199 Waste Identification Diagrams with OEE data

Dinis-Carvalho J, Guimarães L, Moreira F, Rodrigues J, Lima RM.

José Dinis-Carvalho (✉ e-mail:dinis@dps.uminho.pt)
Dpto. de Produção e Sistemas, Escola de Engenharia. Universidade do Minho. Campus de Azurém, 4800-058 Guimarães. Portugal

Abstract: Existing techniques to represent production units are not very effective in representing several dimensions of production, limiting the extent to which diagnose and problem identification is accrued. Value Stream Mapping is one such technique which, although very popular among lean practitioners, exhibits a number of practical limitations. In this paper the authors present the all new Waste Identification Diagram, encompassing a number of new features and improved graphics capabilities, which makes it a feasible alternative technique to that of VSM, while extending its breath of application by integrating Overall Equipment effectiveness data into the diagrams. An example application of the WID technique to a real production unit will be presented, screening its effectiveness for diagnosing problems, measuring performance and providing key visual information and precious clues for improvement.

Keywords: Waste Identification Diagram; Value Stream Mapping;

1 Introduction

A relative small number of visual techniques are available to assist the analyst in the process of representing, analysing and diagnosing production units. These techniques support the identification of important issues that characterize a given shop floor, such as the layout, its production performance, waste forms, waste values, the production flows, equipment utilization, etc. None of the existing techniques, when considered in isolation, is sufficiently complete and powerful to cover the greatest share of such issues. Each one of those techniques is fundamentally biased by narrow focus on partial systems and by specific application perspectives. Some techniques are mainly focused on representing the layout and production routes; others are intended at representing the worker's movements; while others are only focused on the production flow of certain products or a given family of products; and so on. The most popular technique applied in lean production environments is that of Value Stream Mapping (Rother and Shook, 1999). The VSM diagrams depict the chain of processes that are required to be executed to produce a product or a family of products, its production control system, the station related WIP, the value adding time, the throughput time as well as other information. The analyst uses aVSM map to identifypossible actions for value stream improvement while establishing an improved future-state VSM map. Although very popular, VSM holds many limitations, among which we emphasise the difficulty in representing multiple routes and its inadequacy to identify and evaluate many forms of wastes, such as transportation, movements and waiting.

Waste Identification Diagram (Dinis-Carvalho et al., 2014) is a visual tool, being developed at the Department of Production and Systems (University of Minho, Portugal), with the purpose of representing production units in an intuitive visual manner, exposing and evaluating most forms of waste, production flows and other important production data and indicators. Waste Identification Diagram (WID) was designed to overcome the limitations of VSM, eventually becoming a more intuitive and more effective visual tool.

In this paper we will present a new version of Waste Identification Diagram which integrates the Overall Equipment Effectiveness (OEE) information (Hasen, 2001), such as planned downtime, unplanned downtime, speed losses and quality losses. This OEE data is adapted to show its influence in *takt* time as well as station time values. This enhancement is particularly relevant where OEE data in regularly monitored by the company, allowing a more accurate analysis. As a way of illustrating the respective use and testing its applicability, we will present and explain the new version of the WID by representing a real production unit from the semiconductor industry located in the north of Portugal.

2 Existing graphical tools

Table 1 presents a list of graphical tools used in production environments. The tools were classified according to the following criteria: (1) process or product orientation ;(2) visual effectiveness ;(3) scope, and (4) waste types covered. The objective of the first criterion “Orientation” is to clarify if the tool is more focused on the production unit as a whole or more focused on a particular product or family of products. The second criterion “Visual Effectiveness” reflects our perception on the visual effectiveness of the tool. This aims at measuring the quantity and quality of the information that is detected by just looking at the graphical information. The criterion “Scope” measures the quantity of different types of production information that is covered by the tool. Finally the criterion “Waste Types Covered” is focused on identifying which types of production wastes, from the set of seven classic waste types, as defined by Ohno(1988), are covered by the tool.

The most commonly used tool, for the purpose of mapping production flow and production waste, is Value Stream Mapping. VSM is the most popular tool to represent production units and is widely used to record present state during kaizen events across many industries. These maps are used to diagnose problems, to identify improvement opportunities and also to establish future as well as ideal states.

Table 1 Evaluation of existing graphical tools

Tools	**Orientation**		**Visual Effectiveness**	**Scope**	**Waste Types Covered**
	Process	**Product**			
Flow Process Chart (ASME, 1947)	Low	High	Mid	Low	Transportation; Inventories.
Flowchart Map (Barnes, 1968)	High	Mid	High	Mid	Transportation; Inventories; Motion.
Spaghetti Diagram (Neumann&Medbo 2010)	High	---	High	Low	Transportation; Motion.
ModelofSupply Chain and Waste (Hicks et al, 2004)	Mid	Mid	Mid	Mid	Transportation; Defects.
Process Activity Mapping (Barnes, 1968)	---	High	Mid	Low	Transp.;Invent.; Motion;Waiting;Overprod.
Supply Chain Response Matrix (New, 1993)	Mid	Mid	Mid	Low	Inventories; Overproduction.
Production Variety Funnel (New,1974)	Low	High	High	Low	Inventories.
Quality Filter Mapping (Hines& Rich, 1997)	High	---	High	Low	Defects.
Demand Amplification Mapping (Forrester, 1958)	Low	High	High	Low	Inventories; Overproduction.
Decision Point Analysis (Hoekstra e Romme, 1992)	Low	Low	Mid	Low	Inventories; Overproduction.
Physical Structure (Miles, 1961)	Low	Mid	Mid	Low	
Value Stream Mapping (Rother e Shook, 1999)	Low	High	Mid	Mid	Transp.;Inventories; Overproduction.
Waste Identification Diagram (Dinis-Carvalho et al, 2013)	High	Mid	High	High	Transp.;Invent.; Motion;Wait.; Def.;Overprod.

A known limitation of VSM commonly reported on the literature is its inability to represent multiple routes (Irani& Zhou, 1999; McDonald, Van Aken&Rentes, 2002;Seth & Gupta, 2005;Braglia, Carmignani&Zammori, 2006;Chitturi, Glew&Paulls, 2007). Other reported limitations include the absence of layout visualization (Irani& Zhou, 1999) and lack of representation of several waste types (Lovelle, 2001; Huang & Liu, 2005).

Waste Identification Diagram (WID), as proposed by Dinis-Carvalho et al. (2014), is an alternative approach to that of VSM, which aims at overcoming some of itsdrawbacks. Waste Identification Diagrams are intended to give more intuitive visual information, are able to represent layouts, to represent multiple routes and evaluate more waste forms.

The evaluation of WID(see last line in table 1) assumed by the authors of this article is based on the following reasoning: (1) Process orientation criteria –WID is process orientated ("high") since it describes the whole process, all machines, layout. (2) Product orientation criteria –WID is also product oriented ("Mid") since it can contains the routes followed by all product. (3) Visual effectiveness criteria –The size of the items in the WID gives effective notion on important production information such as layout, waste and performance. (4) Scope criteria –WID show more information than any other tool. It shows layout, flows, idle capacity, OEE information, all waste forms, performance, personnel,

In the original form, the WID diagrams are composed by blocks, arrows and a pie chart. The blocks represent stations (benches, machines, equipment or even sectors),the arrows represent the required transportation effort for moving the parts from one station to the other (Sá, Carvalho and Sousa, 2011), and the pie chart depicts the activities and respective shares conducted by the workforce, i.e. the way workers spend their time. The block dimensions (see figure 1) include 4 main types of data: (1) the block length represents the amount of WIP waiting to be processed. It can be measured in units, in Kg, in meters, in cubic meters, in monetary units, or any other aggregate unit. (2) The block total height represents the takt time (TT). (3) The height of the bottom part of the block represents the station time (ST). The difference between the ST and the TT gives an idea about idle capacity. (4) The block depth represents the changeover time (C/O) of that process.

The arrowsbasically represent transportation effort, and, since transportation does not adds to product value, it is considered to be a waste. The thicker is the arrow, the higher is the waste involved on such operation. The transportation effort is calculated by multiplying the distance between the stations (client and supplier) by the quantity of products to be transported per unit of time.

Finally, the pie chart shows how the worker's time is used in different activities, from adding value to waste ones, such as motion, waiting or transportation. The values are gathered using work sampling techniques (Barnes, 1968).

3 Waste Identification Diagram with OEE information

The new WID version, under proposal, uses OEE data to enrich the quality of information regarding the station block icon. In fact, if we think carefully the takt time really useful value depends on OEE information, i.e. the planned stops as well as unplanned stops (see figure 1).

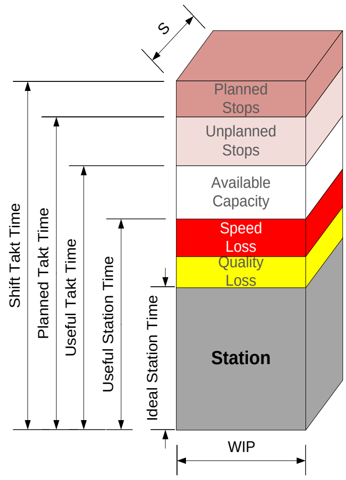


Fig.1 Ideal and Useful Station Times

The value of Useful Takt Time (U_{TT}) is given by the following equation:

$$U_{TT} = \frac{[(S]_T - Ps - Us)}{Qr} \tag{1}$$

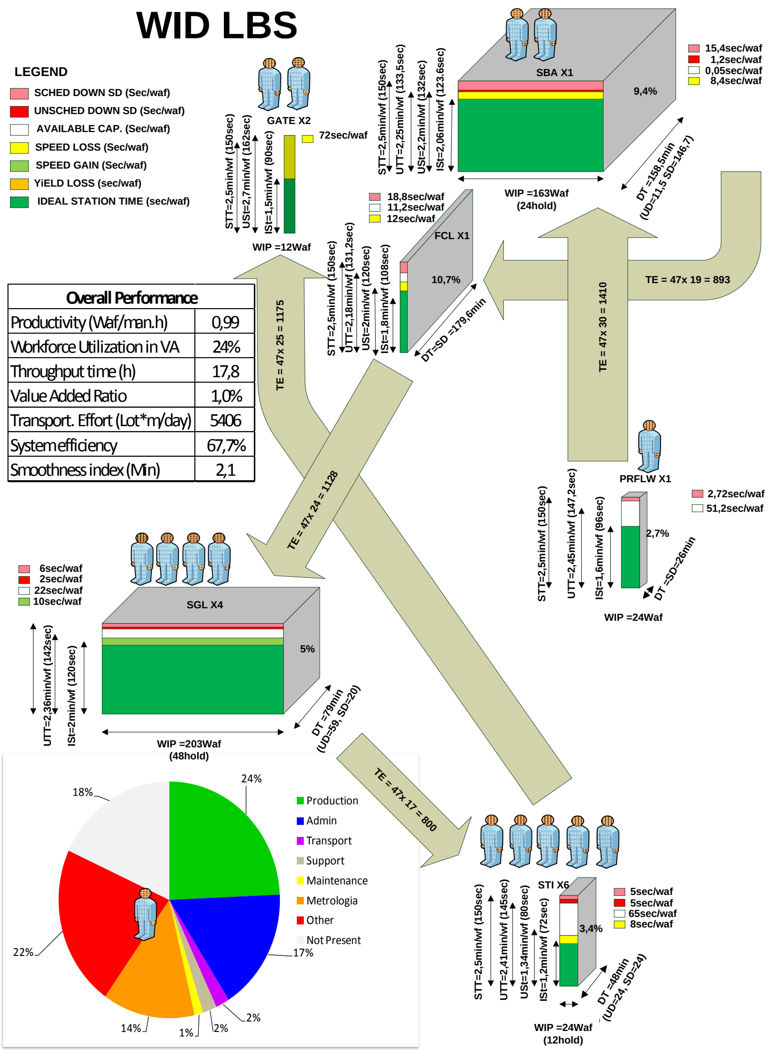
Where: S_T – Shift Time; *Ps*– Planned Stops; *Us* –Unplanned Stops;
Qr– Quantity Required in a shift.

Useful Takt Time can simply be described as the station time required per part in order to fulfil the quantity of parts required in a shift.

Station Time is also influenced by OEE data (see figure 2). In normal production the Ideal Station Time, frequently called standard time (which is determined by motion and time studies), will not be reached in average throughout the shift, since unplanned stops will occur and some parts may be rejected. Under these realistic assumptions, a higher value for station time should be assumed so that more effective planning can be performed. The proposed value for this Useful Station Time ($U_{\downarrow}ST)$ is given by the following equation:

$$U_{ST} = \frac{I_{ST}}{(QL * SL)} \tag{2}$$

Where: I_{ST} – Ideal Station Time; *QL* – Quality Loss; *SL* – Speed Loss



Overall Performance	
Productivity (Waf/man.h)	0,99
Workforce Utilization in VA	24%
Throughput time (h)	17,8
Value Added Ratio	1,0%
Transport. Effort (Lot*m/day)	5406
System efficiency	67,7%
Smoothness index (Min)	2,1

Fig. 2 Waste Identification Diagram forthe LBS unit

The WasteIdentification Diagram describing the current state of the LBS production unit in depicted in figure 2. On this particular diagram the depth of the blocks does not represent the changeover time, instead it represents the downtime information. This follows a specific request from the company managers. Another particularity is that the location of the blocks (representing equipment) corresponds to the relative position in the real layout, thus facilitating the understanding of the real production unit.

By observing at the WID diagram, depicted on figure 2, a person familiarized with the WID icons should rapidly come to the following readings: (1) The layout seems inadequate. The production flow is quite confusing. Transportation effort seems to be excessive. A new layout should be considered. (2) Most inventory (WIP) related waste is exist on SGL and SBA. The WIP associated to other processes is substantially smaller. A project on pull flow should be planned. (3) Speed loss is very high on the GATE process. (4) SBA is critical since it is working at near capacity limits. Planned downtime should be rethought and quality problems should be solved. On the other hand PRFLW and STI still have extra capacity available. (5) Only 24% of the workers time is actually spent on adding value, the remaining 76% is spent of non-value adding activities (waste). This fact requires attention since it represents a lot of waste (14 workers x 0.76 = 10.64 workers).We may roughly express that non-value adding activities (waste) require more than 10 workers. We think that this issue is important enough to justify actions targeting the reduction of the non-adding value activities. (6) The Value Added Ratio is very low (less than 1%). Meaning that 99% of the time the products are standing in queues to be processed.

4 Conclusions

In this paper we introduced and explained a new version of the Waste Identification Diagram, which includes OEE data. We applied it on a real production unit of the semiconductor sector, and conducted a brief analysis of the diagram highlighting a number of key issues that require further attention. The WID allowed a rapid detection of critical processes, available capacity, layout inadequacy and the location of most forms of waste as well as its values. The OEE data helped in detecting possible solutions to increase capacity in the most critical process, the SBA. We believe that these diagrams are very effective in representing and diagnosing production units, showing most forms of waste and giving clues for further improvement.

5 References

American Society of Mechanical Engineers (1947) ASME standard; operation and flow process charts. New York. ASME.

Barnes R M (1968) Motion and Time Study: Design and Measurement of Work. 6th edition, John Wiley & Sons, Inc.

Braglia M, Carmignani G, Zammori F (2006) A new value stream mapping approach for complex production systems. International Journal of Production Research, 44(18-19), 3929-3952.

Chitturi R M, Glew D J, Paulls A (2007) Value stream mapping in a jobshop. Paper presented at the Agile Manufacturing, 2007. ICAM 2007.IET International Conference on.

Dinis-Carvalho J, Moreira F, Bragança S, Costa E, Alves A, Sousa R (2014) Waste Identification Diagrams, Production Planning and Control, Accepted for publication.
Forrester J (1958) Industrial dynamics: a major breakthrough for decision makers, Harvard Business Review, July-August, 37-66.
Hasen R C (2001) Overall Equipment Effectiveness: A powerful production/maintenance for increased profits, New York, Industrial press inc.
Hicks C, Heidrich O, McGovern T, Donnelly T (2004) A functional model of supply chains and waste. International Journal of Production Economics, 89(2), 165-174.
Hines P, Rich N (1997) The seven value stream mapping tools. International Journal of Operations & Production Management, 17(1-2), 46-64.
Hoekstra S, RommeJ (Eds) (1992) Towards Integral Logistics Structure – Developing Customer-Oriented Goods Flows, McGraw-Hill, New York, NY.
Huang C C, Liu S H (2005) A novel approach to lean control for Taiwan-funded enterprises in mainland China. International Journal of Production Research, 43(12), 2553-2575.
Irani S A, Zhou J (1999) Value Stream Mapping of a Complete Product.MS thesis, The Ohio State University, Columbus, OH.
Lovelle J (2001) Mapping the value stream. IIE Solutions, 33(2), 26-32.
McDonald T, Van Aken E M, Rentes A F (2002) Utilising simulation to enhance value stream mapping: a manufacturing case application. International Journal of Logistics Research and Applications, 5(2), 213-232.
Miles L (1961) Techniques of Value Analysis and Engineering, McGraw-Hill, New York, NY.
Neumann W P, Medbo L (2010) Ergonomic and technical aspects in the redesign of material supply systems: Big boxes vs. narrow bins. International Journal of Industrial Ergonomics, 40(5), 541-548.
New C (1974) The production funnel: a new tool for operations analysis, Management Decision, Vol. 12 No. 3, 167-78.
New C (1993) The use of throughput efficiency as a key performance measure for the new manufacturing era, The International Journal of Logistics Management, Vol. 4 No. 2, 95-104.
Ohno T (1988) Toyota production system: beyond large-scale production: Productivity press.
Rother M, Shook J (1999) Learning to see: value stream mapping to add value and eliminate muda: Productivity Press.
Sá JC, Carvalho JD, Sousa RM, 2011 Waste Identification Diagrams. 6º CongressoLuso-Moçambicano de Engenharia.Maputo, Aug 29-Sept 2.
Seth D, Gupta V (2005) Application of value stream mapping for lean operations and cycle time reduction: an Indian case study. Production Planning & Control, 16(1), 44-59.