Identification of parts with logistics potential regarding the inbound supply performance

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Abstract

Improving the performance of the inbound logistics in a time with constantly increasing complexity regarding the supplier network, the product diversity and individual customer wishes is a main challenge especially in the automotive industry. This paper provides a method to identify parts with logistics potential regarding the inbound supply concept by using relevant and measurable influence factors with assigned potential borders for each supply concept. A case study in the commercial vehicle industry is conducted to test the derived method successfully. The results showed that several parts offer logistics potential leading to recommendations for future research for handling those parts.

Keywords: Logistics Potential, Supply Performance, Inbound Supply Concept

Introduction

Nowadays the challenge in logistics is not only to provide the right amount of the right material, at the right place, at the right time, in the right quality, at the right costs, but also to use the appropriate inbound supply concept for each part in order to ensure a high logistics performance to stay competitive (Limère et al., 2012). As commonly known, today's business environment is strongly embossed by uncertainties, which lead to changes in details concerning parts (e.g. in demand or material prices). As a consequence the chosen supply concept may not remain the ideal concept over time and may thus require flexible adjustments (Hua and Johnson, 2010).

But due to the complex nature of the inbound supply chain (i.e. high number of parts to produce the final product, complex supplier network, different supply concepts, etc.), examining the fit of the supply concepts of all parts individually on a regularly basis seems neither to be possible nor efficient. Therefore, it is often not obvious – at least not without much effort – which parts are not delivered with the right supply concept anymore. Hence, the main research question of this paper is the following: How can those parts out of all parts of a product be identified which may not be supplied with the most adequate supply concept and thus contain logistics potential? By detecting those parts, inbound supply inefficiencies can be addressed resulting in an enhanced performance.

The paper is organized as follows: In the next chapter a literature review on supply processes is presented. As the automotive industry applies to be the "best-practice" industry regarding logistics and even a state-of-the-art industry in JIT and JIS supply (Wagner and Silveira-Camargos, 2012; Werner et al., 2003), this industry is focussed. Next, the four stage methodology is derived and tested on a case study with a commercial vehicle manufacturer which is similar to the automotive industry and even more extreme regarding product variety and complexity (Schuh et al., 2008). The paper is summarized in the last chapter and finishes with an outlook of future research.

Literature Review

The objective of the part logistics is to coordinate thousands of parts, hundreds of suppliers and the equipment for moving and delivering parts from the suppliers to the original equipment manufacturer's (OEM) plant. Boysen et al. (2015) provide an overview of the processes of part logistics, namely divided into external logistics (also known as inbound logistics), in-house logistics and reverse logistics. The inbound process covers the activities needed to supply parts from the supplier's plant to the OEM's plant, including the supply concept, call order and physical transportation. The supply concept defines the material and informational flow from the supplier to the plant of the OEM and can be specified as *direct delivery* and *in-stock delivery*. The main difference between both specifications is whether the parts delivered are processed via a storing stage or not. Each specification can be even more detailed – direct delivery can, for example, be JIT or JIS (VDA 5010, 2008; Klug, 2010). The in-house logistics is responsible for receiving the parts at the OEM's plant, forwarding them to storing and/or sequencing processes, and finally delivering them to the assembly line (Boysen et al., 2015).

One decision problem regarding the delivery-to-line process is to select the right line-feeding mode for each part. Line-feeding modes define how to arrange parts and how to deliver them to the point of consumption. Line-feeding modes are either line stocking, kitting, kanban-based JIT or a hybrid feeding (Kilic and Durmusoglu, 2015). This decision problem has been prominent in literature in the last few years, especially with the focus on kitting vs. line stocking, although it was already addressed in the nineties (see e.g. Limère et al., 2012; Caputo and Pelagagge, 2011; Bozer and McGinnis, 1992; Caputo et al., 2015; Limère et al., 2015). A similar decision has to be made for the inbound supply concepts: which parts should be delivered directly and which parts should be delivered in-stock? The related highlights in literature regarding those decision problems in in-house and inbound logistics can be found in Table 1. Obviously, only a small amount of literature focuses on the supply concepts of the inbound logistics and the ones that do so examine the concepts in a merely isolated way. Wagner and Silveira-Camargos (2011) move within the direct delivery concepts to decide on a cost basis between the JIS and JIT concepts. The analysis of a sole concept without providing any decision model, e.g. JIS or JIT, was done by Daugherty and Spencer (1990), Fandel and François (1993) and VDA 5010 (2008). The latter also examined in-stock delivery. A framework considering both direct and in-stock delivery does not exist.

Table 1 – Overview of some related literature

Source	Supply concept (Inbound)			Line-feeding mode (In-house)			Research type
	JIT	JIS	In-stock	Kitting	Line stocking	other	
Bozer and McGinnis (1992)				X	X		Descriptive model
Caputo et al. (2011)				X	X	X	Descriptive model
Caputo et al. (2015)				X	X	X	Optimization model
Daugherty and Spencer (1990)	X						Conceptual
Fandel and François (1993)	X						Conceptual
Hua and Johnson (2010)				X	X		Literature Review
Kilic and Durmusoglu (2015)				X	X	X	Literature Review
Limère et al. (2015)				X	X		Decision model
VDA-5010 (2008)	X	X	X				Conceptual, Case Study
Wagner & Silveira-Camargos (2011)	X	X					Decision model
Werner et al. (2003)		X					Case study

But certainly the attention to inbound logistics should not be neglected. As commonly known, there are trade-offs regarding the obvious benefits of direct delivery concepts: although JIS and JIT are promising in terms of inventory cost-savings, the inbound transportation costs may rise due to smaller shipment sizes and higher frequencies (Bagchi, 1988; Boysen et al., 2015). Hence, as it is important in in-house logistics to select the right line-feeding mode, it is just as important in inbound logistics to select the right supply concept. Furthermore the presented literature does not address the existence of uncertain changes, e.g. regarding supplier networks or technological alterations, which may affect the inbound logistics and therefore requires flexible adaptions.

The only identified cost decision model of Wagner and Silveira-Camargos (2011) shows that the decision between the JIT and JIS concepts requires a lot of detailed information regarding the analysed parts – such as variants, series size or defect rate at the assembly line to name only few. And as the final product in the automotive industry consists of thousands of parts, applying extensive decision models to decide over the suitability of the supply concept of each part individually is obviously inefficient. Hence, it is important to identify those parts which may not be delivered using the right supply concept (i.e. parts with logistics potential) and thus affect the following in-house process delivery-to-line. Logistics potential and supply chain performance is a broad field of research offering different instruments to assess potential – one of them is performance measurement providing also a not monetary evaluation (Wahl, 2008). Regarding the operative supply chain, non-financial measures apply to be the most suitable for a day-to-day monitoring (Gunasekaran, 2001). As far as we know, logistics potential with reference to the underlying decision problem has not been addressed in literature.

Methodology

The developed method consists of four parts: identification and ranking of influence factors, calculating the potential borders, and determining the logistics potential.

In a first step the relevant influence factors of the supply concept selection have to be identified. Both an extensive literature review and opinions of experts from the regarded industry can be taken into consideration. In order to identify the relevant influence factors, the following mandatory characteristics regarding influence factors based on Werner (2004) and Schedlbauer (2008) are defined: influence factors should have a *high importance* regarding the field of interest, i.e. the selection of the right supply concept. Influence factors should have a *direct impact* on the performance of the chosen supply concept (e.g. transportation costs only have an indirect impact; the direct impact would be the distance to the supplier). Influence factors need to be *measurable* in order to be able to conduct the further analysis. Influence factors which *vary over time* should be focussed so that the scope of a changing environment is addressed (e.g. influence factors like storage space is neglected because it is assumed that it will not change in the short-term).

The second step is to rank the influence factors using the analytic hierarchy process (AHP). The main idea of AHP is to derive a ratio scale for the elements related to a decision by conducting paired comparisons of all elements. The comparison is performed by using a fundamental scale reflecting “the relative strength of preferences and feelings” (Saaty, 1987, p. 161). Due to the fact that AHP enables multiple criteria decision making considering not only objective but also subjective factors, this method is adequate for ranking the identified influence factors on the inbound supply concepts. In the context of inbound supply, the AHP has even been applied to perform a risk analysis (Wu et al., 2006). The procedure to derive a ratio scale for the influence factors of the supply concepts is the following: conduct the pairwise comparison of the relevant influence factors using Saaty’s fundamental scale (Saaty, 1987). Create the comparison matrix and calculate the relative weights for the different influence factors. Determine the consistency ratio by measuring the discrepancy between the principal eigenvalue of the comparison matrix and the number of influence factors. If the consistency ratio exceeds 10 percent, the pairwise comparison has to be repeated according to Saaty (1987).

The third step is to create potential borders for each influence factor and for each supply concept. Since the objective is to identify logistics potential of each supplied part regarding the supply concept, the focus is not the detailed supply concept (e.g. just-in-sequence or just-in-time), but the fact whether the parts supplied are directly delivered or in-stock. Literature suggests for each supply concept certain framework conditions under which the concepts are expected to be more suitable. For instance, direct delivery is preferable for parts with a high number of variants, a small distance to the supplier, a large size, etc. (see e.g. Thun et al., 2007). Those suggestions are the basis for the identification of outlier parts, i.e. parts that are not in accordance with those suggestions. The idea of how to identify outlier parts is explained with the example influence factor “number of variants”, which is shown in Figure 1.

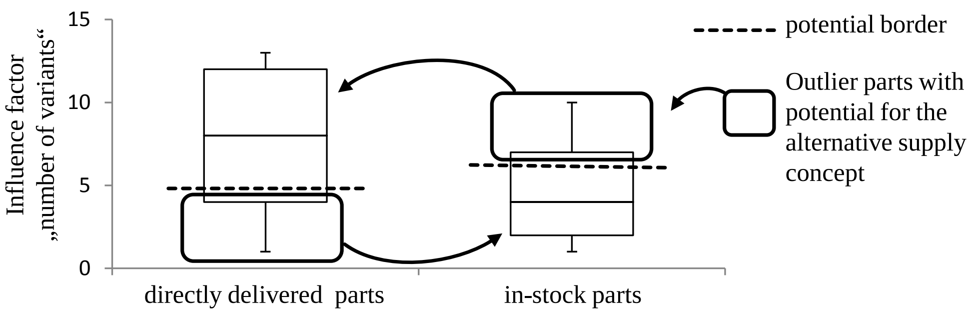

Figure 1 – Example for potential borders for the influence factor “number of variants”

The figure visualizes the distribution of directly delivered and in-stock parts regarding the number of variants using boxplots. Literature suggests that parts with a high number of variants should preferably be directly delivered, whereas parts with a low number of variants should be supplied in-stock (see e.g. Thun et al., 2007; VDA 5010, 2008). This leads implicitly to the conclusion that parts with a high number of variants should not be supplied in-stock and parts with a low number of variants should not be directly delivered, if the number of variants is the only considered influence factor. However, due to the complexity of the inbound supply and the high number of related influence factors, there are only general statements in literature, but no explicit thresholds stating what number of variants directly delivered parts are preferred over in-stock parts and vice versa. Those explicit thresholds are named *potential borders* in the following. This leads to the question how potential borders can be calculated in order to identify outlier parts. In this paper, the statistical approach two-sigma method (see e.g. Runkler, 2000) is used. The two-sigma rule is in general given by

$$\left|\frac{x_i - \bar{x}}{\sigma}\right| > 2, \qquad i \in (1, \dots, n) \tag{1}$$

where x_i is the value of an influence factor of a specific part i, $\bar{x}$ is the average and σ is the standard deviation of the corresponding influence factor. Adapting this formula 1 to the example of Figure 1, the outlier parts for directly delivered parts j are calculated by formula 2 (i.e. parts below the potential border) and the outlier parts for in-stock parts k are calculated by formula 3 (i.e. parts above the potential border).

$$x_j < \bar{x} - 2\sigma, \qquad j \in (1, \dots, m), \tag{2}$$

$$x_k > \bar{x} + 2\sigma, \qquad k \in (1, \dots, l). \tag{3}$$

The two-sigma method identifies outliers if the value of an influence factor differs from the average value more than the twofold standard deviation. The decisive direction of the deviation from the mean depends on each supply concept and influence factor.

In the fourth step, the results from step two and three are combined leading in the logistics potential for each supplied part. If a part is identified as an outlier regarding an influence factor, the derived weight for this influence factor equates the fraction potential of this part. The sum of all fraction potentials per supplied part results in the overall potential (i.e. between 0 and 100 percent). The higher the overall potential of a part is, the more adequate the alternative supply concept might be.

A Case Study in Corporation with a Commercial Vehicle Manufacturer

Analysis Framework and Dataset

There are two main objectives of the performed case study: first, the case study should show that the developed method is an applicable option to identify supplied parts with logistics potential regarding the alternative supply concept; second, the executed data analysis should give an overview of whether the contemporary inbound supply of the commercial vehicle manufacturer is in accordance with the suggestions from literature.

A commercial vehicle manufacturer with a production site in Munich, Germany, was chosen for the case study. There are over 15,000 parts systemically registered corresponding to the initial database from October 2015. This database was cleaned by parts belonging to certain groups (i.e. prototypes, raw material, working and auxiliary materials, bulk good and loose material) so that the database was reduced to 10,107 different parts, which are used for the series production of heavy trucks.

Applied method

The first step was to identify the relevant influence factors for the company taking the above-described characteristics *high importance*, *direct impact* and *variation over time* into consideration. However, the challenge was to discover those influence factors that can be expressed by key performance indicators (KPI) per part. Otherwise the influence factors would not be *measurable*. The resulting influence factors are shown in Table 2.

In the second step the AHP was executed by interviewing several logistics experts from the commercial vehicle manufacturer. The resulted weights of the AHP are shown in the second column of Table 2. The obtained consistency ratio from this AHP equals 8.78 percent and lies below the recommended threshold of 10 percent, i.e. the derived ratio scale is consistent. Obviously, the three influence factors *material price*, *distance to supplier* and *fluctuations in demand* were seen as more important than the other influence factors regarding the supply concept.

Table 2 – Identified influence factors and derived weights at a commercial vehicle manufacturer

Influence factor [KPI]	**Weights from AHP**	**Literature suggestions for *direct delivery***	**Literature suggestions for *in-stock***	**Source**
Fluctuations in demand [XYZ-Analysis]	21.26 %	low	high	Thun et al. (2007), Klug (2010)
Yearly demand [units of a part /year]	3.94 %	high	low	VDA 5010 (2008)
Number of variants [number of part specifications]	7.20 %	high	low	Wagner and Silveira-Camargos (2011), Thun et al. (2007)
Material price [€/unit of a part]	36.33 %	high	low	Wagner and Silveira-Camargos (2011), Klug (2010)
Distance to supplier [km from supplier to OEM]	27.50 %	low	high	Thun et al. (2007), VDA 5010 (2008)
Sourcing strategy [number of suppliers]	3.77 %	single	multiple	Klug (2010)

The third step was to divide all supplied parts into the two groups of directly delivered and in-stock parts. Furthermore, for each influence factor and each supply concept the potential border was calculated with regards to the underlying KPI using the two-sigma method. To calculate the mean and standard deviation only the parts containing a value for the respective influence factor were included. Although the influence factors *fluctuations in demand* and *sourcing strategy* were measurable, the two-sigma method could not be applied. For *fluctuations in demand*, the database for the XYZ-classification, which is based on Conze et al., 2012 who define X-parts as constantly consumed parts, Y-parts as parts with less constant demand than X-parts and Z-parts as parts with a sporadic demand, was not available and for *sourcing strategy* the two-sigma method was not reasonable since distinct borders are given by literature. In the fourth and last step, the outlier parts per influence factor were identified and the corresponding weights were assigned so that the overall potential for each part could be calculated.

Case Study Results

The results for the influence factors *yearly demand*, *distance to supplier*, *number of variants* and *material price* are illustrated in boxplots in Figure 2. For *fluctuation in demand* and *sourcing strategy,* boxplots were not appropriate since only few values for both influence factors exist. Regarding the *fluctuations in demand* it was noticeable that for both supply concepts over 50 percent of the parts are classified as Y-parts. The other parts are mainly classified as Z-parts and only a minimal portion of the parts (for each supply concept less than 2 percent) was categorized as X-parts. This is a surprising finding as literature suggests X-parts to fit best for direct delivery. Although, only 70 percent of all parts are classified by XYZ at all. Regarding the *sourcing strategy,* the dataset shows that almost all parts (99 percent) are delivered by only one supplier. Against the suggestions from literature, only 11 parts out of all the in-stock parts are delivered by two suppliers. The reasons for this sourcing strategy cannot be explained by this dataset and may be caused by strategic issues. But as a matter of fact the direct delivered parts with one supplier are consistent with suggestions from literature.

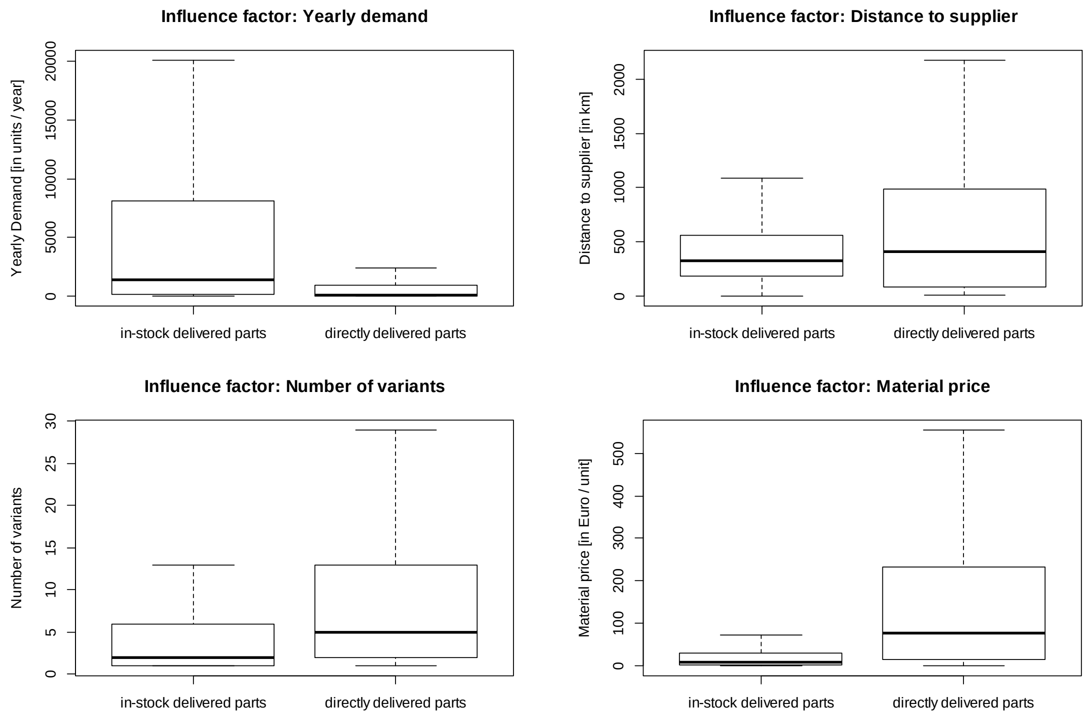

Figure 2 – Boxplots per supply concept for different influence factors

The boxplots for the *yearly demand* show a high divergence between in-stock (mean of 8,953 units) and direct delivery (mean of 2,326 units), i.e. contrary to tendencies from literature. A possible explanation for the low demand in directly delivered parts is that for a part that has several variants, the demand is split up on these variants since each variant accords to one part in the dataset. The influence factor *number of variants* reflects tendencies from literature, as the mean of *number of variants* for direct delivered parts (i.e. 15.81 variants) is higher than the mean for in-stock parts (i.e. 6.09 variants). The same is true for the influence factor *material price,* which has a mean of 37.91 Euros for the in-stock and a mean of 322.30 Euros for the direct delivery. The influence factor *distance to supplier* shows for the direct delivery surprisingly high distances with a mean of 441.69 kilometres, which is almost equal to the average of the in-stock delivery with 415.86 kilometres. As the manufacturer is able to perform long-distance JIS delivery due to a high stability of the production sequence, this result is comprehensible.

Regarding the logistics potential, each part of the dataset received an overall potential. The maximum overall potential achieved by one part was 48.76 percent. Figure 3 shows evaluations of the overall potentials. The left hand side of the figure shows the share of parts with a minimum overall potential of 10 percent, i.e. the potential that the alternative supply concept is preferable over the current supply concept. One quarter of the analysed parts have at least a potential of 10 percent. Furthermore it can be seen that 15.98 percent of the regarded parts (i.e. 1,615 parts) have an overall potential of over 20 percent. The parts with the highest logistics potential (i.e. higher than 20 percent, because this potential indicates that the parts is an outlier regarding at least one of the three important influence factors) are recommended for further investigations regarding a change in the supply concept. On the right hand side the evaluation shows the number of outliers identified per influence factor. The most outlier parts are identified in the influence factor *sourcing* with 4,944 outliers, which is not surprising as the dataset consists mainly of single sourcing. Noticeably are 1,472 outliers in *fluctuations in demand* and 1,015 outliers regarding the *number of variants*.

As mentioned above, identifying parts with logistics potential does not guarantee that those parts should be supplied differently. For each part a detailed cost model has to be calculated for selecting the supply concept, which is not in the scope of this work. But this work helps to prioritise which parts to analyse first on a more detailed cost level, i.e. parts with the highest logistics potential. After consulting logistics experts of the analysed manufacturer it was clear that some of the identified parts seem promising for a more detailed further investigation.

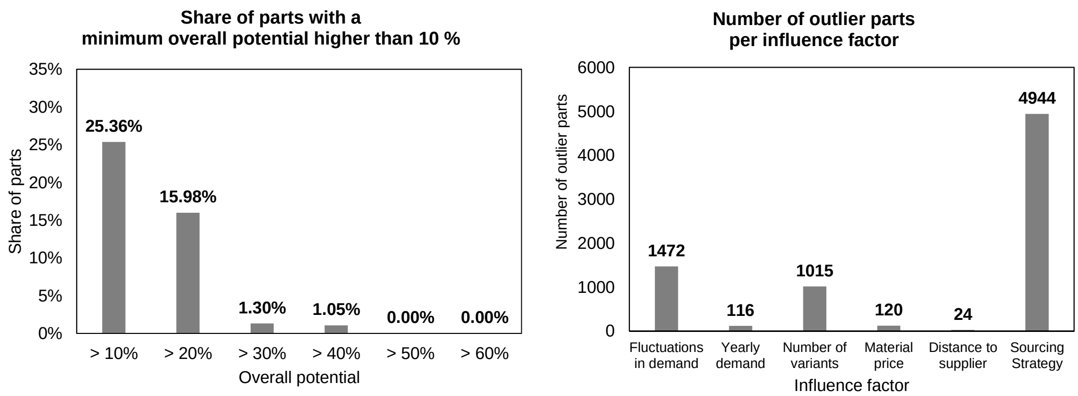

Figure 3 – Evaluation of the resulting overall potentials

Critical reflection of the presented method

The presented method was successfully executed resulting in a list of parts with logistics potential. An advantage of the method is that a high number of parts was analysed without much effort to get an overall picture of the supply situation of the company. Therefore it can be easily reproduced at any point in time. Furthermore, the method is flexible, because the chosen weights and influence factors can be defined according to the individual requirements of a company. As always for empirical studies, the quality of results depends on the quality of the data available. Nevertheless, this approach provides a tendency for which parts a revision of the supply concept is necessary.

A disadvantage is that the analysis prohibited considering connections between different parts due to the data available. E.g. a part A contains characteristics for in-stock delivery and is pre-installed on a directly delivered part B, so that part A and B are directly delivered together, but still the data of part A indicates misleadingly logistics potential. Furthermore, a critical reflection on the potential borders is needed. By this calculation, the individual situation of the examined company is taken into account, but therefore no general guidelines for other companies can be drawn. Moreover, in some cases the potential borders could not be calculated and in other cases the calculated borders were negative so that no outliers were identified. By performing a sensitivity analysis to examine how the results changed if the potential borders are chosen less pessimistically than with two-sigma, it was found out, as expected, that more parts are identified as outliers. Thus, the right calculation method of a potential border may individually depend on the particular manufacturer.

Conclusion

The presented method offers a first effort aiming to detect parts whose current inbound supply concept should possibly be revised by assigning logistics potential to each part. The results from the case study showed that the structure of in-stock and directly delivered parts regarding the influence factors does not always correspond to tendencies from literature. The calculation of the potential identifies almost 20 percent of the parts with a potential higher than 20 percent to change to a more efficient supply concept. Consulted logistics experts from the manufacturer confirmed that the identified parts are promising for a detailed cost analysis. Hence, this work offers a basis for the improvement of the inbound performance, which is highly relevant for practice.

However, the presented method reveals ideas for future research. To derive general statements regarding the influence factors and potential borders, a survey on different companies of the same industry is recommended. As the two-sigma method is not applicable for every influence factor and results in pessimistic potential borders, a possible option is to choose the borders for each influence factor individually. Moreover, the identification process should be phased starting with influence factors that exclude parts directly from the potential analysis (i.e. knock out criteria). Additionally, the analysed parts should be bunched to part families to avoid missing connections between parts. Furthermore, the presented method is conducted statically at a certain point in time. By developing a dynamic analysis it is imaginable to calculate potential areas, which enable a continuous monitoring of the supply concepts covering the performance measurement idea even more. The monetary effects of parts with logistics potential need to be disclosed by detailed cost analysis, taking existing literature into account.

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