TRAFFIC LOAD HEAT MAP – AN INNOVATIVE APPROACH FOR THE ANALYSIS AND OPTIMIZATION OF INTERNAL TRAFFIC

Dagmar Piotr TOMANEK[1], Jürgen SCHRÖDER[2]

[1]University of Bayreuth, Graduate School, Universitätsstraße 30, 95447 Bayreuth, Germany and Technische Hochschule Ingolstadt, Zentrum für Angewandte Forschung (Research Center), Esplanade 10, Ingolstadt, Germany

[2]Technische Hochschule Ingolstadt, Business School, Esplanade 10, Ingolstadt, Germany

Abstract

The Traffic Load Heat Map (TLHM) is a method for holistic visualization of the internal traffic load. Based on a production layout, the entire traffic in a production plant is visualized with different colors. Within a defined scale of colors, each color represents a specific frequency range of current traffic. Consequently, busy driveways that potentially cause delays in delivery can be easily identified in the resulting heat-map and appropriate measures can be discussed. In literature, a wide variety of methods and tools for visualizing the traffic load are found. For example, common methods are hydrographs or Sankey diagrams. These methods result in strongly simplified models that have limited informative value. Additionally, they often solely focus on parts of the whole traffic load, like crossings. Some of these methods analyze a wider spectrum of the traffic load. This often has negative effects on the clarity of the resulting visualization. The Traffic Load Heat Map method approaches an integrated assessment of the traffic load. Even though the traffic load is wholly analyzed, the resulting heat map is still easily understandable and clear. In this article, the innovative Traffic Load Heat Map method is described and exemplarily applied to a real-life production shop floor. It is a practical basis for optimizing the production layout and thus facilitates value concentration.

Keywords: internal traffic, intralogistics, optimization of driveways, production space efficiency, value concentration

1. INTRODUCTION

1.1 Value Added Concentration

According to Womack and Jones, the value of a service or a product is defined by the customers [1]. Finkeissen underlined the term Value Added as all activities that create the value of a product in relation to customer benefit [2]. Consequently, all activities that are not creating value are equal to wastage, which should be reduced or eliminated. Wastage is defined as the share of creation effort that a customer is not willing to pay for [3, 4].

An approach to assess the Value Added is the analysis of the Value Added Concentration (VAC). The Value Added Concentration negatively correlates to wastage. The more wastage occurs within a process the lower is the VAC. The same applies vice versa. Key factors for assessing the Value Added Concentration are personnel deployment, resource usage as well as space usage [5, 6]. A maximum utilization of the personnel, which is directly participating in the value creation, is expedient because they perform the creation of products or services. In order to concentrate the Value Added, the value added staff members should focus their working capacity and on their core tasks. Optimization of the resource usage, e.g. equipment or machines, should also be pursued to ensure the maximum concentration of benefit. Spaces within the shop floor are usually a highly limited good. Unused or reserved space create no or only limited value. The primary aim should be to reduce spaces that do not create value, to ensure that sufficient space for the actual value adding process is available.

An innovating method for the analysis of the Value Added Concentration of a shop floor concerning the space usage is the Value Added Heat Map.

1.2 Value Added Heat Map

The Value Added Heat Map is a visualization tool that indicates the level value creation concerning production relevant factors. It is following the practicality of a thermal heat map camera. A main goal of this innovated method is to visualize the usage of space with regard to their value. 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 that are not directly used for value creation, but which are 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 limited value added contribution. Spaces that are not used at all do not contribute to value creation. In a Value Added Heat Map, each square meter of an analyzed shop floor is evaluated with regard to a value level [7].

The prior aim of the Value Added Heat Map is to visualize the value creation level spaces using color scaling and assigning 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. It is a practical basis for optimizing a production layout to generate smaller area with the same value. This method can be used as the basis for deriving a series of measures that may improve the usage of available space. Consequently, investments in buildings or 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 [7].

1.3 Movement Matrix, Sankey-Diagram and Transition-Line-Diagram

In the literature, there is a wide variety of visualization and modeling tools for representing traffic volume. All these forms of visualization have a model-like character and display a simplified picture of reality.The simplest form of visualizing the traffic volume is by means of a Movement Matrix. A factory layout is not necessary for this drawing. For the representation of traffic volume, the frequency of movements for a specified area in a predefined period is initially documented and compressed. For example, the data could represent the movements of industrial vehicles, such as forklifts or route trains at an intersection in an 8-hour shift [8].

A Sankey-Diagram only visualizes activities that actually occur in a flow. Sankey-Diagrams had originally only been used for thermodynamic systems, but were later successfully applied to other different disciplines [9]. In thermodynamics, heat losses could be identified with this tool. The Sankey-Diagram is an analyzing tool that can be used to visualize the flow of goods, energy, or costs [10]. Applied in a shop floor, it can also be used to identify inefficient traffic load. The main component of a Sankey-Diagram is arrows. An arrow interlinks two points with each other and visualizes the direction of the flows between these points. The arrow's thickness represents the quantity of the activities that occur in the flow [11]. With the help of a Sankey-Diagram, the data from the movement matrix can be simply represented within a graphic. Then the thickness of the arrows corresponds to the number of floor vehicles from one position point to another. The direction of the arrow represents the direction of travel. The visualization of this diagram can be combined with a factory layout. The finished Sankey-Diagram can be the basis for deriving measures for improving the benefit. Rearranging the internal traffic can result in reduced transport routes and less transport vehicles [11]. The Sankey-Diagram considers the absolute traffic volume only and does not allow any conclusions on temporary congestion of traffic volume [12].

Temporary overloads can be visualized using a transition-line. A transition-line visualizes the traffic volume over a predefined period of time that is usually selected to be short (e.g. one hour). On the Y-axis, the number of transport and conveying floor vehicles is recorded. The X-axis corresponds to the time [13]. The peaks in a transition-line diagram correspond to the temporary congestion in the recorded period.

2. METHOD DESCRIPTION – TRAFFIC LOAD HEAT MAP

The Traffic Load Heat Map is a new developed visualization tool for the evaluation of intralogistics traffic loading industrial applications. Intralogistics are logistical material and goods flow that occurs within an operational facility [5]. This term represents a demarcation except transport of goods that, for example, can be carried out by a forwarding service. The goal of the Traffic Load Heat Map is the documentation and visualization of vehicle movements on the shop floor over a defined period. The main purpose is to visualize relevant aspects of the traffic area with regard to their traffic load. The graphical result resembles a thermal image [14]; therefore, it is called Traffic Load Heat Map. Potentials for improvement can easily be recognized by the use of this method. An evaluation of traffic processes must not be limited to a point, such as an intersection, but can also be visualized using a plurality of selected points on the factory layout. This has the advantage that the vehicle and material movements shown are mapped holistically and can be assigned simultaneously more easily and spatially. The disadvantage of such diagrams is that the clarity usually diminishes due to the increase of activities. The Traffic Load Heat Map provides a method for the holistic view of the internal transport processes without major loss of clarity. This newly developed approach visualizes the roads that are used especially intensively in red. The less a road is used, the more the color tends towards blue. The pursued objective is, if possible, to achieve a uniform distribution of traffic volume over the internal transport system. The Traffic Load Heat Map helps to visualize congestion and constrictions across the factory, which hinders the supply of materials at the production line. The TLHP may be a useful complement to such methods like Sankey-Diagram, Transition-Line-Diagram and Value Added Heat Map (see Fig. 1).

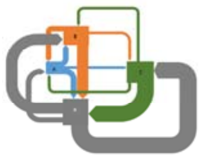
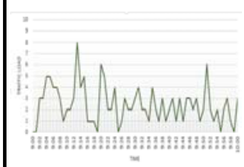
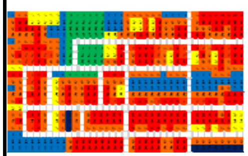
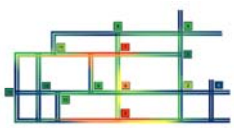
		Illustration of intralogistics traffic load	Visualization of intralogistics traffic load	Graphical evaluation of intralogistics traffic peaks	Holistic view
Movement Matrix	, A, B, C, D A, -, 10, 5, 10 B, 10, -, 5, 20 C, 5, 5, -, 30 D, 10, 20, 30, -	+	-	-	+
Sankey-Diagram		+	+	-	+
Transition-Line-Diagram		+	+	+	-
Value Added Heat Map		-	-	-	+
Traffic Load Heat Map		+	+	+	+

Figure 1 – Classification of the Traffic Load Heat Map

The theoretical foundation for drafting a Traffic Load Heat Map (TLHM) is the previous concept of Value Added Concentration. The value creation level space in a production plant depends on space usage. Production lines (e.g. machines, robots, etc.) are high value added. Unused areas for empties, waste, and blocked defective parts are low value added. An innovated method to evaluate the value creation of space usage is the above-mentioned Value Added Heat Map. The Value Added Heat Map and other widely known approaches that evaluate value creation ignore the importance of intralogistics traffic. In best case, driveways that are used by industrial cargo trailers to ensure material supply are to be classified as neutral. Driveways within a factory are comparable to a blood circulatory system of a human body. Ineffective and inefficient intralogistics are directly related to the low Value Creation. Driveways serve for the provision of required materials. The production personnel require driveways to reach their workplaces. The increasing value concentration of space and personnel increases the importance of intralogistics traffic.

3. SURVEY DESCRIPTION

To draft a TLHP, a current layout of the analyzed shop floor is required, which serve as the basis for the definition of the traffic area. In this area, the traffic position points to be analyzed should be defined before data acquisition. The authors recommend defining major crossroads as position points for Traffic Load Heat Map. The amount of determined traffic points depends on the size of the shop floor and the availability of recording persons. A dense network of recorded traffic points increases the quality of the Traffic Load Heat Map.

Before data acquisition, also the types of vehicles used in the shop floor should be catalogued. For data collection, the authors recommend the use of standardized recording sheets that include photos and names of industrial trucks and forklifts. It could also be helpful to label the vehicles. The recording sheet should also include space for details like position points number, name of the recording person, time specification, when a truck or forklift passes the position point, the direction a vehicle comes from and the direction in which the vehicle is driven to (see Fig. 2). It is particularly important that the position and viewing direction of the receiving person be also fixed on the layout and the recording sheet. This is important for the analysis of the data. Depending on the position and viewing direction of the recording person, the information about vehicle movements on the shop floor changes.

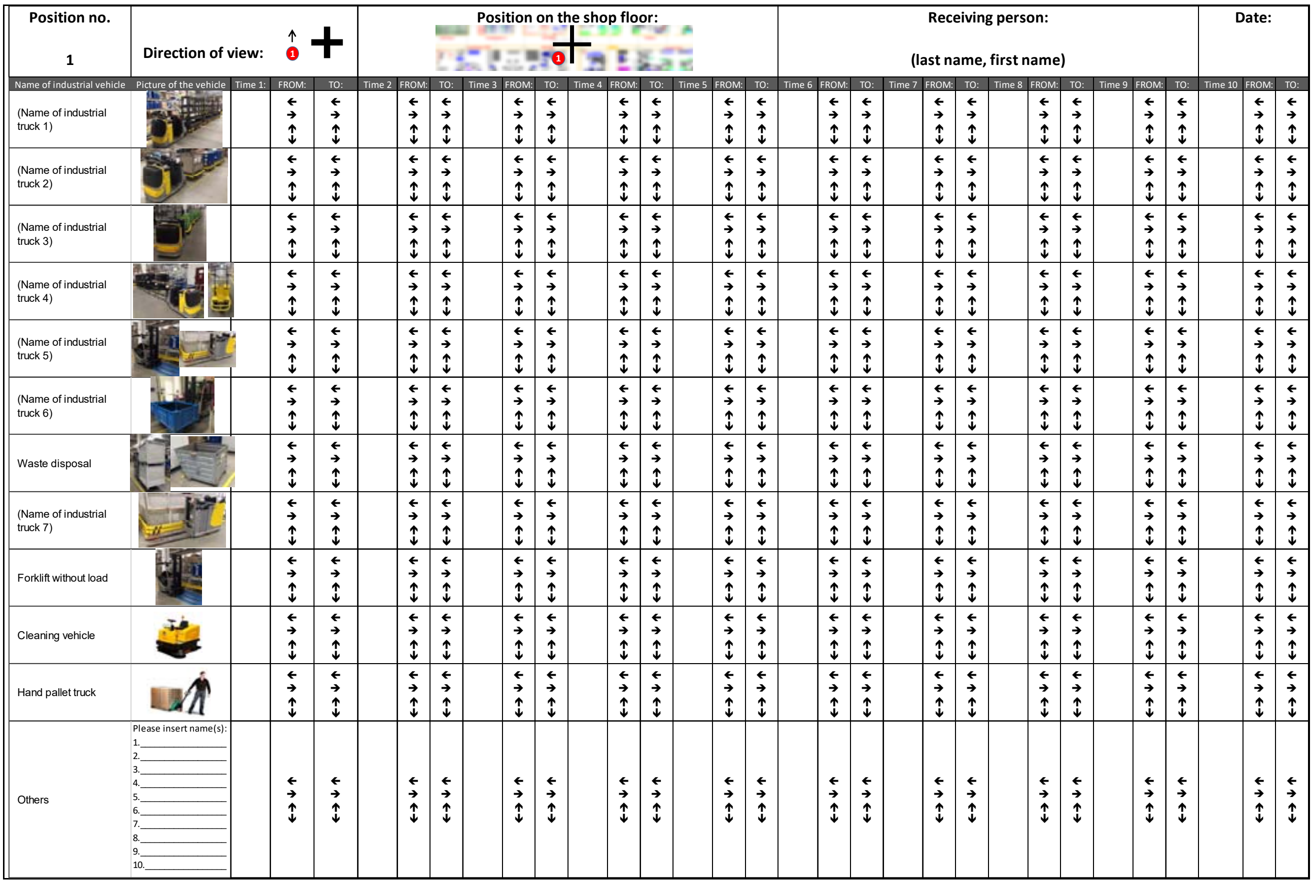


Figure 2 - Example of a standardized recording sheet for the documentation of vehicle movements on a plant shop floor over a period

With the help of the defined pre-selected position points and standardized recording sheets, the data collection takes place on the shop floor. Time studies or multi-moment recordings are carried out over a defined period (e.g. an hour or a shift). The authors recommend collecting the data during a rush hour. This makes it easier to identify bottlenecks and the improvement potential of traffic load. It is important to notice that the personnel of the production or logistics processes should not be involved in data collection. Otherwise, the measured values might be distorted. The authors recommend deploying external personnel for this task. Due to the risk of accidents on the shop floor of a production plant, the authors recommend also the priority to the safety of the employees and recording staff.

The traffic load of each traffic point is evaluated by the quantity of vehicles passing this position point in a period. The quantity of vehicles passing a position point in a period can depend on the amount of work, the size of the shop floor and the number of vehicles used. For each Traffic Load Heat Map an individual evaluation scaling has to be developed based on the multi-moment recordings. The authors recommend scales between „1“ and „9“. The level „1“ represents the lowest degree of traffic load. Positions points with a minimum traffic load are visualized in blue color in the Traffic Load Heat Map. The level „9“ represents the highest degree of traffic load. Positions points with a maximum traffic load are visualized in red color in the TLHM. The levels between „2“ and „8“ represent various degrees of limited traffic load. Each level is visualized by a unique color.

In a TLHM, also the driveways between two traffic points are evaluated depending on their traffic load. Driveways with a minimum traffic load are visualized in blue color. The red color represents driveways with a maximum traffic load. Between the minimum and maximum traffic load, there are degrees of driveways in analogy to the traffic points, further levels of limited traffic load.

Bottlenecks of an intralogistics traffic load can be caused by the traffic directions of vehicles. The traffic load from a random position point to another can be different then the reverse case. Therefore, in a Traffic Load Heat Map driveways between two position points are evaluated in two directions.

4. RESULTS

The authors applied the TLHM method at a production facility of an automotive supplier. The resulting Traffic Load Heat Map is shown in Fig. 3. It displays the evaluation scale as well as the Traffic Load Levels of the position points and driveways.

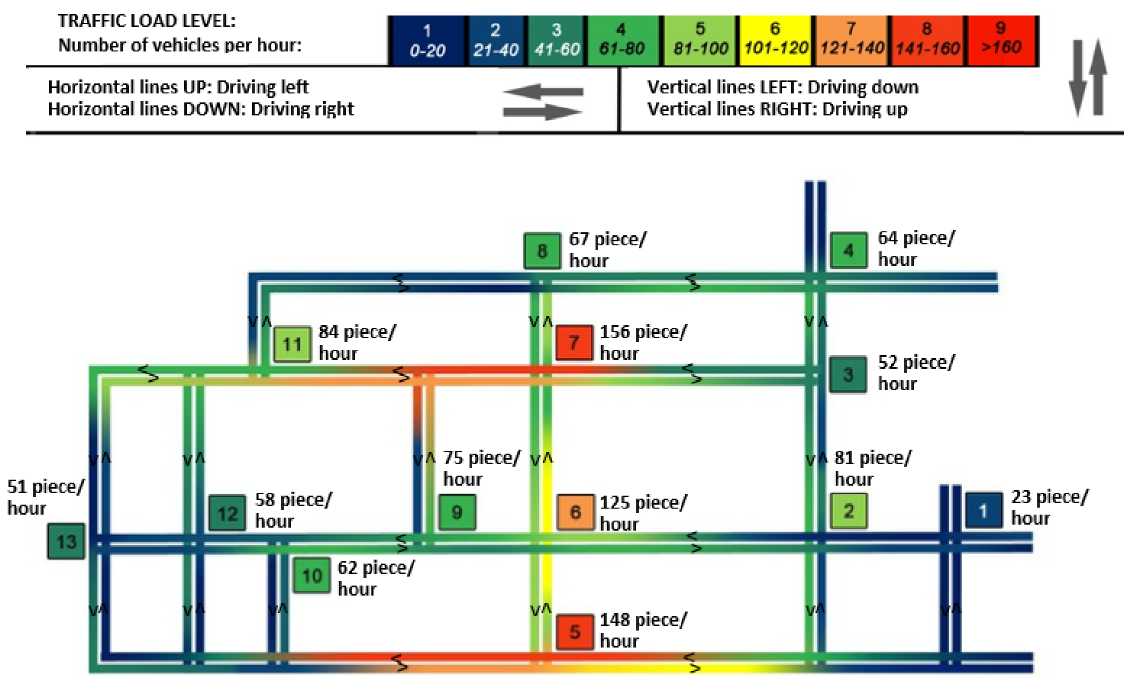


Figure 3 - Example of a Traffic Load Heat Map with Evaluation Scale

In the illustrated Traffic Load Heat Map, 13 traffic position points that were defined based on the layout are included. The limitation to 13 corresponds to the amount of recording personnel. At each position point, the traffic load of floor vehicles was recorded from 9 a.m. to 10 a.m. The minimum traffic load of the multi-moment recording is 23 vehicles per hour at point 1. The maximum traffic load is 156 vehicles per hour at the point 6.

According to the recorded traffic volume, the evaluation scale begins at level „1“ and ends at level „9“. The traffic load level „1“ corresponds to vehicle movements per hour of 0 to 20. None of the analyzed position points is classified with level „1“. The traffic load level „2“ corresponds to the interval of 21 to 40 vehicle movements per hour. In the TLHM, point 1 is classified with this level. The traffic load level „3“ corresponds to vehicle movements per hour of 41 to 60. The position points 3, 12 and 13 are located within these limits. The measures of the position points 4, 8, 9 and 10 are located between a limit of 61 to 80 vehicle movements per hour. This corresponds to a traffic load level „4“. The position points 2 and 11 corresponds to level „5“. The traffic load level „6“ has as dimension of 81 to 100 vehicle movements per hour. The traffic load level „6“ with a movement between 101 and 120 vehicles per hour is not represented in the Traffic Load Heat Map. The traffic load level „7“ corresponds to the interval of 121 to 140 vehicle movements per hour. In Fig. 2, the point 6 is classified with this level. The traffic load level „8“ corresponds to vehicle movements per hour of 141 to 160. The position points 5 and 7 are located within these limits. The maximum traffic load level „9“ with a movement over 160 vehicles per hour is not represented in the Traffic Load Heat Map. The classified traffic load points are visualized in colors according to the defined scaling. As point 1 has a low traffic volume, the square stored in the heat map with the number 1 has a blue background at this point. The points 5 and 7, however, point to a high traffic volume and the squares with the appropriate numbering are red.

Based on the recording of the driving directions in the multi-moment-analysis, not only the traffic volume at a single position point, but also the driveways are classified and visualized in a Traffic Load Heat Map regarding to their traffic volume. At this point, the authors would like to pick up two examples to describe the evaluation of the driveways in the TLHM. The traffic load at position point 1 is classified with the level „1“. The analysis of the traffic load around this point shows also a low traffic load level the driveways. According to this, in the Traffic Load Heat Map, the vertical line up, vertical line down, horizontal line right and horizontal line left from point 1 and to point 1 is visualized with the color blue.

By contrast, the traffic load level at point 7 is particularly high. The traffic load at position point 7 flows from the points 8, 3, 6 and 11. In analogy, the traffic load from point 7 flows further to the positions points 8, 3, 6 and 11. The analysis of traffic load into the position point 7 shows a higher volume from point 3 and 11. More precisely, the upper horizontal line representing the direction of travel to the left is marked red from point 3 to point 7 at the intersection. Similarly, the lower horizontal line, which represents the direction to the right, starts at the junction 7 from point 11 in the orange range. In comparison, the vertical traffic from point 8 and 6 to 7 is rather low. At pick-up point 7, the vertical lines on the left, depicting the downward direction from point 8, and the vertical line to the right, representing the upward direction from point 6, are green. The traffic from the crossing can also be identified using the Traffic Load Heat Map. At analyzed point 7, it can be seen that the outgoing traffic is particularly pronounced in the direction of travel to the left. This is shown in the red horizontal line above, which leads from point 7 to point 11. The traffic from the corresponding intersection to points 8, 3 and 6, is assigned to the green category (see Fig. 2). In summary, this means that the traffic load at point 7 in the direction of travel from right to left and from left is particularly high. At this point the probability of delays is particularly high, e.g. by congestion. Driveways with an above-average vehicle load may also increase the risk of accidents.

5. CONCLUSION

The main driveway of the factory runs horizontally between point 1 and point 13. This driveway is designed for a high traffic load, because it is simultaneously passable in two directions and arranged centrally between the production lines. Contrary to the expectations in the Traffic Load Heat Map, the main driveway is occupied below average. Instead, two other driveways in the Traffic Load Heat Map in Figure 2 show an above-average vehicle load. These are the horizontal connections to and from points 5 and 7. These driveways are not simultaneously passable in two directions.

The cause of this unexpected result lies in the analyzed behavior of the workers in the production lines between point 1 and 13. The reason for the low utilization of the main driveway is the storage of grid boxes with material in the production hall. Due to an increase of the volume of orders, unneeded boxes with raw materials and finished goods were put on the main driveway. Because of that, the two-lane road became passable in reality - partially in a single-lane. In the main material supply driveway, designed for a two-lane and two-way traffic, overtaking and unnecessary waiting time of industrial vehicles increase. As a further result, the drivers of floor vehicles use different routes to avoid traffic congestion in the main driveway. That is the reason for increasingly using bypasses for material delivery. Since the bypasses are not designed for high vehicle load, above-average congestion occurs at points 5 and 7.

Such unequal congestion can lead to delays or even to a decrease in material supply. This leads to an increase of the ranges in the production and surplus stocks that continue to narrow driveways again. The value concentration decreases. In the end, this leads to an internal traffic chaos or in the worst case to an internal gridlock. Through the application of the Traffic Load Heat Map, bottlenecks of the traffic in the shop floor are visualized. The TLHM provides a starting point for the optimization of internal traffic. By colored representation of the traffic load, it contributes to better clarity, by which it can be placed directly over a factory layout without deteriorating the readability of different arrow thickness. For the development of a target concept, it may be additionally purposeful to evaluate the traffic load on the mounting points per type of vehicle, in order to achieve a better line balance, for instance. Cleaning vehicles e.g. should not be used during the main traffic peaks.

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