VALUE ADDED HEAT MAP – A NEW METHOD FOR THE OPTIMIZATION OF PRODUCTION SPACE

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Abstract:

The VAHM (Value Added Heat Map) is a visualization tool that indicates the level of value creation concerning production relevant factors like space usage. Common methods for the evaluation of added value, e.g. Value-Stream Mapping or Sankey-Diagram, are inadequate concerning the rating of production spaces. The VAHM approaches an integrated assessment of the named factor. In this article the innovative VAHM method is described and applied as a model to a production shop floor. It is a practical basis for optimizing a production layout to generate smaller area with the same value.

Keywords:

Value Added Heat Map, VAHM, Value Creation, Value Added Concentration, Production Space Efficiency

1. INTRODUCTION

1.1. Value Added Concentration

According to Womack and Jones, the value of a product or a service is defined by the customer [1]. Finkeissen summarized the term Value Added as all activities, which create the value of a product in relation to customer benefit [2]. Consequently, all activities that are not creating value are to be seen as wastage, which should be reduced or eliminated. Wastage is the share of creation effort that the customer is not willing to pay for [3].

An approach to assess the Value Added is the analysis of the Value Added Concentration. The Value Added Concentration negatively correlates to wastage. The less wastage occurs within a process the higher is the VAC. The same applies vice versa. Relevant factors for assessing the Value Added Concentration are personnel deployment, resource usage as well as space usage

[4,5]. A maximum utilization of the personnel, which is participating in the value creation, is expedient because they perform the actual creation of products or services.

In order to concentrate the Value Added, these staff members should focus their working capacity solely on their core tasks. Optimization of the resource usage, e.g. equipment or machines, should also be pursued to ensure the concentration of added value. Spaces within the shop floor are usually highly limited. Supporting logistic processes like the provision of material use such limited spaces. Reserved material only create limited value. They cannot be eliminated completely, but at least be minimized. Reducing spaces which do not create value, to ensure that sufficient space for the actual value adding process is available, should be the primary aim.

Methods for analysing and assessing the added value of processes have already been designed. In the following, the Value-Stream Mapping as well as the Sankey-Diagram methods will be discussed.

1.2. Value-Stream Mapping

Value-Stream Mapping is a proven method for identifying and avoiding wastage within a production process. It was originally developed in the 1990's in the course of the Toyota production system. Today, it is also used in other industries for process improvement [6].

A Value Stream is the combination of all activities, which are required for processing a product from its initial to its final stage that is desired by the customer [7]. Wherever a product for a customer is, there also exists a Value Stream [8]. A Value-Stream Map captures the current state of the production process in the form of a Multi Moment Recording, which is a sampling procedure for determining the frequencies of occurrences of predefined phenomena [9]. Defined components, which are recorded are the customer, the supplier, the production- and business processes as well as the flows of materials and information. Specific values can be assigned to each of these components in order to enhance the conclusiveness of the map.

In order to draft a Value-Stream Map, four steps are necessary. The definition of product families; the analysis of customer needs; the recording of the Value-Stream within the production; as well as identifying and visualizing improvement potentials within the Value-Stream [10]. An important element in this model is the lead time. It consists of the actual processing times of the different production steps and the timeframes in between these processing times [11]. To assess the value creation, this method uses a Value Added coefficient. It shows which share of the total lead time is taken up by the actual processing time [12]. Thus, it also shows which part of the lead time is not used for value creation.

In conclusion it can be said that Value-Stream Mapping is a pure analyzing tool. The used nomenclature allows a simple but complete graphic representation of the whole production process from a bird's-eye perspective. The quick identification of occurring wastage as well as the enhancement of the overall transparency make this tool especially valuable [10].

1.3. Sankey-Diagram

The Sankey-Diagram is an analyzing tool that can be used to visualize the flow of materials, energy or costs. It consists of two main components, the individual process steps and arrows. The arrows interlink the occurring process steps and the direction of the different flows. The arrow's thickness represents the quantity of the substance which occurs in the flow [13].

The Sankey-Diagram had originally only been used for thermodynamic systems, but was then successfully applied to different disciplines [14]. In thermodynamics, heat losses could be identified with this tool. Applied in a production plant it can be used to identify material losses, for instance by production faults or inefficient processes. Thus, in industrial management, it provides a needs-based design of material flows.

A Sankey-Diagram only visualizes substances that actually occur in a flow. In a production context, these would be e.g. the materials in between the goods receipt and the goods issue. Stocks at a warehouse or at the individual workplaces are not included [15].

The drafting of a Sankey-Diagram starts with recording the flows of the occurring substance within the analyzed subsystem. With production bills of materials as well as work plans, the sequence of the process steps are derived. Additionally, the production quantities are assigned to the relevant processes. The quantitate relations are then recorded. Usually, a matrix which covers start and end points as well as the frequencies and volumes are used for that purpose. The finished matrix may then be converted into a Sankey-Diagram. The numeric values in the matrix determine the thickness of the visualized arrows [16].

The visualization of this diagram can be combined with a factory layout. This would result in a correct special assignment of process steps and material flows. The simple, model-like format of the Sankey-Diagram allows for a practical assessment of the regarded system concerning its value creation. Within a production plant the Sankey-Diagram can e.g. display crossing material flows, which cause production backlogs. Transport bottlenecks or material loops are further examples that can be displayed with this tool. Consequently, waiting times in the production could be explained.

The finished Sankey-Diagram can be the basis for deriving measures for improving the added value. Rearranging the production layout and the workplaces can result in reduced transport routes and less transport vehicles [13]. Additionally, positive effects can be achieved concerning total quality, personnel ergonomics, the economic efficiency as well as the environment [17].

2. METHOD DESCRIPTION – VALUE ADDED HEAT MAP

The theoretical foundation for drafting a VAHM (Value Added Heat Map) is the previously described concept of Value Added Concentration. Widely known methods for evaluating the value creation are Value-Stream Mapping or the Sankey-Diagram. In contrast to these two methods, the VAHM focuses on other value-related aspects of the production process, like the usage of space. The Value Added Heat Map is a visualization tool that may be a useful complement to Value-Stream Mapping or the Sankey-Diagram. It facilitates the evaluation of value creation aspects and additionally visualizes occurring wastage.

2.1. Evaluation of Production Space

The main purpose of the VAHM method is to visualize production relevant aspects with regard to their value. The following descriptions will be about the usage of space.

In production and service companies, the proportionate costs per square meter or comparable rental costs are considered for the economic assessment of spaces. There is normally no distinction made between the value and a square meter has in relation to the production plant and the necessary infrastructure. This often results in an insufficient analysis of the existing layouts and those that are to be planned anew. Potentials to further concentrate spaces or to provide a more practical plant layout cannot be realized.

In the VAHM method spaces have different values. Spaces that are used for actual value creation, e.g. with production plants, are considered especially valuable. There are also spaces which are not directly used for value creation, but which necessary for operating the plant, like staging areas for required materials, spaces for intermediates and finished goods or transport routes for reaching the plants. These spaces only have limiteded value added contribution. Spaces that are not used at all do not contribute to value creation.

The prior aims of the VAHM are to visualize the value creation level of spaces using a color scaling and to assign a conclusive key performance indicator for facilitating comparison. The graphical result of the analysis resembles a thermal image, therefore it is called Value Added Heat Map. Potentials for improvement can easily be recognized.

The VAHM can be used as the basis for deriving a series of measures that may improve the usage of the available space. As a consequence, investments in buildings or the rental of production or logistic spaces may be avoided. Alternatively, new plants could be integrated into the existing factory. The overall productivity on production spaces could be enhanced and costs reduced.

2.2. Evaluation Scale for Space Usage

Concerning the space usage, it is important to note that different spaces contribute differently to the added value. As shown in the left-hand column of Table 1, the three main categories for the space usage are “no added value”, “limited added value” and “maximum added value”. The middle column shows a possible way of organizing the Value Creation Levels with colors and numeric values. In the right-hand column, criteria for each scale value are defined. Production spaces in which production lines are classified as having maximal added value “8”. Spaces that are not used and are not accessible have “no added value” and are to be assessed “0”.

The driveways within a factory can be compared with the blood circulatory system of a human. They serve the purpose of providing required materials and are important for the production personnel to reach their workplaces. Factors like safety, corporate design or the historically grown infrastructure are to be considered while planning or optimizing driveways. These are some reasons why it is recommended to assess driveway spaces as “neutral” within a VAHM.

The lowest level of added value “no added value” considers spaces that are neither accessible nor used. These areas are e.g. used for storing defective parts or empty containers. These kinds of spaces are to be categorized “0”, as they have to be cleared with physical effort before being ready for use. Areas for defective parts are, if possible, to be located in the logistics area but in not within the shop floor. Spaces for empty containers can be minimized if they are carted away each time new materials are supplied.

A very high potential for improving the value added hold unused spaces, which are freely accessible but unused. They are to be classified with a Value Creation Level of “1”. In contrast to spaces with a value of “0”, these spaces can directly and without physical effort be used for creating value.

Staff wardrobes, meeting and recreation as well as office spaces that are within the shop floor are not value creating in the strict sense. But they are necessary, because they enable the personnel to hold short meetings and to take a break. Depending on the size of the factory, there may be no alternatives to establish these kinds of rooms outside the shop floor. This is why these spaces are valued “2”.

Table 1 – Evaluation Scale for Space Usage

Categorization	Value Creation Level	Dimension Space Usage
Neutral	-	To be classified as neutral - usually driveways that are used by industrial cargo trailers to ensure material supply.
No Added Value	0	Unused area (not accessible and unused) and areas for empties, waste and blocked defective parts.
Limited Added Value	1	Unused space (accessible but unused).
	2	Meeting and recreation rooms, staff wardrobes and office space on the shop floor.
	3	Area with semi-finished products and finished products as well as material staging areas more than 5 meters away from the workplace.
	4	Material staging area 1-5 meters away from the workplace.
	5	Material staging area surface max. 1 meter away from the workplace.
	6	Workplace (administrative) of the production personnel on the production line.
	7	Workplace (operative) of the production personnel at the production line.
Maximum Added Value	8	Production line (e.g. machines, robots, etc.).

Material flows within the shop floor do not directly contribute to the added value, but are necessary to enable value creation in the first place. The flow of material leads to stocks that consequently consume space. The closer required material is brought to the workplace, the more efficient the personnel can work when looging at their required movements. Consequently, the levels of value creation for the material staging areas are dependent on the distance to the location of usage. Material stages which are more than five meters away from the workplace have a Value Creation Level of “3”. This level also includes intermediates and finished products that are the output of a process step. Their value creation level is always “3”, as their distance to a workplace does not matter. Their usage usually takes place at another location.

A Value Creation Level of “4” are material stages, which are located between a radius of one and five meters from the actual workplace. While the production personnel can easily reach the required materials, leaving the workplace is still needed for a continuous value creation.

Material stages with a distance of less than one meter from the workplace are to be considered level “5”. This most efficient and optimal form of providing material is present, if the production personnel does not need to leave their workplace in order to perform their core tasks. In this situation the personnel can avoid inefficient tasks, which do not create value, like gathering required materials. Consequently, materials should be directly provided at the workplace to ensure a maximal utilization of the production personnel. It is to be noted however that spaces at workplaces are highly limited.

The actual workplaces have a high level of value creation. The VAHM model distinguishes between administrative and operative workplaces of production staff. Administrative workplaces include required spaces for computers, printers, desks or access opportunities. They can be seen as an interface between the personnel and the production control and therefore serve administrative purposes within the shop floor. These spaces have a value creation level of "6". The workplace of an operative employee, who is e.g. required for the assembly of a product at a plant, has a value creation level of "7". The only thing creating more value than an operative workplace are plants, e.g. machines or production robots, which create maximum value. Thus a plant has a Value Creation Level of "8".

2.3. Survey description

To draft a Value Added Heat Map, a current layout of the analyzed shop floor is required. This serves as the basis for the assessment of the production space. In the next step, the size of one spatial unit needs to be defined. The authors recommend using one square meter, as it easy to measure and spatially imagine. Smaller or bigger units can defined as well.

In a spreadsheet application (e.g. Microsoft® Excel) it is possible to integrate the production layout as a background. It is advisable to adjust the dimensions of each cell within the application true to scale, e.g. so that one cell will represent one square meter. Based on a Multi Moment Recording on the shop floor each grid or square meter has to be determined according to the evaluation scale for space usage (see Table 1).

In the next step, the determined Value Creation Levels for each square meter have to be inserted into the spreadsheet application. The Value Added Heat Map for the factor space usage is supplemented by the key performance indicator "Value Added Density". The Value Added Density indicates to which percentage degree the production spaces create added value (see Equation (1) – Key Performance Indicator "Value Added Density").

$$ValueAddedDensity = \frac{\sum_{i=1}^{N} grid \times ValueCreationLevel}{N \times \max(ValueCreationLevel)} \times 100 \tag{1}$$

grid $i = 1, \ldots, N$,

N – amount of analysed grids

2.4. Results

The authors applied the VAHM method at a production facility of an automotive supplier. One single production line was analyzed with said method. The resulting Value Added Heat Map for this single production line is shown in Figure 1. It displays the color scaling as well as the relative to Value Creation Levels. The driveways surround the analysed shop floor. They are represented in the visualization with white colored cells but not in the calculation for Value Added Density.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM
1																																							
2		1	6	6	5	5	5	5	5	1	3	3	3	3	3	3	1	1	1	6	6	6	6	6	6	1	1	1	1	1	6	8	8	8	8	8	8	8	
3		6	8	8	5	5	5	5	5	1	3	3	3	3	3	3	1	1	1	6	5	5	7	5	8	6	6	6	6	6	6	8	8	8	8	8	8	8	
4		6	8	8	8	8	6	1	1	1	3	3	3	3	3	3	1	1	1	6	5	5	7	5	8	6	6	8	8	6	6	6	6	8	8	6	8	8	
5		6	6	6	6	8	6	1	1	1	3	3	3	3	3	3	5	5	6	6	6	8	8	6	8	6	6	8	8	6	8	8	6	6	6	6	8	8	
6		1	6	6	6	8	6	6	6	1	3	3	3	3	3	3	5	5	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	
7		6	6	8	8	8	8	6	6	1	3	3	3	3	3	3	5	5	8	7	7	8	8	8	7	6	6	8	7	6	8	7	6	8	8	7	8	8	
8		6	8	7	7	8	7	7	6	1	3	3	3	3	3	3	5	5	8	7	6	8	8	8	7	6	5	8	7	6	5	8	6	5	8	7	8	8	
9		6	6	7	7	8	8	6	6	1	3	3	3	3	3	3	6	6	8	6	6	8	8	8	6	6	5	8	8	6	5	6	6	5	8	6	8	8	
10		5	5	8	8	8	6	6	1	1	3	3	3	3	3	3	8	8	8	6	6	8	8	8	6	6	6	8	8	6	6	6	6	6	8	6	6	6	
11		8	8	7	7	8	8	8	1	1	3	3	3	3	3	3	8	8	8	6	6	6	6	6	6	1	6	6	6	6	1	1	1	6	6	6	1	1	
12		6	6	7	7	8	6	5	5	6	6	6	6	6	6	6	6	6	6	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
13		1	6	6	6	8	6	5	5	6	8	6	6	8	8	8	8	6	5	8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	6	6	1	1	
14		6	6	8	8	8	6	5	5	6	8	6	6	8	8	8	8	6	5	8	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	8	8	8	
15		6	8	7	7	8	6	5	5	6	8	6	6	8	8	8	8	7	8	8	7	8	8	6	7	8	8	8	7	8	7	7	8	8	6	8	8	8	
16		5	5	7	7	8	6	5	5	6	6	6	6	8	8	8	8	7	8	8	7	8	8	6	7	8	8	8	7	8	7	7	8	8	6	8	5	5	
17		6	6	8	8	8	6	5	5	6	0	6	8	6	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	6	8	5	5	
18		6	8	7	7	8	6	5	5	6	0	6	8	6	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	5	5	
19		6	6	7	7	8	6	5	5	6	0	6	8	6	6	6	6	6	6	6	8	6	6	8	8	6	8	6	6	8	5	5	7	5	6	6	5	5	
20		1	1	1	6	6	6	6	6	6	0	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	5	5	7	5	6	6	5	5	
21		1	1	1	1	1	1	1	1	1	6	8	8	8	8	8	8	8	8	8	6	8	8	8	8	6	6	8	8	6	6	6	6	6	6	6	6	6	
22		1	1	1	1	1	1	1	1	1	6	8	8	8	8	8	8	8	8	8	6	8	8	8	8	6	6	8	8	6	0	0	0	0	0	0	0	0	
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Figure 1 – Example of a Value Added Heat Map for a Single Production Line Analyzing the Space Usage

The shop floor of the analysed single production line area is 777 square meters. 33% of the area are maximum value added and classified as an "8". This corresponds to 258 square meters. 44 square meters (6%) are classified with the Value Creation Level of "7". 241 square meters (31%) is equal to level "6", 68 square meters (9%) to level "5", 60 square meters (8%) to level "3", 94 square meters (12%) to level "1" and 12 square meters (2%) to level "0". The Value Creation Levels "4" and "2" are not identified in this production line. The calculated Value Added Density for the VAHM in Figure 1 amounts to 71% which is relatively high. Consequently, the improvement potentials were few and the company in the study decided not to take action.

The same single production line was analyzed a second time, after a rearrangement of the production space due to increasing demand. The VAHM method was then used again by the supplier in order to analyze how the rearrangement measures impacted on the value creation. According to the supplier's calculations, the Value Added Density declined significantly. With the Value Added Heat Map the improvement potentials of the rearranged production line were visualized.

The VAHM method was deemed to be a very practical tool for monitoring the value creation in real-life situations. As a consequence, this method was applied to all production lines on the supplier's shop floor. Inefficiencies and improvement potentials were identified and measures were taken accordingly.

3. CONCLUSION

3.1. Optimizing the Production Layout

Through the application of the Value Added Heat Map, insufficiently used areas are visualized. This visualization can be used to form the basis for the optimization of the production layout.

14% of the space in Figure 1 is unused area classified with “0” or “1”, which can immediately be used for value creation. 39% percent of the area is highly value adding and is classified with “7” or “8”. The Value Added Density of 71% in the shown example implicates that on average 29% of the analyzed space can be optimized. More added value can be generated with less space used. This can, for example, be achieved by:

1. Space-concentration through an optimized arrangement of the production line and
2. Optimized arrangement of the supply areas to achieve shorter distances for the production personnel.

In practice a Value Added Density of 100% cannot be achieved. A production line, which solely uses highly value adding machines and robots is still a utopia. Furthermore it’s neither required nor reasonably necessary. Buffer storage of raw material, operational workplaces or storage of finished goods at the production line is essential for having a functioning production system. In the opinion of the authors, the optimum Value Added Density lies between 70% and 80% and depends on the automatization degree present on the production line. In order to determine an optimal Value Added Density, benchmark tests seem appropriate.

The idea of having an area with only value adding machines and robots is still utopian. The authors believe the optimum lies between 70% and 80% and depends on the degree of the automatization in the production line. To determine the optimum Value Added Density benchmark tests seems to be advisable and appropriate.

3.2. Benchmark

The Value Added Heat Map method can be used to benchmark the value creation of different production layouts and also in service companies. The benchmarking could be carried out for a single production line or for a whole factory. It can be also used to compare space usage from various plants from one company too. An industry-wide or cross-industry comparison would also be possible.

3.3. Transfer to other Production Relevant Factors

The VAHM methodology can be applied to factors other than just space usage. Asset utilization, material stock or the exchange of information are some examples for factors that can be assessed and then visualized. On a business process map, inefficiencies in the flow of information and unnecessary or costly processes could also be visualized. Especially with regard to digital transformation, this method could be of great use to identify the aspects of networking which hold the greatest potential for improvement.

Possible examples to apply this method could be the production process of companies within the automotive industry or the interlinking of data and information in the healthcare sector.

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