ISSUES

Many organizations in their drive to become “lean”, face a major obstacle when they see the need to manually map and analyze the flow paths of anywhere between 100 to 5,000+ routings being produced in the typical custom parts manufacturing facility [11]. This will be the case of manufacturing facilities that work under the scheme Make-To-Order and Engineer-To-Order, which manufacture complex assemblies (furniture, security cabinets, cranes, tractors), repair and maintenance facilities, job shops (machining, welding fabrication, stamping, die casting) that process a large variety of products and must design their facilities for flow. Being the context more related to a project environment than to a serial production type, there is a need to choose the proper tool, in order to be able to see the complete flow and trace the exact routing for each value stream. One cannot have the same considerations under different contexts of application: job shop, serial production or project; According to the literature analyzed it is noted that before mapping and choosing an specific tool to be applied there should be defined characteristics as: complexity of bill of materials, levels of assembly, number of processes, production strategy or scheme, business type and demand in order to gain the most at the journey and do not truncate the efforts.

#### V. AFTER MAPPING

Based on the analysis of what is called Current state map, one then develops a Future state map by improving the value adding steps and eliminating the non value adding steps known as waste or muda. According to Rother and Shook [2], there are seven adapted and modified guidelines, based on the concepts of Lean Thinking that can be followed when generating the Future State Map for a lean value:

- 1) Produce to takt time.
- 2) Develop continuous flow.
- 3) Use supermarkets to control production where continuous flow does not extend upstream.
- 4) Schedule based on the pacemaker operation.
- 5) Produce different products at a uniform rate (Level the production mix).
- 6) Level the production load on the pacemaker process (Level the production volume).
- 7) Develop the capability to make every part every time period “EPE.

TABLE I

COMPARISON BETWEEN MAPPING TECHNIQUES.

<i>Mapping technique / Key aspects to evaluate</i>	<i>Use of quantitative data (processing times, takt time, lead time, inventory, travel distances, processing quantities, etc.)</i>	<i>Flow through plant layout</i>	<i>Influence of ergonomics in value creation</i>	<i>Job sequencing</i>	<i>Material handling</i>	<i>WIP buildup</i>	<i>Capacity constraints</i>	<i>Economic investment</i>	<i>Context of practical application</i>
<i>Process mapping based on flow maps</i>	H	NC	NC	NC	L	NC	NC	L	SP, JS
<i>IDEFO</i>	L	NC	NC	NC	NC	NC	NC	L	SP, BP
<i>GRAI</i>	M	NC	NC	NC	NC	NC	NC	L	SP, BP
<i>Material and information flows' modeling and simulation software</i>	H	M	NC	H	L	H	H	H	SP, JS, BP
<i>Process activity mapping</i>	H	NC	NC	NC	L	NC	NC	L	SP, JS
<i>Supply chain response matrix</i>	H	NC	NC	NC	NC	NC	NC	L	SP, P
<i>Production variety funnel</i>	H	NC	NC	NC	NC	NC	NC	L	SP
<i>Quality filter mapping</i>	H	NC	NC	NC	NC	L	NC	L	SP, JS
<i>Demand amplification mapping</i>	H	NC	NC	NC	NC	NC	NC	L	SP
<i>Decision point analysis.</i>	M	NC	NC	NC	NC	NC	L	L	JS
<i>Physical structure (a) volume (b) value.</i>	M	NC	NC	NC	NC	NC	M	L	SP
<i>VSM</i>	H	NC	NC	NC	NC	NC	NC	L	SP, P, B
<i>VSMM</i>	H	NC	NC	NC	NC	NC	NC	L	SP, P
<i>VNM</i>	H	H	NC	NC	NC	NC	NC	L	SP, JS, P, B

Low (L), Medium (M), High (H), Not considered (NC), Serial production (SP), Job shop (JS), Project (P), Business processes (BP).

Reference [12] summarized the guidelines needed for the definition of the future state map with base on lean thinking principles which match the statements from [2]:

- The production rate must be imposed by the product demand. Takt time is the concept that reflects such rate.
- Establishment of continuous flow where possible (unique product transfer batches).

- Employment of pull systems between different work centres when continuous flow is not possible.
- Only one process, called the pacemaker process, should command the production of the different parts. This process will set the pace for the entire value stream.

In lean thinking is usual to be value mapping based that support strategies that precede any specific mapping linked to tools such one-piece flow, visual control, kaizen, cellular

manufacturing, inventory management, Poke yoke, standardized work, workplace organization, among others that share the same purpose: to deploy a production system close as possible to an agile system which makes an appropriate use of resources available.

## VI. CONCLUSION

Among the mapping techniques analyzed, it has been shown that VNM is an approach that seems to be more suitable in complex working environments where the manufacturing processes involve several subassemblies and complex bill of materials. Product families engage themselves several material and information flows, which can be connected in different ways within the same or different family; sharing occasionally production resources and using dedicated resources in order to become deliverable products.

Between all the mapping techniques analyzed, VNM has shown to have an approach that seems to be more suitable for the context we see now is predominant in companies structures and in their production strategies, which is: working in complex environments where the processes require to manufacture products involving several subassemblies and complex bill of materials, they work under make to order or engineer to order scheme, the volume is low but variety high, lead times must be low at a reasonable cost and budgeted for tool application is limited; despite the improvements that VNM brings to VSM, in the application of the tool to contexts that are more like a project environment than a serial production scheme, there have been defined several deficiencies in it, which suggest that there is still much research work to be done:

- Lacks including information on lot sizing, cycle time, job sequencing and work in process buildup at each process due to queuing delays, required to better design of the future state map.
- Does not consider capacity limitations of the system when multiple assemblies require to use capacity of a shared process.
- Lacks detailed analysis of the material handling systems and processes connecting different pairs of process boxes.

There is research in process being done, focused on a case study application under a job shop environment, make to order scheme, with products involving several assembly levels and complex bill of materials; it is intended to propose a redesign on the system that be able to improve the manufacturing system's performance and also make an academic contribution to value mapping tools by working on attack the deficiencies of the analysis of the material handling and plant layout.

## ACKNOWLEDGMENT

C. Z. thanks her thesis tutor for the support and guide given so far and for what will be needed in future through the whole research process.

## REFERENCES

- [1] H. Lau and K. Mak, "The design of flexible manufacturing using an extended unified framework". *Journal of Manufacturing Technology Management*. Vol. 15 (3), 2004, pp. 222-238.
- [2] M. Rother and J. Shook, *Learning to see: Value stream mapping to add value and eliminate Muda*, Massachusetts, EEUU: Lean Enterprise Institute, 1998. 2
- [3] I. Serrano, C. Ochoa, R. De Castro, "An evaluation of the value stream mapping tool". *Business Process Management Journal* Vol. 14 (1), 2008, pp. 39-52. 3
- [4] P. Hines and N. Rich, "The seven value stream mapping tools", *International Journal of Operations & Production Management*, Vol. 17, 1997, pp. 146-64.
- [5] I. Serrano, "Análisis de la aplicabilidad de la técnica Value Stream Mapping en el rediseño de sistemas productivos", Ph.D. Thesis, Dept. D'organització, Gestió empresarial I Disseny de producte, Universitat de Girona, España 2007.
- [6] Z. N. Khaswala and S.A. Irani, "Value Network Mapping (VNM): Visualization and Analysis of Multiple Flows in Value Stream Maps. *Proceedings of the Lean Management Solutions Conference*. St. Louis, MO, 2001.
- [7] D. V. Goubergen and H. V. Landeghem, "Using value stream mapping to Redesign Engineering Project work". *Virginia Polytechnic Institute and State University*. Van Goubergen P&M gc, 2005.
- [8] K.J. Duggan, *Creating mixed model value streams, Practical lean techniques for building to demand*. Nueva York, EEUU: productivity Press, 2002.
- [9] M. Braglia, G. Carmignani, and F. Zammori, "A new value stream mapping approach for complex production systems". *International Journal for Production Research*. Vol. 44 (18 - 19), 2006, pp. 3929 - 3952.
- [10] P.S. Fontanini, F.A. Picchi, "Value stream macro mapping- A case Study of aluminum Windows for construction supply chain". *Proceedings of the 12th Annual Conference of the International Group for Lean Construction (IGLC-12)*, Elsinore, Denmark, 2004.
- [11] A. I. Shahrukh, "Value Stream Mapping in Custom Manufacturing and Assembly". *The Ohio Manufacturer*, Num. 9, 2000, pp. 12-13.
- [12] S. Bhim and S.K. Sharma, "Value stream mapping as a versatile tool for lean implementation: an Indian case study of a manufacturing firm". *Measuring Business Excellence*, Vol. 13 (3), 2009, pp. 58-68.