

Development of a Tool for Measuring Performance of Higher Educational Institutions by Applying Six Sigma Methodology in Teaching-Learning Process

Jayamohan K. G

Division of Mechanical Engineering, School of Engineering, Cochin University of Science and Technology, Kerala, India,

Bhasi. A.B

Division of Mechanical Engineering, School of Engineering, Cochin University of Science and Technology, Kerala, India,

Abstract - The purpose of this paper is to develop a statistical tool for measuring severity in higher educational institutions' performance by applying the six sigma methodology. The performance of institutions is affected by students' performance, faculty performance and management involvement. The methodology is applied to evaluate the teaching-learning process and management involvement. The team used the measurement and analysis approach, Total Failure Mode Effects Analysis Methodology of Six Sigma, in the B.Tech programme in Mechanical Engineering. The six sigma tools and techniques could be successfully applied to develop a tool for measuring the teaching and learning process. The newly developed tool can improve the delivery of courses by the faculty. The results presented were collected from five courses of the Mechanical engineering branch. The validation of outcomes is possible by applying the concept in more courses under other departments and programmes. This paper discusses a new approach and format to measure the teaching-learning process. The measurement and feedback system will improve teaching quality and the involvement of students and sponsors.

Index Terms - Higher Educational Institution, Severity value, Six Sigma DMAIC, TFMEA.

INTRODUCTION

In recent years, India's technical higher education sector has been facing turbulence in terms of 'reducing number of applicants' at the graduate and postgraduate level because of the fastest growth rate in the number of educational institutions. Higher education institutions (HEIs) should ensure quality excellence in teaching-learning and other services to improve stakeholder satisfaction. Measurement of the teaching-learning process is an essential requirement for evaluating and improving the quality of higher education sectors. It is also needed to accelerate instructional activities by taking course reflection and feedback from primary stakeholders of HEIs like students to improve the teaching-learning process. An innovative supporting tool like the six sigma methodology can be the best choice for higher education institutions to improve the quality of service provided [1].

Measurement of the performance of higher educational institutions (HEIs) is a complex process. It depends on factors such as quality of performance of graduating students, quality

of performance of faculty, quality of teaching-learning process and availability of quality infrastructural facilities.

This paper aims to develop a simplified tool for measuring the performance of HEIs by evaluating severity in the teaching-learning process in higher education sectors with the help of the six sigma define-measure-analyse-improve-control (DMAIC) methodology. The Failure Mode Effects Analysis (FMEA) is a standard statistical tool under the 'Analyse' and 'Improve' phases of the six sigma DMAIC methodology. The tool, Total Failure Mode Effects Analysis Methodology (TFMEA), is a simplified FMEA model. The TFMEA tool is based on the concept 'score of severity'. Improvement of performances of students and faculty and active involvement of Management is needed to reduce the severity in performance of HEIs. The total score of severity is calculated by measuring severity in various factors of HEIs like student's performance, faculty performance and management involvement. The research paper tries to answer the following research question.

RQ1. How can HEIs apply the six sigma DMAIC methodology to develop a tool for measuring its performance by evaluating severity in the teaching-learning process and management commitment?

The rest sections of this paper are divided into the following sections. Section II demonstrates a review of literature on six sigma implementation in HEIs. Section III presents the methodology applied to develop statistical tools for measuring the teaching-learning process in HEIs. Section IV describes the results and analysis of the developed tool, and section V gives the concluding remarks on the statistical tool.

LITERATURE REVIEW

In this section, the authors focus on studying the application of six sigma define-measure-analyse-improve-control (DMAIC) in HEIs and existing techniques available for measuring the quality of the teaching-learning process in HEIs. The quality of the engineering education system improves the quality of engineering graduates, which produces a quality technical workforce for the nation. The five indices for quality in the context of education are; quality as exceptional, quality as fitness for purpose, quality as value for money, quality as perfection and quality as transformative [2]

The educational institutions in general and engineering educational institutions, in particular, have been attempting to adopt models that were found to be successful in industries for addressing the quality challenges of the institute [3]. Unlike

industries, educational institutions cannot control the quality of inputs like incoming students. Colleges are not getting quality students due to a drastic increase in the number of colleges [4].

Six sigma is a management business strategy that seeks to detect and eliminate causes of errors, defects in business processes by concentrating on critical outputs. It is also a measure of quality that strives to eliminate defects by applying statistical methods. A defect can be defined as anything which could lead to customer dissatisfaction. The six sigma methodology's fundamental objective is implementing a measurement-based strategy that focuses on process improvement and variation reduction. Statistically, the definition of six sigma is 3.4 defects per million opportunities.

Higher educational institutions must consider six sigma to maintain academic quality at high standards [5]. The six sigma DMAIC methodology can be utilised to solve problems that students experience during the learning process [6]. The six sigma DMAIC tool can be applied directly to improve students' performance in a particular course. The students should be involved in six sigma and other excellence initiatives for improving the quality of HEIs [7].

Understanding six sigma business strategy metrics like the cost of poor quality (COPQ), defect rates, and customer complaints is essential for implementing DMAIC methodology [8]. However, in service processes, a defect may be defined as anything which does not meet customer needs or expectations. A wrong admission procedure, lack of training required by a staff member, misbehaviour of staff members, unwillingness to help patients when they have specific queries are examples of the defect in a hospital [9]. The customers play vital roles in all six sigma initiatives [7]. The adaptation of the six sigma to the University environment can be achieved through a mix of University staff and practitioner involvement [10]. The continuous course improvement depends directly on evaluation. The continuous evaluation method can communicate between the lecturer and the students [11].

The six sigma can be applied in activities like course plan design, curriculum development, learning objectives of courses, classroom instruction, laboratory exercises, and student learning assessment to establish a good quality culture in institutions. The tool, total failure mode effects analysis (TFMEA), can be used in analyse phase of six sigma implementation in HEIs [12].

The employability and high quality in education are rated as one of the crucial key result areas of all successful higher learning institutions [13]. The deployment of six sigma in the educational services sector can enhance the academic performance of students as well as the employability of graduates [14].

The six sigma project implementation in the educational services sector depends on factors like top management commitment and Management's ability to overcome the resistance of employees against six sigma implementation [15]. However, the top Management should identify the problem according to customer feedback, strategy, mission, and vision [16].

MATERIALS AND METHODS

Setting

Based on the research type and conditions, the authors planned an action research approach to support readers to understand

the exact procedure of applying six sigma DMAIC to measure the teaching-learning process in HEIs. This research was conducted in the Mechanical engineering department of an institute of higher education offering engineering courses in the southern part of India. The action research environment involves five courses of a Mechanical engineering department. The term of study of this particular project was six months. As a lecturer of this institution, the author followed ethical guidelines and procedures in this action research. In Universities, stakeholders are students, employees, society, industry, government, media and environment. The success and failure of HEIs like engineering colleges depend directly on three major stakeholders, viz the students, faculty and Management [5].

The students can be considered as one of the main stakeholders, and they may be regarded as the customers of Universities. Feedback from the students is an essential consideration in higher education quality management [17]. The general course evaluation by feedback from students in Indian universities is conducted only at the end of the six-month term. In this research, two evaluations cum feedback sets were designed to conduct a feedback survey after the first and second internal examinations. The first feedback survey will give inputs to students and faculty for improvement. The results of the second feedback will provide additional information to students for the final examination.

The Questionnaire Instrument

To facilitate this study, three survey questionnaire tools entitled "ISEQ1(Institutional Severity Evaluation Questionnaire1), ISEQ2 and ISEQ3 were prepared by covering three essential elements of the institutional environment with a specific focus on the higher educational institutions imparting engineering education at the bachelor degree level. The bachelor of technology program students, who are pursuing their fifth semester of an 8-semester mechanical engineering program, participated in this survey and registered their objective response. In the pilot study, a total of 56 stakeholders were covered, and the completed questionnaires were returned from 33 stakeholders. Six questionnaires were discarded due to incomplete responses of the stakeholders to all the items. Respondents were given sufficient time to respond without any pressure. Throughout the study, the authors took special care to protect the anonymity of the evaluators. Table I, Table II and Table III show the ISEQ tools prepared for circulating among the stakeholders. In the ISEQ tool, a 10-point Likert scale consists of 10 questions with ten response options with severity in ascending order. The severity is denoted as SEV-value in the Table: 1=Outstanding; 2=Excellent; 3=Very good; 4=Good; 5=Above average;6=Average;7=Below average;8=Loss of goodwill;9=Untrustworthy and 10=Catastrophic. HEIs must intensely focus on activities to improve the function if a high SEV-value is obtained for that particular function. For example, the SEV-value '1'assigned to a function such as 'Performance in University examination' will indicate outstanding performance. A value of '10' will give signs of HEI's severe or pathetic situation in that function. In the latter case, the HEI must take extra effort to reduce severity value to improve students' performance in University examinations.

TABLE I
INSTITUTION SEVERITY EVALUATION QUESTIONNAIRE-ISEQ1 FOR STUDENTS

<i>Measurement of SEV-Value -Students</i> (To be filled by faculty handling the class)												
Six sigma project code:												
Roll no. of student :			Class /Semester:				Branch:					
Name of student (Optional)												
S l N o	Function											Severity(SEV)
		Outstanding	Excellent	Very good	Good	Above Average	Average	Below average	Loss of goodwill	Untrustworthy	Catastrophic	
1	Performance in University Examinations	1	2	3	4	5	6	7	8	9	10	
2	Percentage of Attendance	1	2	3	4	5	6	7	8	9	10	
2	Submission of Assignment	1	2	3	4	5	6	7	8	9	10	
3	Whether the student has an interest in academic activities	1	2	3	4	5	6	7	8	9	10	
4	Sincerity in attending classes and involving in the learning process	1	2	3	4	5	6	7	8	9	10	
5	The ability of the student to understand lectures	1	2	3	4	5	6	7	8	9	10	
6	The level of knowledge of the student in the subject	1	2	3	4	5	6	7	8	9	10	
7	The ability of the student to work in groups	1	2	3	4	5	6	7	8	9	10	
8	Innovative skills	1	2	3	4	5	6	7	8	9	10	
9	Soft skills like communication, presentation	1	2	3	4	5	6	7	8	9	10	
10	Leadership quality of the student	1	2	3	4	5	6	7	8	9	10	
The average score of severity (SEV-Value)-Students												
Measured value (%)		1-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	
Performance SEV-Value		10	9	8	7	6	5	4	3	2	1	
Attendance SEV-Value		10	9	8	7	6	5	4	3	2	1	
Assignment SEV-Value		10	9	8	7	6	5	4	3	2	1	

The students are one of the primary stakeholders of HEIs. The major factors affecting students' performance in HEIs are external and internal examinations, attendance and participation in the teaching-learning process, submission of mandatory assignments as per curriculum, student ability, and attitude towards the teaching and learning process. The ability of the student is affected by knowledge in the subject and soft

skills, and leadership. Students' attitude depends on various factors like self-motivation, involvement in studies and dedication and interest in studies. The ISEQ, as per Table I, was designed to measure the average severity value on performance and attitude of students. The overall average severity score of student performance denoted the term SEVsp.

The second major stakeholder in HEI is faculties. The factors affecting the performance of faculties in engineering educational institutions are faculty's skill, ability, and attitude. The faculty's skill depends on soft skills, presentation and use of teaching aids and subject delivery. The ability of faculty depends on the capacity to learn and the Management of courses. The attitude of faculty depends on various factors like self-motivation, involvement and dedication and interest in handling studies.[12].The overall average severity score of faculty performance was denoted by the term SEVfp. ISEQ, as per Table II, was designed to measure the average severity value on the performance of faculty

The third vital stakeholders of HEI are the sponsors. The sponsors can be government or quasi-government, or private Management. Management involvement is affected by factors like maintenance and management of assets and human resources. The attitude of Management is affected by the interest shown by the firm in infrastructural development, motivation of employees and students. The Management's ability depends on the capacity to invest and the availability of funds for future growth. The overall average severity score of Management was denoted by the term SEVmi. ISEQ, as per Table III, was designed to measure the average severity value of management involvement.

The ISEQ gave the selected institution a review of the overall academic environment practices. The tool, total failure mode effects analysis (TFMEA), was commonly utilised in analyse phase of six sigma implementation in HEIs. In TFMEA, the severity score of HEI is the product of severity values of students, faculty and Management. For a world-class institute, the total score of severity should be minimum[18]. Efforts must be taken to improve management involvement, student performance, and faculty performance to reduce the total score of severity to '1'. In this research, the overall performance of HEI was measured by calculating the Total Score of Severity (TSS).TSS is calculated as the product of SEVm, SEVfp and SEVmi. The objective of the six sigma project in HEI must be to reduce the TSS from any higher value to normal value '1'.

TABLE II
INSTITUTION SEVERITY EVALUATION QUESTIONNAIRE-ISEQ2 FOR FACULTY

<i>Measurement of SEV-Value -Faculty</i> (To be filled by students attending the classes)												
Six sigma project code:												
Name of Subject			Class /Semester:				Branch:					
Faculty code/Name of Faculty												
S l N o	Function											Severity
		Outstanding	Excellent	Very Good	Good	Above Average	Average	Below Average	Loss of goodwill	Untrustworthy	Catastrophic	
1	The level of knowledge of the faculty in the subject	1	2	3	4	5	6	7	8	9	10	
2	Experience of faculty	1	2	3	4	5	6	7	8	9	10	
3	The ability of faculty to	1	2	3	4	5	6	7	8	9	10	

	organise lectures																				
4	The clarity and understandability of explanation of subject by the faculty	1	2	3	4	5	6	7	8	9	10										

8	Behaviour of faculty	1	2	3	4	5	6	7	8	9	10											
9	Presentation and use of teaching aids like blackboards/projector	1	2	3	4	5	6	7	8	9	10											
10	The proportion of classes engaged by the teacher (Refer to Table below)	1	2	3	4	5	6	7	8	9	10											
The average score of severity (SEV-Value)-Faculty																						
	The proportion of classes (%)	10	20	30	40	50	60	70	80	90	100											
	The proportion of classes -SEV	10	9	8	7	6	5	4	3	2	10											
	No. of years	1	2	3	4	5	6	7	8	9	10											
	Teaching Experience-SEV	10	9	8	7	6	5	4	3	2	1											

TABLE III
INSTITUTION SEVERITY EVALUATION QUESTIONNAIRE-ISEQ3 FOR
MANAGEMENT INVOLVEMENT

$TSS = SEV_{mi} \times SEV_{fp} \times SEV_{sp}$ (1)
Where,
TSS=Total Score of Severity,
SEV_{mi} =Average severity score for management involvement,
SEV_{fp} = Average severity score for faculty performance,
SEV_{sp}=Average severity score for students' performance.

RESULTS AND DISCUSSIONS

This section gives insight into results obtained on evaluation and feedback based on the ISEQ survey conducted after the first internal examination. The surveys were filled out in person. Table IV shows the information about the questionnaires.

TABLE IV
INFORMATION ABOUT QUESTIONNAIRES

S/No	Subject	No. of questionnaires forms distributed	No. of stakeholders responded
1	Analysis of Management	56	33
2	Analysis of Faculty	35	18
3	Analysis of students	30	18

Results of ISEQ1

The survey was conducted by distributing ISEQ1 among faculty handling fifth-semester classes to measure the score of severity of performance of students (SEVSp). Faculties assessed the students by considering their performance in internal examinations, the attitude of submission of

Measurement of SEV-Value -Management (To be assessed by the stakeholders)												
Project code:		Type of stakeholder: (put a tick mark)										
		1. Student 2. Parent 3. Employee										
S/No	Function	Outstanding	Excellent	Very good	Good	Above Average	Average	Below Average	Loss of goodwill	Untrustworthy	Catastrophic	Severity(SEV)
1	Capacity of Management to invest	1	2	3	4	5	6	7	8	9	10	
2	Ability of Management in financial matters	1	2	3	4	5	6	7	8	9	10	
3	Interest of Management in infrastructural development	1	2	3	4	5	6	7	8	9	10	
4	Sincerity like involvement and dedication in future development	1	2	3	4	5	6	7	8	9	10	
5	Obedience of Govt. and statutory norms by the Management	1	2	3	4	5	6	7	8	9	10	
6	Maintaining quality standards in the establishment	1	2	3	4	5	6	7	8	9	10	
7	Ability in Management of Human resources	1	2	3	4	5	6	7	8	9	10	
8	Providing Salary and maintaining the welfare of employees	1	2	3	4	5	6	7	8	9	10	
9	The motivation of employees by the Management	1	2	3	4	5	6	7	8	9	10	
10	Maintenance and timely repair of Assets by the Management	1	2	3	4	5	6	7	8	9	10	
Average score of severity (SEV-Value)-Management												

5	The willingness of the faculty to help	1	2	3	4	5	6	7	8	9	10												
6	The interest of faculty in handling subjects	1	2	3	4	5	6	7	8	9	10												
7	Sincerity in terms of involvement and dedication of faculty	1	2	3	4	5	6	7	8	9	10												

assignments, sincerity in attending classes, skill, knowledge and leadership quality.

The survey analysis on student performance indicated that the factor like performance in internal examinations has a higher severity value. Hence efforts must be initiated to improve students' performance in internal examinations for reducing the severity value. Figure 1 shows the results of the survey of students' performance.

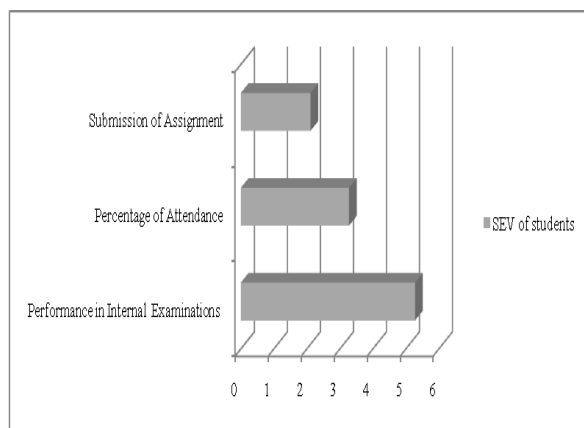


FIGURE 1 RESULTS OF ISEQ1

that for reducing severity value to improve students' performance, additional efforts must be taken by HEI to improve the attendance percentage of students in the classes and submission of mandatory assignments in time. The survey ISEQ1 helped the faculties handling fifth-semester classes to categorise students. The survey identified the areas to focus on by the students to improve their performance. The survey depicted the levels of sincerity, leadership and communication skills of students as per the assessment of their faculties.

Results of ISEQ2

The survey questionnaire ISEQ2 was distributed among fifth-semester students to measure the severity of faculty performance (SEVfp). The students assessed the performances of faculty handling subjects mathematics (F1 MATHS), advanced mechanics of solids (F2 AMOS), thermal engineering (F3 TE), fluid mechanics (F4 FM), machine tools and digital manufacturing (F5 MT) and basic electronics (F6 BE). The average severity value of faculty performance assessed by 18 students is depicted in Table V and figure 2.

The graphs found that the SEVfp of faculty, 'F2 AMOS', is slightly higher than the SEVfp of other faculties. Hence more in-depth analysis of the performance of this faculty was conducted by analysing the survey results for identifying factors for reducing SEVfp value to improve his performance.

TABLE V AVERAGE SEVERITY VALUE OF FACULTY

SL NO	FACULTY	SEVfp
1	F1 MATHS	1.417647
2	F2 AMOS	3.605882
3	F3 TE	2.017647
4	F4 FM	1.776471

5	F5 MT	2.588235
6	F6 BE	2
	SEVfp(Avg.)	2.33

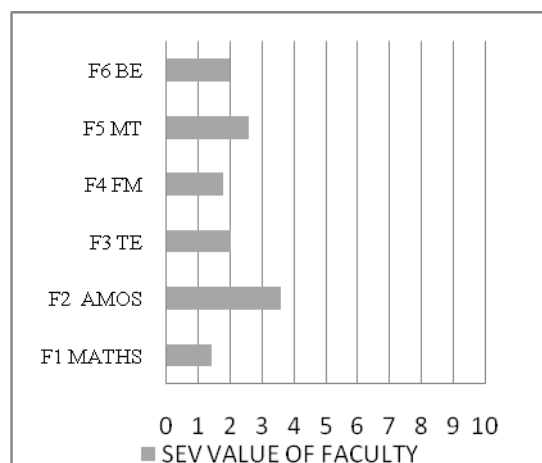


FIGURE 2 RESULTS OF ISEQ2

While referring to the factors of 'F2 AMOS', it was observed that the severity of the factor 'clarity and understandability of explanation of course contents' was too high compared to other factors like the behaviour of faculty, sincerity and proportion of classes engaged.

Hence, the ISEQ2 survey had helped the faculty, 'F2 AMOS', change his teaching style to improve factors like clarity and understandability of explanation and the organisation of lectures. Table VI presents the results of the ISEQ2 survey on faculty performance of 'F2 AMOS'

TABLE VI PERFORMANCE OF F2AMOS

S1 No	Description	SEV
1	The level of knowledge of the faculty in the subject	3.705882
2	Experience of faculty	4.823529
3	The ability of faculty to organize lectures	4.411765
4	The clarity and understandability of explanation of subject by the faculty	4.941176
5	The willingness of the faculty to help	2.882353
6	Interest of faculty in handling subjects	3.294118
7	Sincerity in terms of Involvement and dedication of faculty	2.588235
8	Behavior of faculty	2.823529
9	Presentation and use of teaching aids like blackboards/projector	3.411765

10	Proportion of classes engaged by the teacher	3.176471
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The survey questionnaire ISEQ3 was distributed among primary stakeholders of HEIs—students, faculties and parents to assess the involvement of Management in the development of HEI by various factors like the capacity to finance, sincerity and interest in institutional development and maintenance and motivation of employees. The survey on management involvement by stakeholders revealed a higher severity value (SEV mi) in almost all the factors in the questionnaire.

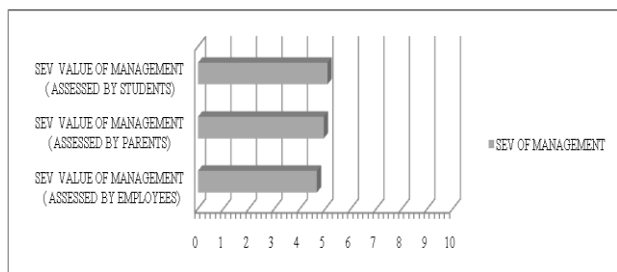


FIGURE 3
RESULTS OF ISEQ3

For reducing severity value, attention should be given to lowering complaints of stakeholders, thereby improving customer satisfaction. Figure 3 shows the results of survey ISEQ3 on management involvement as assessed by its stakeholders. The survey ISEQ3 helped the Management identify the area to be focused on improving the performance of HEIs. The Management must show more commitment to institutional and infrastructural development for reducing the severity value SEVmi, which will enhance the institutions' performance.

The average score of severity obtained by ISEQ1 was 4.67. The average score of severity obtained by ISEQ2 was 2.33 and the average score of severity obtained by ISEQ3 was 4.76. The contribution of the selected department to a total score of severity of the higher educational institution was measured to be 51.79. Hence actions must be taken to reduce the TSS value from 51.79 to '1' by considering the factors considered in the survey questionnaire for obtaining a six sigma quality in the performance of the HEI and for maximising the satisfaction of stakeholders. Table VII shows the results of severity calculations.

TABLE VII
TOTAL SCORE OF SEVERITY

Category	SEVsp (a)	SEVfp (b)	SEVmi (c)	Total score of severity(1) TSS= (a)*(b)*(c)
Fifth semester ME	4.67	2.33	4.76	51.79

The survey was conducted only at a class in the mechanical engineering department. The survey must be extended to other classes of the same department to get the department's average severity score. The survey must be extended to all other HEI branches to calculate the total score of severity of HEI.

CONCLUSIONS

The measurement of performance of complex systems like HEIs is possible with the help of statistical tools of six sigma. A simplified statistical survey tool in the form of three survey questionnaires was developed to measure the performance of HEIs by assessing severity in the teaching-learning process and management involvement. The tool was based on the TFMEA tool of six sigma DMAIC methodology. The results of surveys indicated the areas to be focussed by students, faculties for reducing the severity in their performance. The survey also helped Management to identify the place where they ensure their commitment and involvement in improving the performance of HEIs. Results of the study had helped faculties change their teaching styles to ensure stakeholder satisfaction; it is also helped the students identify the area of improvements such as communication skills and leadership quality as assessed by their faculties. The study also concludes that Management has a vital role in reducing the severity value to improve the performance of higher educational institutions. Hence Management must be more committed to ensuring their involvement in the institution. To validate the results of the survey, the tool must be applied in other classes and branches by adding various other performance factors like career guidance and placements provided by HEIs.

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