The absence of variation in key performance indicators

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Abstract

The research to be presented has been performed in two parts; a literature review and case studies including interviews, observations and analysis of archival data. The literature review shows that there are gaps concerning variation tracking and analysis when monitoring KPIs. The benefits of taking variation into account in strategic measures have been described in the literature. However, reports on implemented examples of how variations are utilized for a systematic support of decisions are limited. The case studies show similar results; the display of variation in performance measurements is very limited.

Keywords

Variation, KPI, BPMS, control chart

Introduction

Measuring performance, with different sets of Key Performance Indicators (KPIs), is almost defacto standard within manufacturing industry today. A question is however to what extent the measures in a Business Performance Measurement System (BPMS) are used to make improvement decisions. Another issue is to increase the knowledge about what information in relation to different measures that is needed to make well informed strategic decisions.

Our belief is that variation in KPIs is not considered to the extent necessary for making the right decisions. In this context variation is considered as deviations from a mean value over time. Decisions are mainly drawn from a mean calculation of a KPI, implying the underlying distribution is symmetrical (e.g. normal distributed) meaning the level of variation will not

influence the level of the mean. However, a lot of business decisions are based on cost, lead-time, number of parts, etc. and such data is **not** symmetrical (e.g. there is no negative time or cost). For such data the level of variation will drive the level of the mean. When mean is used to represent an uncertain quantity, it ends up distorting the results because it ignores impact of the inevitable variations (Savage, 2002). Understanding variation and mitigate its influence, will therefore imply an improvement of the mean.

The described belief is in line with what Wilcox and Bourne addressed in their research 2003. They point out that the performance measurement literature has not addressed the concept of predicting performance with sufficient detail and rigour. They also say that performance measurement could benefit from the early developments by e.g. Shewhart (Wilcox and Bourne, 2003).

The purpose of the study presented here is therefore to analyse to what extent variation is accounted for in BPMS by considering literature and use in practise. It is also of interest to review what kind of variation is considered for variation display. The research presented here has therefore been conducted in two parts; a literature review and case studies including interviews, observations and analysis of archival data. The case studies identifying if and how variation is used by practitioners is involving seven Swedish manufacturing plants.

The practical implication potential is expected considerable when using extended information on KPI variation in decision making. Result from a case study not yet published points towards improved decisions owing to the use of control chart on one KPI. The savings in that particular case are estimated to be in the range of 10 000 Euro.

The major finding from this research is that there is still a lack of information regarding variation in KPIs, both in literature and in industrial practice even though the benefits of taking variation into account in strategic measures have been described in the literature (Deming, 1994).

The paper will first introduce the ideas behind control charts as a mean of displaying variation in KPIs and how it affects decision-making. After an overview of the methodology used, the literature review is presented followed by the empirical case studies. After that the analysis is presented, in which the literature review and empirical findings are combined. The paper concludes with a discussion and ideas for future research.

Variation and performance measurement system

One tool suitable for studying variation is the individual (x) moving range control chart, XmR. It was invented already in the 1920s by Dr. Walter A. Shewhart at Bell Laboratories (Shewhart, 1926). The control chart consists of a central line (the mean value), upper control limits, lower control limits, and plotted data as Figure 1 shows.

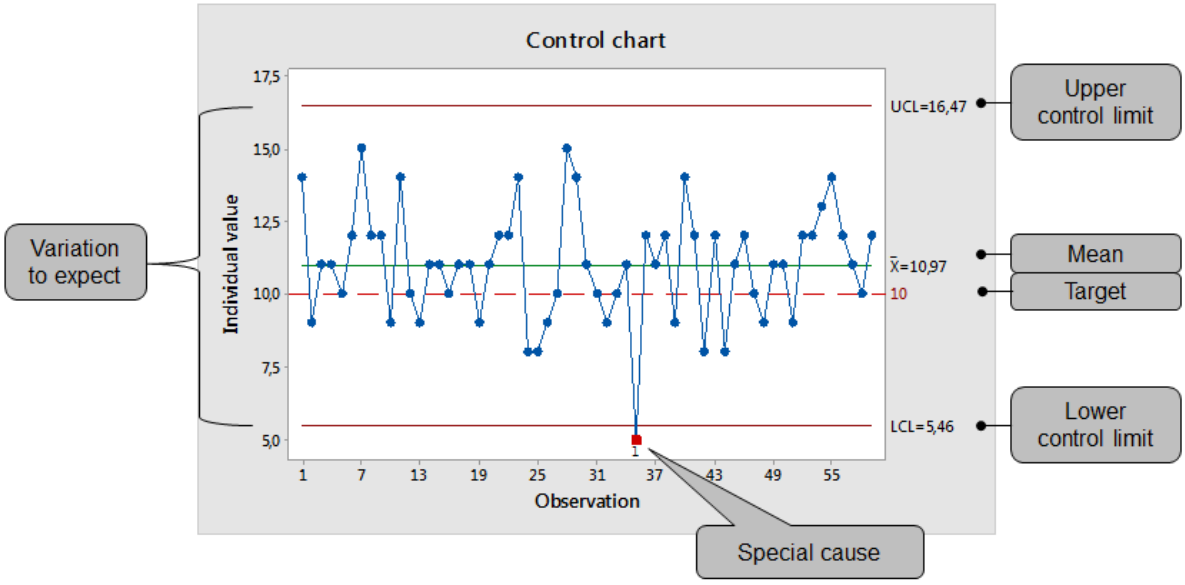

Figure 1. A control chart displaying upper control limit, lower control limit, mean, target, and sign of instability due to special cause.

The control limits capture the voice of the process, VOP, and should not be mixed up with tolerance limits, which is the voice of the customer, VOC. The control limits are statistically calculated, without assumptions of homogeneity, and express the limits for the natural variation present in the process, whereas tolerance limits are set by customer requirements. The control limits in other words effectively filter out the routine variation, noise, in the data. When all data points are within the control limits the process is said to be stable and only contains natural variation. When instead a data point falls outside the control limits or an unnatural pattern is shown, it is a sign of instability and special causes affecting the underlying process. All types of data can be visualized using control charts; there are different kinds of charts depending on the type of data. According to Wheeler XmR is the only control charts required in the beginning. It is robust to different underlying distributions, it does not assume homogeneous data, it is robust against a lot of measurement noise, etc. If it seems like a “one size fits all” approach, it is (Wheeler, 2009).

When using control charts to study variation it is possible to distinguish between assignable causes of variation and chance causes of variation (Shewhart, 1931). This is important since the actions suitable to improve the process are different depending on if the process is stable (only chance causes of variation) or unstable (contains assignable causes of variation). This ability of guidance on suitable actions is one reason why BPMS should benefit from including control charts. Another is the possibility of prediction. A stable process can be expected to deliver within the control limits as long as no assignable causes occur. It operates at its best, as it is designed to do. There is in other words no point in hoping it will perform better tomorrow without substantial renovation. The knowledge of the expected performance makes it possible to compare the expected outcome with the desired target value and decide on suitable actions if they do not match. A third reason would be the possibility to monitor a process and get a warning signal if the process becomes unstable. Several authors analogously point out the suitability of using control charts on performance measurements on management level (Caulcutt, 1996; Deming, 1994; Wheeler, 2000; Danielsson and Holgård, 2010; Roth, 2005; Dull and Tegarden, 2004).

KPIs should be used as a base for initiation of improvement initiatives. If variations in KPIs are not considered, the consequences could be incorrect decisions and focus on issues of less importance to economic efficiency. A variation analysis can provide information on process stability or instability and support decisions on suitable actions needed in either

case. A stable process can be afflicted with sources of common variation, but the combined outcome of them is known. A stable process is not the same as a process operating satisfactory in meeting the management expectations. The process output can be predictable but not necessarily within required limits. An unstable process instead contains one or a few unpredictable, but often traceable causes of variation. When these causes are understood and managed, variation drops and mean level usually improve as an indirect consequence.

The actions needed to improve an unstable or stable process are different and should be addressed at different management levels (Deming, 1994). The special cause of variation in an unstable process is usually easier to detect and should (preferably) be rectified directly on shop floor level. Improvements of stable processes, i.e. reducing the level of common cause variation, can only be realised by a redesign or update of the process equipment or technology. These decisions should therefore be made on a higher management level. This means that the basis for decisions on improvement actions needed differs, depending on the level of process stability, leading also to involvement of different organizational levels depending on the stability level. Information about performance variation is thus necessary to be able to make the right decisions.

Another aspect is that different organizational levels might use the same type of data even though different types of decisions are made on different levels. A result could be that top management tends to prioritize low level issues instead of acting strategically based on deeper knowledge on KPI variation. The focus should be put on strategic decisions and long term system solutions for improving or updating already stable processes. Shop floor management often need to make faster decisions, focusing on daily problem solving of unstable processes. With a lack of information on if a process is stable or not, the risk is that decisions will not be the best suited for each situation.

Methodology

To map the attention variation in relation to production monitoring is given in the literature and by practitioners on different organizational levels this study is divided in two parts; a literature review and case studies including interviews, observations and analysis of archival data. The purpose has been to compare what is described in the literature with the level of implementation in the context of the study. The methodology used for the two parts are further described in the separate sections.

Literature review

A literature review was conducted in order to identify the academic coverage of presence of variation in performance measurements in production settings.

Literature review methodology

The literature review consisted of two parts; a systematic and traditional approach (Jesson et al., 2011). The systematic part consisted of six steps.

1. *Define the research question*
   The research question is defined as follows: Is the variation displayed in key performance indicators at companies?
2. *Design plan*
   The databases and search query suitable for the topic is defined.
3. *Perform search*
   The searches are conducted at four points in time.
4. *Apply exclusion and inclusion criteria*
   The time span is set to all years. The search field included depends on the database searched but is stated in the result.
5. *Apply quality assessment*

For some databases the result is filtered only to include academic journals and articles to exclude e.g. newspapers and advertising material. The result is evaluated to assess the fit to the research question by reading the title and abstract.

6. *Synthesis*
   The result is collected and evaluated.

The traditional literature review consisted of a personal selection of materials believed to have important contribution to the topic. The starting point was relevant papers and therefrom other interesting papers were identified by tracing other publications done by the author, papers referred to by the author or other papers referring to the paper in question.

Literature review findings

Findings from the systematic literature review

A total of 10 databases were included in the systematic literature review. The initial result when using the search query (variation AND KPI AND (performance measure*)) was very limited in Scopus, Web of Science, Business Source Premier, Compendex, Springer link, Taylor & Francis online, ABI/Inform, and Sage. Wiley online returned a high number of hits but because of lack of overview of titles and abstracts it was difficult to judge the applicability of the result from that database. The most promising database was Emerald. The result from the systematic review is summarized in Table 1. The returned result at this stage included papers within areas as scattered as healthcare, maintenance, food industry, and simulation. No common denominator could be found. All search results are not unique but some papers were duplicates occurring in several databases.

Table 1 – Results from the systematic literature review

Database	Search query	Search field	Time span	Document type	Search date	Search result	Result fit
Scopus	Variation AND KPI AND performance measure*	title, abstract, keywords	All years	All	2016-03-02	7	one further read (Bai and Sarkis, 2014)
Web of Science	Variation AND KPI AND performance measure*	Topic	All years	All	2016-03-02	5	one further read (Bai and Sarkis, 2014)
Business Source Premier	Variation AND KPI AND performance measure*	not stated	All years	Academic journals	2016-03-02	9	one further read (Bai and Sarkis, 2014)
Compendex	Variation AND KPI AND performance measure*	All fields	All years	All	2016-03-03	9	one further read (Bai and Sarkis, 2014)
Emerald	Variation AND KPI AND performance measure*	All fields	All years	All	2016-03-03	385	see more detailed searches
Springer link	Variation AND KPI AND performance measure* /filter on production engineering	not stated	All years	Article	2016-03-03	300/28	Not applicable
Taylor & Francis online	Variation AND KPI AND performance measure*	Abstract	All years	All	2016-03-03	2	Not applicable
Wiley Online	Variation AND KPI AND performance measure*	All fields	All years	Journals	2016-03-03	450	Lacking overview of titles and abstract therefore difficult to judge the applicability
ABI/INFORM complete	variation AND KPI AND (performance measure*)	Anywhere except full text	All years	Scholarly Journals Dissertations & Theses Conference Papers & Proceedings	2016-03-14	2	one further read (Bai and Sarkis, 2014)
Sage	variation AND KPI AND (performance measure*)	All fields	All years	All	2016-03-14	0	

Since the Emerald database was showing the most promising results it was therefore chosen for further detailed searches. The results from the detailed searches are summarized in Table 2. Changes were made to the search query including more key words like *SPC, control chart* and *implement* to narrow down the result. In one case the search field was limited to only include when key words were present in the abstract.

Table 2 - Detailed search result

Database	Search query	Search field	Time span	Document type	Search date	Search result	Result fit
Emerald	Variation AND KPI AND performance measure*	abstract	All years	All	2016-03-04	4	1 further read (Bai and Sarkis, 2014)
Emerald	Variation AND KPI AND performance measure* AND SPC	all fields	All years	All	2016-03-04	10	3 further read (Chakraborty and Chuan, 2013; Brown, 2013; Morgan and Dewhurst, 2007)
Emerald	Control chart AND performance measure* AND variation AND implement* AND SPC	all fields	All years	All	2016-03-14	325	5 further read (MacCarthy and Wasusri, 2002; Caulcutt, 1996; Hamza, 2009; Antony, 2000; Elg et al., 2008)

The paper by Bai and Sarkis was assessed not to be relevant for the current research issue even though it was the most common paper occurring in the literature review. The paper is handling rough set theory within the data mining realm (Bai and Sarkis, 2014). The paper by Chakraborty and Chuan is also out of scope (Chakraborty and Chuan, 2013) since it is mainly focusing on Six Sigma implementation and not variation in performance measurements. The same situation applies for the paper by Brown which is mainly focusing on the development of quality (Brown, 2013). The paper by Morgan and Dewhurst is however relevant. They suggest a composite approach to improve supplier performance in which descriptive statistical analysis is used to establish standards and control charts form the basis for measuring and monitoring actual performance (Morgan and Dewhurst, 2007). MacCarthy and Wasusri reported a review of non-standard applications of SPC from 1989-2000 where they divided them based on objective into process monitoring, planning, evaluating customer satisfaction, and forecasting (MacCarthy and Wasusri, 2002). Caulcutt argues that few people realize the powerful potential of SPC to the achievement of business excellence. He explains that the manager should seek assignable causes but not chase random causes. By questioning only the low result the manager distract attention from the important issue and causes the operator to seek explanations which cannot be found. Even though Caulcutt conclude that control charts can be found in every industry sector the use is not spread uniformly or evenly (Caulcutt, 1996). The paper by Hamza presents an example of variation follow-up in a non-manufacturing context. The paper describes when control charts were used to track performance of engineering deliverables during a design process project completion (Hamza, 2009). Antony's paper describes 10 key ingredients for successful introduction of an SPC project in an industrial setting (Antony, 2000), however not specific in the context of displaying variation in performance measurements. Elg et al. describe the implementation of a performance measurement system for monitoring and controlling of non-conformities in a production unit (Elg et al., 2008). The context of their study, non-conformities in a production unit, is however on a lower organizational level than the scope of this paper.

Findings from the traditional literature review

Wilcox and Bourne (Wilcox and Bourne, 2003) state that early work on performance measurement by Shewhart (Shewhart, 1931), later recognized by Deming (Deming, 1994) and Wheeler (Wheeler, 2000), has been overlooked by recent authors. They also conclude that adaptions of Shewhart's ideas in e.g. Six Sigma have lost the emphasis on prediction and follow more mathematical approaches. That is consistent with Woodall's description

saying that researchers rarely put their narrow contributions into the context of an overall SPC strategy (Woodall et al., 2000). There is a role for theory in the application of control chart but theory is not the primary ingredient for successful applications.

Bourne describes how previous work has been done in the area of managing with measures but little has evolved outside the context in which it was developed (Bourne, 2008). He concludes that co-creation of solutions is important with a combination of research and practise.

Taticchi states that research should specifically address to the effort of companies in effectively translating information coming from the measurement of processes into effective actions (Taticchi et al., 2012). This problem is well-known as the ‘‘knowing-doing’’ gap and depicts the difficulty of moving from performance measurement to performance measurement and management. Coleman identifies a cross-functional development challenge, that either statistical thinkers get trained and become interested in leadership or that managers become more technically educated (Yvonne Coleman, 2013). Maleyeff provides a framework for comparing the performance index of an organizational entity to an appropriate target. He concludes that managers must be more effectively educated in the basic statistical methods. Not only would this work allow for more effective performance benchmarking, but will also lower the resources necessary for implementation (Maleyeff, 2003).

Brimson states that management systems have remained unchanged for many decades. By creating a process understanding managers can recognize why results are as reported and what results are likely to be in the future (Brimson, 2004). There is no description of actual implemented cases but rather a theoretical description with guidelines.

The result of a survey conducted by Bergquist and Albing shows that the students employed in the Swedish industrial sector witness a modest use of statistical methods (Bergquist et al., 2006). Applications in other areas than production are also exemplified in the literature e.g. using quality control methods in a hospital (Canel et al., 2010), a department at a university and an elderly care operation in a municipality (Larsson et al., 2011), and on university student grading (Edwards et al., 2007). Many of the criticisms of statistical quality control use in services stem from an incomplete conceptualisation of service process quality (Sulek, 2005). Since service quality is really a function of the entire service process, a systems perspective is needed to assess service performance and plan quality interventions. Thus, statistical quality control, which addresses the problem of unnatural variation, represents a critical tool for enacting a systems perspective of service quality according to Sulek.

Empirical study

Case study methodology

The case study had multiple-case design with embedded units of analysis according to Yin’s definition (Yin, 2009). The cases consisted of seven production sites in large Swedish manufacturing companies, all with a global manufacturing footprint. Two of the plants belong to the same company.

The data collection is a part of a research project with the aim of developing resource efficient BPMS. The purpose of the initial study in this project, of which the data collection was a part of, was to map and categorize the existing range of KPIs used at the seven participating sites. The mapping procedure consisted of three parts; interviews, observations and analysis of archival data. The objective was to capture both the managerial perspective on performance measuring (top-down), as well as performing thorough analysis of what KPIs that are already displayed on different organizational levels (bottom-up). The interviews were made with managers at different levels within the organization. The set of questions used for

the interviews was based on Neely's performance measurement record sheet (Neely et al., 1997) which was altered to fit to the purpose of the study. Observations were made by studying available visualizations in production (usually whiteboards) where performance measures are presented and by attending daily production control meetings at different levels in the organization. Archival data, such as excel sheets and presentations, were made available by the managers. In the top-down interview one question was specifically inquiring if variation is displayed in the performance measurements. In the bottom-up study including observations, archival data and interviews it was also noted how the performance measurements was displayed e.g. as a bar chart or control chart hence providing information if variation is displayed.

Case study findings

The data collected during observations and interviews at the partner companies where assembled and mined for information about variation. Since the use of different charts and diagrams indicates a level of maturity to be able to move on to using control diagrams to visualize variation, this was also extracted from the collected data. The findings from the interviews, observations and analysis of archival data are summarized in Table 3.

Table 3 - Performance measures at the case companies

Company	Number of performance measures	Number of control charts	Number of bar charts, pareto, pivot, and trend [percentage]		Number of blanks [percentage]	
Company A	503	0	134	27 %	69	14 %
Company B	390	0	117	30 %	213	55 %
Company C	1204	0	790	66 %	19	2 %
Company D	212	0	3	1 %	0	0 %
Company E	190	0	142	75 %	6	3 %
Company F	478	0	78	16 %	110	23 %
Company G	395	1	112	28 %	11	3 %

The top-down interviews with managers at the case companies gave consistent results. On the question "Is the variation displayed?" most of them answered no. Company A however perceived variation as deviation from target value and therefore answered that it is displayed for some KPIs. Two of the companies did not answer the question explicit.

Analysis

To conclude the literature review findings, reports on implemented visualisation of variation in BPMS in the literature are scarce. The literature review conducted confirms the picture described by Wilcox and Bourne that the performance measurement literature has not addressed the concept of predicting performance with sufficient detail and rigour by using KPIs displaying process variation (Wilcox and Bourne, 2003).

The structured literature review gave a very limited number of hits with the search queries used. Only four of the few articles found in the systematic literature review were within the scope. When instead using traditional literature review following references from paper to paper some additional articles were identified. The result still show very scarce presence of papers describing implementation of control charts on performance measurements even though the predicted benefits are well described. The statistical view has been pointed out as an area stopping the implementation. The need for a cross-functional understanding between statisticians and managers is identified. There are other areas of implementation of control charts e.g. in service sectors that could show similar issues as when using control charts on key performance indicators.

The case studies show almost complete absence of display of variation in the performance measures at the case companies. Only one example out of 3372 measures included display of variation in the form of a control chart. There are however differences in the number of blanks, meaning the visualisation choices are unknown to the researchers. In company D all information about the visualisation was present whereas in the case of Company B more than half of the measures lacked information of visualisation. The causes of these differences probably stem from the fact that the studies were performed by different researchers with varying knowledge and possibilities to spend time finding all information on every measure. The effort needed to get this data also differed between the companies.

As indicated in Table 3 bar chart and pareto diagrams are to a varying extent already used as for visualization of KPIs at the companies participating in the study. When using these types of diagram, the measurement data is already organised in a way relatively easy to transfer into e.g. control charts. Therefore the threshold for adopting a visualisation of variation is low, for companies already using these types of diagrams.

Discussion

The literature review indicates that the implementation of displaying variation in a company's strategic measures is not a thoroughly researched phenomenon. It might however be that other key words are used to describe the phenomenon. That indicates a problem of getting access to this information. One reason could be the cross-discipline nature of the phenomenon, intersecting the areas of performance measurement, quality, and production. Each area has its own research traditions and nomenclature and if not familiar with that, the access becomes limited. Academic traditions can also be the reason for the limited presence of described implemented cases. In general publication focus tends to be on methods and models rather than actual implementation. Again the cross-discipline nature could make a challenge to publish result in this area.

There are differences in terms of understanding the expression variation itself. In the bottom-up study one company stated that they are handling variation. In reality they are referring to the deviation from the target value and not the variation in time. This indicates that there is a need for a common understanding of the term variation before being able to improve the usage in performance measurements. The respondents need to have some knowledge of the variation concept or else their answers will be more of a guessing game.

KPIs are used as a base for initiation of improvement initiatives. If variations in KPIs are not considered, the consequences could be incorrect decisions and focus on issues of less importance to the company. The financial impact of incorrect decisions is substantial. Authors have pointed out the benefits of visualising variation in this context for 90 years! Therefore it is very surprising that the implementation is still limited.

Research on control charts in the statistical area is very common, where the calculations are altered depending on its usage. There is however not mainly statistical or technical issues limiting the implementation. A challenge is to tackle the soft issues such as achieving increased cross-functional work without creating a perceived threat for the specialist. To choose as simple techniques as possible to reduce complexity in implementation without compromising the specialist's confidence in the selected option is important. The same applies for the manager. If characteristics, such as being energetic, are rewarded it can counteract the intention to introduce management principles that no actions should be made when a process is stable.

The need for a cross-functional understanding between different functions within the company, such as statisticians and managers, is therefore identified as one important area to consider. To take on this opportunity to implement visualisation of variation in strategic

measures it is necessary to involve theories from yet another area of research – change management.

The choice of KPI could certainly affect the implementation success when introducing visualisation of variation. Does it offer a possibility to visualize the existing data in a better way or is it necessary to start collecting new data? In the latter case, the implementation would certainly slow down. Therefore the result from the case studies showing that the visualisation choice often is a bar chart is good news. That means the measurement data is already organised in a way relatively easy to transfer into e.g. control charts, lowering the implementation threshold. The control chart is not necessarily the only mean to visualise variation even though the most obvious. Depending on context, knowledge etc. other solutions could apply. It is however important not to get stuck in the technical details but to use it as it is intended – as a mean to stimulate discussion, create consensus and guide to suitable actions.

Conclusion and future research

The literature review and empirical study show similar result. There are limited reported examples in the literature where variation is considered in performance measurements. The case studies confirm the theoretical result. Control charts on key performance measurements were practical non-existent at the seven investigated plants.

The examples reported however indicate that there are actual opportunities missed when not considering variation in the performance measurement system, as discussed in the introduction section. This area therefore needs further attention. The intention is to deepen the understanding of the benefits of using variation for strategic decisions and the challenges of choosing and displaying variation in a suitable way from a practitioner's point of view. Initially this is planned to be analysed by conducting a case study where variation in key performance indicators at different organizational levels is displayed using control charts.

The case studies have been performed at Swedish manufacturing companies, all with a global manufacturing footprint. To further enhance the understanding of how to use variation the study could be extended to include plants from more diverse geographical locations.

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