An empirical study of competitiveness measurement methodology: A case study of the automotive manufacturing sector

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Abstract— The automotive industry have experienced remarkable changes in competitiveness level, between the emergence of first generation vehicles and now. The paper seeks to examine the methodology applied, in analyzing firm level competitiveness, as it focuses on tier 2 components manufacturers, which supply components to tier 1 enterprises, within the automotive production value chain. Furthermore, it aims at determining the applicability, effectiveness and relevance of Key Performance Indicators (KPIs) considered in firm performance measurement. This was achieved through review of past competitiveness assessments carried out in the manufacturing sector, which informed the instrument developed for the empirical enterprise assessment. The findings from the research highlights factors, which need to be considered for industries to be competitive locally and internationally. The study considered a wide range of indicators, using a questionnaire with 21 observation themes and approximately 100 observation pointers. However, this paper shall be limited to general background, productivity, performance measurement, product development and labor relations. The methodology examined the relevance of each indicator within the context of the study, by quantifying the feedback received, against questions without responses. The questions without feedbacks which had no link with identified gaps, were tagged as extraneous, hence, inappropriate for future assessment.

Keywords—competitiveness; KPI; automotive; tier 2; OEM

I. INTRODUCTION

Improvement in organizational competitiveness, cannot easily occur without taking conscious steps for assessing their status, within a cluster of similar industries either locally or internationally. The paper presents an empirical work, based on methodology adopted by the authors, while executing competitiveness assessment of the South African tier 2 automotive component suppliers. Tier 2 automotive suppliers are those components manufacturers which supply tier 1 suppliers. They do not supply directly to Original Equipment Manufacturers (OEMs) such as Mercedes Benz, Toyota Corporation, Volkswagen Inc.; however, some have the capacity to produce directly for OEMs but are lacking in minimum level requirement such as ISO 14,001, 18,001 and TS 16,949 amongst others. As such, there is a middle level enterprise between tier 2 suppliers and OEMs, and these enterprises fall under the category referred to as tier 1 automotive suppliers. Tier 1 enterprises supply directly to OEMs within the automotive supply value chain similar to what is obtainable in the aerospace component manufacturing sector [1].

In carrying out the task, a needs assessment approach was utilized, at the early stage of the research. The method adopted was informed by literature, reviewed at the inception phase of the study. The methodology adopted was based on similar industry competitiveness assessments at both local and global levels. Needs assessment is simply a methodology for identifying gaps, opportunities and requirement for scale up [2]. It involves a systematic approach that progresses through a defined series of phases that helps recognise priorities, make organizational improvements, and rightly channel resources. Its principle is quite similar to the popularly known SWOT analysis, which deals with “Strength, Weaknesses, Opportunities and Threats”.

The study was designed to effectively cover these 6 objectives, which includes productivity, financial competitiveness, labour relations and compliance, product development, communications and performance measurement.

The study provides validated evidence on the state of tier 2 automotive component suppliers within the South African automotive industry space by measuring their competitiveness position, to identify the most suitable training interventions that will effectively address the identified gaps in the enterprises. It further presents a review of similar competitiveness assessment

conducted in the automotive industry, by considering Key Performance Indicators (KPIs) considered, based on the applied techniques.

II. LITERATURE REVIEW

Competitiveness within the manufacturing industry dates far back as the first industrial revolution; however, the term “competitiveness", came to light much later, and it goes beyond local boundaries and regions [3]. Continuous improvement in products and production processes have been on the front burner, due to need for cleaner production, thereby reducing cost. Globalization have greatly increased the expectations, higher tier companies demand from tier 2 component suppliers. Higher standards in terms of products and processes are being requested for at all levels. KPIs for competitiveness have been analyzed extensively from diverse school of thought. According to the World Economic Forum (WEF), competitiveness is described as the set of institutions, policies, and factors that determine the level of productivity of a country [4]. Productivity, which is a major factor in competitiveness, indicates the sustainability level of prosperity that can be earned by an economy [4].

According to literature, there are 12 major factors considered for measuring productivity. However, not all the factors are applicable due to other prevailing factors which are unique to each industry and environment. The key indicators mostly considered are: (1) How institutions perform (2) macro-economic environment (3) technological readiness (4) capacity to innovate by developing new products, improving business models and sustaining macro-economic stability (5) Higher education & training structure (6) State of existing infrastructures (7) Access to health and primary education (8) Good market efficiency (9) Labour market efficiency (10) Financial market inclusion and development (11) market size (12) Business sophistication.

As stated by [5], competitiveness indicators can be broadly classified as: (1) Financial indicators which include price indicators, exchange rate, Return on Investment, Return on Assets and other financial indices and (2) Non-financial competitiveness indicators such as quality measures, customer satisfaction, market share, market share growth, sales volume, sales growth, productivity, inventory, lead time, preventive maintenance, performance to schedule and utilization. In a case study of the South African automotive industry, [6] claimed that the automotive sector in developing country’s need to continuously upgrade performance, skills, and technology to remain relevant within the global automotive value chains.

The Organization for Economic Cooperation and Development (OECD) [7] bases its product indicators of relative competitiveness on export unit values of manufacturers, Unit Labour Cost (ULC) of manufacturing each product, and major economic indicators. On an international competitiveness level, average export values are widely used. This is often used to study changes in competitive positions. According to [7], average export values pose a great risk of uncertainties and subjective claims, because every exporter is assumed to use an identical pricing policy on all markets which is not the case in true perspective because of lack of comprehensive bilateral price data. Labour cost equally vary across the world due to economic dynamics prevailing to some degree in each country. For a number of homogenous products, pricing are often determined at international levels. Therefore, it is imperative to combine both labour cost and export prices.

In evaluating firm competitiveness, a two-way fixed effect model for estimation of a firm’s growth was utilized [8]. In explaining the correlation, it captured the variables that determine growth level as being a function of technology, Research and Development (R&D) expenditure from sales revenue, foreign equity participation and import of capital goods. According to [9], a related study of Korean and Malaysian automotive supplier industries reveals that automotive component suppliers compulsorily require to operate in global value chains to remain competitive. Currently, Korean and Malaysian automotive manufacturers’ competitiveness, depends largely on their alliance with foreign automobile suppliers, modularization, and national automotive policies and institutions.

III. METHODOLOGY

The competitiveness of enterprises is usually measured through an appropriate feedback mechanism. The proposed methodology was intended to derive answers to indicators which help in determining and measuring the competitiveness level of tier 2 automotive industry. It is equally designed to provide results that will guide in taking informed decision for suitable strategies capable of improving the automotive industries competitiveness level. In a bid to assess the enterprises, a suitable assessment tool was developed. This was designed to capture information on gaps and lapses within the tier 2 automotive industry of South Africa. It was also designed to identify the existing practices, which make some of them competitive. The tool was developed analytically for effective communication of KPIs. For the pilot phase of the study, the tool was tested on 15 enterprises. This was used to validate the tool, and the information gathered from the findings were important for improving future competitiveness assessments.

Each of the key observation themes were carefully selected because the processed data from the assessment, should be sufficient to adequately project the competitiveness of the tier 2 and lower tier suppliers and also to provide sufficient results for recommendation, needful in taking the study from the pilot phase to a full roll out.

In testing the tool in the enterprises, meetings were scheduled with the different company Chief Executive Officers (CEOs) and company executives and answers were provided to the questionnaires, during the meetings. Shop floor walk through with interviews of supervisors was equally conducted, to validate claims made by the business heads, which were earlier interviewed. Findings made during the factory walkthrough were filled into an observation sheet, designed for data validation.

The study was phased in a bid to achieve the set deliverables within speculated timeframe. It was structured to be implemented as indicated in figure 1 below.

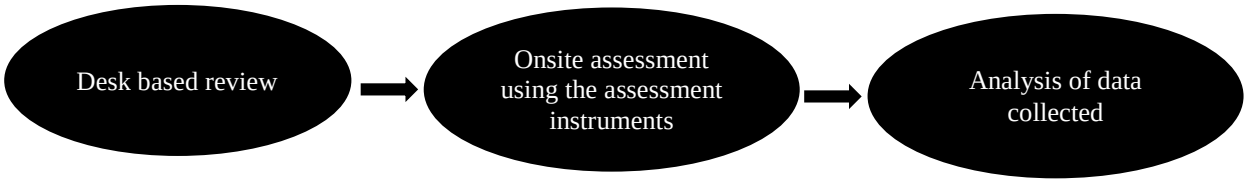

Fig. 1. Study design

This approach guaranteed identification of the most suitable methods, tools and techniques to achieve optimal results. As such, the data collection instrument for onsite feedback was methodically developed to synthesise value stream mapping, required for gap identification and future roadmap. One important aspect of the study involved examining how well tier 2 component manufacturers compete in foreign markets. This was achieved by evaluating the level of internationalisation of these firms on factors relating to size, productivity, employment, innovation and ownership ratio of local to foreign equity.

A. Question categorization

The developed questionnaire comprised a total of 73 questions, of which 54 questions were close ended and 19 questions were open ended. An observation sheet, using Likert Scale, was also prepared to aid the interpretation of the questionnaire [10] which had 21 observation themes with approximately 100 observation pointers. It was designed to acquire opinions on issues relating to productivity, labour relations, communication, cleaner production, Safety Health and Environment and quality [10].

The research is exploratory in nature hence, it had the potential of providing the opportunity to gain in-depth understanding of the challenges witnessed in various enterprises assessed. Qualitative research method can be used to analyse a well-defined business structure and examine in greater depth than would be possible in other method [11]. Equally, there was need to go a step further by adopting a quantitative research method using the Likert scale of measurement in an attempt to weigh the challenges [10] and these were coded on a cumulative bases according to the variables scored on a scale of 1 to 5 with 5 representing strong agreement and 1 representing strong disagreement.

B. Results analysis

To effectively analyse the Likert data, the items were arranged in an ordinal measurement scale using the descriptive statistical approach for ordinal measurement scale. For the Centre of Tendency measurements, the median and mode were utilized while the frequencies were observed for the variability measurements and this was achieved by analysing the variables at intervals.

The questions were structured and analyzed against selected advanced manufacturing practices and parameters. Statistically, the results were summarized based on the number of firms that responded and the weighted scores as per the questionnaire. The parameters considered include:

1) *Quality management practices and tools adopted*
2) *Productivity*
3) *Innovativeness, technology and environmental indicators*
4) *Product development and performance*
5) *Lead times (timely delivery, manufacturing, procurement, scheduling, warehousing)*
6) *Productivity improvement tools adopted*
7) *Organization structure*
8) *Human resource development, labour relations and compliance*

9) *Financial performance*
10) *Communications and consumer satisfaction*
11) *Performance measurement, growth viability*

The collected results were normalized using a Range Equalization Method (REM) because of the need for enhanced interpretation of individual response by rescaling to 1-100 % scale using the formula expressed in equation 1.

$$\text{Normalization} = \left[\frac{\text{Actual Value} - \text{Minimum Value}}{\text{Maximum Value} - \text{minimum Value}}\right] \times 100\% \qquad (1)$$

The maximum value for questions rated on scale of (1 to 5) is five (5).
The minimum value is zero (0).
The actual value is the score selected by the respondent for each question.

To evaluate the collective importance of response received from each indicator, Relative Importance Value (RIV) was used for analyzing collected data. RIV describes the level of importance of respondent's views in a survey. The individual views per question can only be measured relatively, thus an index value is adopted based on the 5 point rating scale adopted for questions and answers within the questionnaire. Relative index technique has been extensively explored and utilized in structured surveys when analyzing collected data [12] [13]. The measure RIV for each individual competitiveness indicator is obtained from the weighted average using the survey data through the following formula:

$$RIV = 100 \times \frac{\sum ax}{5N} \qquad (2)$$

X represents the frequency of the responses for a specific indicator;
a: the weighting value corresponding to a specific question (ranging from 1 to 5 as suggested in the questionnaire) where 1 is least acceptable (most unacceptable) or insignificant and 5 is extremely important (most acceptable) or critical.
N: total number of responses.

For the open ended questions, a subjective scale was developed which is intended to rate the perception of the respondent on each of the questions answered. The design of the scale largely depended on the pattern and type of answers received during the field survey. It tended more towards a two (2) point differential breakdown similar to the YES and NO questions contained in the assessment instrument. The aggregate index for each of the indicators is derived first using relevant variables (sub-indicators).

$$V_i = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad (3)$$

Where, V_i is ith indicator, x_i is the ith sub-indicator, n is the number of sub indicators within the indicators [14]. The aggregating of all the indicators into competitiveness index for a firm in the automobile industry.

$$C_j = \frac{\sum_{i=1}^{n} W_i V_i}{\sum_{i=1}^{n} W_i} \qquad (4)$$

Where, C_j is the competitiveness index of *jth* firm, Wi is weight of the ith indicator, Vi is ith indicator and n is the number of indicators.

The Likert scale of measurement is utilized in an attempt to weigh responder's opinions in a survey [15]. It is applied by coding the results on a cumulative bases according to scale of 1 to 5 with the following representations: strongly agree-5, agree-4, Indifferent (Neither agree nor disagree)-3, partially disagree-2, strongly disagree-1. To effectively analyze the Likert data, the results were arranged in an ordinal measurement scale using the descriptive statistical approach for ordinal measurement scale.

For the Centre of Tendency measurements, the median and mode was utilized while the frequencies were observed for the variability measurements and this was achieved by analyzing the variables at intervals. The likert scale items were be tested for reliability at the onset and also tested for outliers and missing data. Since most of our data were normally distributed, one tailed Grubb's Test was used to analyze the data for presence of outliers.

For the reliability test, Cronbach Alpha data analysis was carried out using Real Statistics, a data analytic tool that works seamlessly as an add-on in Microsoft Excel. Given variable $x_1, \ldots, x_k$ and $x_0 = \sum_{j=1}^{k} x_k$ and Cronbach alpha is defined to be

$$\frac{k}{k-1}\left(\frac{\sum_{i\neq j}^{k} cov(x_i,x_j)}{var(x_0)}\right) = \frac{k}{k-1}\left(1 - \frac{\sum_{j=1}^{k} var(x_j)}{var(x_0)}\right) \quad (5)$$

If $x_j = t_j + e_j$ where each e_j is independent of t_j and all the e_j are independent of each other. Also assuming $x_0 = \sum_{j=1}^{k} x_j$ and $t_0 = \sum_{j=1}^{k} t_j$, then the reliability of $x_0 \geq \alpha$ where α is Cronbach's alpha. According to [16], Cronbach's alpha coefficient should fall between 0.70 and 0.80 or higher to be acceptable.

Also needful was a need to identify correlated challenges which are useful as they can indicate a predictive relationship that can be explored while determining the level of competitiveness. Based on aggregated feedback received, single factor Analysis of Variance (ANOVA) was conducted and there was need to test the null hypothesis because it was assumed from the onset that every question is the same with null difference.

IV. OUTCOME

These section attempts to rank the relevance of questions asked, based on feedback received from the companies, during the needs assessment. Questions with low feedback which are however, identified to be related to competitiveness gaps, shall be taken as being appropriate and applicable. However, those that have no direct link with identified gaps, which also have very poor feedback, was flagged among erroneous questions which are not appropriate for this type of survey on tier 2 auto suppliers within the South African socio-economic environment. These information will guide research teams which intend embarking on similar competitiveness assessment, within the medium scale manufacturing sector, in developing nations.

A. Identified gaps from analyzed results

This section shares findings from the research, which all within the coverage of this article. After the needs assessment, the most important gaps were identified within the tier 2 enterprises examined. Based on these gaps, a baseline assessment will have to be conducted in future, to rank the companies on each of the observation teams. The baseline assessment will show the status of the companies in terms of competitiveness level, and this can be achieved by benchmarking the companies against existing industry standards. As such, areas that need improvement will be specifically addressed when an intervention is being designed.

The major findings from the research are shown below:

1) There was distinctive gap between tier 1 and tier 2 enterprises in terms of skills, productivity, continuous improvement, adherence to safety etc.
2) Little evidence of shop floor employees being empowered or engaged to take ownership of processes and therefore initiatives are not sustained
3) Low literacy levels on shop floor hindering continuous improvement initiatives.
4) No evidential structures and plans in place for long term sustainability of initiatives
5) Little evidence to show performance measurement was being tracked and passed down to the shop floor employees
6) Tier 2 enterprises are not in tune with changing technology because of little investment in Research & Development
7) Wide communication gap between management and shop floor employees and regular feedback meetings focused on business objectives are not in place
8) Company goals and objectives are not known to staff at the bottom, due to poor employee engagement
9) Poor feedback mechanism is observed across a large number of enterprises
10) The use of suggestion boxes have been largely unsuccessful for harnessing contributions
11) There are no formal problem solving processes applied within the shop floors
12) There is little evidence to show that shop floor employees are trained and expected to take ownership of processes
13) Absenteeism is a major problem observed within the organizations, which most employers' link to level of commitment of workforce, and sometimes, overwhelming socio-economic challenges especially in the home front.
14) Regular welfare awareness program not part of the organization system, only available in some companies as part of their induction process
15) Poor adherence to health and safety requirements
16) Lower literacy levels (education & competence) on shop floor, which limits roll out of continuous improvement initiatives which stimulates sustainability. Equally, skill sets are low despite average level of cross training matrix within organizations
17) Team based continuous improvement is extremely poor and lacking in most enterprises

18) Employees are not rewarded according to their performance level, as there are little or no compensations and workforce incentive schemes capable of motivating workforce to perform better
19) To some extent, there is little enforcement of cleaner production principles
20) Low confidence and trust in management's views amongst workforce at the lower levels
21) Waste minimization and resource efficiency needs to be improved upon through continuous improvement schemes
22) Industry perception shows that Foreign Direct Investments and direct financial injections are lacking in the industry because of protracted industrial actions and high energy cost
23) Business plans do not contain targets and budget allocation, for productivity improvement initiatives
24) Poorly planned maintenance mechanism
25) No formal continuous improvement systems in place
26) Little evidence of shop floor employees being empowered to take ownership of processes

B. *Analysis of feedback received*

The research method utilized involved the design of an instrument, covering themes utilized in previous industry needs assessment within all spheres of the automotive components manufacturing value change. These industry sizes includes Original Equipment Manufacturers (OEMs), tier 1 manufacturers, tier 2 manufacturers and lower tiers, such as Small, Medium and Micro Enterprises (SMMEs). On testing the instrument, it became clear that not all questions are appropriate for tier 2 manufacturers based on the feedback received. The study was designed to be fully customized for South Africa lower tier automotive industry, due to the uniqueness of the socio-economic environment, which is quite different from countries where similar assessments have been carried out. As such, tables 1 to 5 presents the synthesised results, based on the appropriateness of the assessment questions. The indicator utilized are the feedback received from the industries assessed, and the feedback eventually utilized after the assessment.

1) TABLE 1: BACKGROUND INFORMATION

Question	% feedback received	Comment
Ratio of turnover generated from local & international markets?	93.33	Appropriate/Feedback utilized
% increase and inflation in prices from suppliers?	60.0	Appropriate/Feedback not utilized
Financial trend (Upward or downward) ?	80%	Appropriate/Feedback not utilized
Years in operation?	100%	Not Appropriate/Feedback not utilized
Equity between local and foreign investment?	100%	Appropriate/Feedback not utilized
Ratio of local to international client?	80%	Appropriate/Feedback utilized
workforce education level?	93.33%	Appropriate/Feedback utilized
Ratio of fulltime to part-time employees?	93.33%	Not appropriate/ Feedback not utilized
Management system certification owned by organization?	100%	Appropriate/Feedback not utilized
Gender distribution?	100%	Appropriate/Feedback utilized
Analysis of questions: 8 were appropriate , 4 were utilized		

2) TABLE 2: PRODUCT DEVELOPMENT

Question	% feedback	Comment
Investment in R&D?	100%	Appropriate/Feedback utilized
Customer involvement in product development?	100%	Appropriate/Feedback not utilized
Approach to new product development (streamlined or multidisciplinary)?	60%	Appropriate/Feedback not utilized
Average % lead time in product development?	66.5%	Appropriate/Feedback not utilized
Analysis of questions: 4 were appropriate , 1 was utilized		

3) TABLE 3: PRODUCTIVITY

Question	% feedback	Comment
Implementation of Total Production Maintenance (TPM)?	100%	Appropriate/Feedback not utilized
Shop floor arrangement of equipment for effective processes?	100%	Appropriate/Feedback utilized
Tooling management system in place?	93.33%	Appropriate/Feedback not utilized
Control methods and change validation process?	93.33%	Appropriate/Feedback not utilized
Cleaner production systems for cost saving (8 wastes)?	100%	Appropriate/Feedback utilized
Order driven production scheduling?	80%	Not appropriate/Feedback not utilized
Contingency plan for utility interruptions, labour shortage?	93.33%	Appropriate/Feedback not utilized
Existence of change control methods?	80%	Appropriate/Feedback utilized
Risk analysis before accepting orders?	93.33%	Not appropriate/Feedback not utilized
Enterprise improvement teams?	93.33%	Appropriate/Feedback utilized
SWOT analysis for business positioning?	100%	Appropriate/Feedback not utilized
Presence of enterprise improvement teams?	100%	Appropriate/Feedback utilized
No of improvement projects within last 6 months?	60%	Appropriate/Feedback not utilized
Relevant in-house training for improvement. e.g. 5s, 7waste, Kaizen and VSM?	100%	Appropriate/Feedback utilized
Measurement system analysis?	80%	Appropriate/Feedback not utilized
ISO 9001 systems?	100%	Appropriate/Feedback utilized
monitoring/measurement of supplier performance?	93.33%	Appropriate/Feedback not utilized
Inventory management system?	100%	Appropriate/Feedback not utilized
Customer needs evaluation?	100%	Not appropriate/Feedback not utilized
Customer satisfaction survey?	100%	Appropriate/Feedback utilized
Potential customer identification?	93.33%	Not appropriate/Feedback not utilized
High level of customer retention?	100%	Appropriate/Feedback not utilized
Volume of scraps reused?	93.33%	Appropriate/Feedback utilized
Volume of wastes and postproduction scraps recycled?	93.33%	Appropriate/Feedback utilized
Analysis of questions: 20 were appropriate , 10 were utilized		

4) TABLE 4: PERFORMANCE MEASUREMENT

Question	% feedback	Comment
Overall equipment effectiveness (OEE) measurement?	53.33%	Appropriate/Feedback utilized
Tracking water use, electricity use and other utilities?	100%	Appropriate/Feedback utilized
Analysis of questions: 2 were appropriate , 2 were utilized		

5) TABLE 5: LABOUR RELATIONS

Question	% feedback	Comment
Difficulty in finding skilled labour?	100%	Appropriate/Feedback utilized
Dependence on foreign experts for equipment maintenance?	93.33%	Not appropriate/ Feedback not utilized
Level of training given to workers?	100%	Appropriate/ Feedback utilized
Fairness of wages relative to economic realities?	100%	Appropriate/ Feedback utilized
wages linked to workforce performance?	80%	Appropriate/ Feedback utilized

flexibility in hiring and firing?	93.33%	Not appropriate/ Feedback not utilized
Part of union	93.33%	Appropriate/ Feedback not utilized
Analysis of questions: 5 were appropriate , 4 were utilized		

V. DISCUSSION/CONCLUSION

The methodology adopted for identifying appropriate indicators for competitiveness of the tier 2 automotive suppliers, was based on literature and former competitiveness assessment, carried out in the manufacturing sector. Effort was made to cover as much topical areas as was possible, while the instrument was being developed. The instrument was tested in 15 companies out of the 33 tier 2 suppliers identified across South Africa, based on the inventory provided by the Automotive Supply Chain Competitiveness Initiative (ASCCI). The method employed by the authors was effective, because the gaps were identified, and areas that need to be considered for future baseline assessment were clearly seen.

The feedback received were of two types namely: (1) YES and NO responses and (2) Rated responses using scores from 1 to 5 through a likert scale. The likert scale responses were normalized to square up the results to percentages (0% minimum and 100% maximum), this strategy created a bases for proper evaluation of the cumulative responses received. The application of Cronbach Alpha data analysis helped to test the reliability of the data collected. To determine question balance, Single Analysis of Variance was needful because it was utilized to determine null hypothesis which makes it possible to predict presence of inappropriate questions in each of the 5 categories of questions outlined.

From the research findings, not all the questions were appropriate and the level of importance was seen by the feedback received during the assessment. According to table 1 to 5, questions with very low feedback were further queried using a qualitative research approach to determine the reason for low feedback. It was gathered that not all questions with high responses, were fully appropriate for this type of study; equally, some of the questions with low response were appropriate. Based on the findings, researchers interested in carrying out competitiveness assessment within the automotive industry can easily see the appropriate questions and those that were utilized in the final results.

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