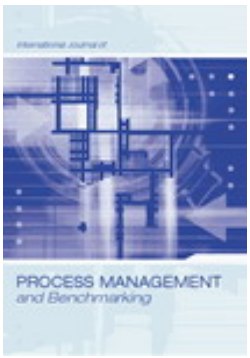

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Clustering and identifying the Lean Six Sigma projects: higher education institutes

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Clustering and identifying the Lean Six Sigma projects: higher education institutes

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Abstract: Lean Six Sigma (LSS) is an effective quality improvement program. The deployment of LSS in organisations is done with significant investment as it has many benefits. As to higher education institutes (HEIs), this system has not been applied in the manner it should be. Identifying an appropriate project requires a precise analysis of the data to make all the selected projects in line with the organisation strategy objectives, and with the least uncertainty rate in implementation. Actually, the concern is not merely the application of LSS, but also the successful implementation of the best improving project. In this study, 133 main processes were identified in the determined four zones of the University of Isfahan, and assessed using the five Lean Six Sigma indicators clustered in SPSS Clementine 12.0 S/W based on the viewpoints of the managers and professionals of the zones. 19 out of 133 processes were found critical, with higher priorities in defining the Lean Six Sigma projects. While clustering is an appropriate approach for the identification of higher education institutes, it is not possible through the common methods. Based on the evaluation of the involved managers and professionals, the proposed approach is efficient, practical, and dynamic.

Keywords: Lean Six Sigma; LSS; higher education institutes; HEIs; identifying the LSS projects; clustering.

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1 Introduction

The ability of an organisation in adjusting to the changes of market conditions and providing high quality service to the customer at low cost is no longer a distinguishing measure in the competitive market. However, such ability is transformed and limited into the ability of service provision in the global trade. Regarding process management, applying the improved cycles changed organisations' functionality, and the product improvement processes become the most important strategies in the modern trading (Haerizadeh and Sunder, 2019).

In this regard, universities have a strategic contribution in training human capital, growth, and expansion of knowledge. In the past decades, despite the increase in costs next to the decrease in their revenues, the mission of universities was to enhance the scientific growth curve to follow an ascending trend (James and Bruce, 2015). Having standard criteria is essential to evaluate the higher education quality. Improving higher education quality is not a new issue in the educational system. There exist many methods to measure and improve the quality of higher education institutes (HEIs), such as total quality management (TQM), quality function deployment (QFD), ISO 9001, lean, quality awards, etc. (James and Bruce, 2015). It is clear that the nature of the higher education system in relation to other systems is unique. The HEIs' duty is to educate participants for living, not solely money earning, which seems quite essential (Sunder, 2016). Among the quality approaches, Lean Six Sigma (LSS) as a hybrid lean philosophy is one of the latest steps in advancing the efficient quality systems. This convergence allows organisations to support and promote the analytic measures and to solve problems by providing infrastructures that focus on process improvement (Peteros and Maleyeff, 2015).

For the past two decades, the synergy of lean and Six Sigma has been a continuous improvement strategy to reduce costs, increase productivity, and increase product/service quality in organisations that are agile enough to be able to respond to the dynamic needs customers and maintain their position in the market (Mundra et al., 2021). The LSS faces the difficulty of selecting issues and projects with high priority in organisations, i.e., if the improving projects are not selected properly, they may not be suitable for the organisation's strategies and may encounter inefficiency risks.

Implementing LSS projects requires time, high investment, manpower, and accurate planning, although in some cases, LSS failed in yielding the anticipated results

(Vinodh and Swarnakar, 2015). The available assessments indicate that compared to manufacturing organisations and other service organisations that used LSS projects to improve their processes, there are generally few higher education institutions that deployed LSS. This is because their managers may be unaware of LSS or are not interested in implementing such projects due to data privacy and proposed budget constraints (Sreedharan et al., 2020). However, in recent years some universities implemented the LSS and benefited from it. Examples are Miami University that actualised significant savings in energy consumption; the pharmaceutical department of North Carolina University that adapted the Kaizen approach; Valdosta University wherein, few LSS projects were implemented; Kings College, wherein, more than 150 improvement opportunities were assessed on college infrastructure process via LSS (Sunder, 2016). Despite the limited contexts of what has so far been done, it is revealed that there is no constructive method in determining the most appropriate approach in identifying the best LSS projects (Haerizadeh and Sunder, 2019).

In general, establishing LSS in universities become an issue of the concentration of the researchers in this field, and consequently, the number of scientific articles with this subject is increasing. After considering the advantages of the LSS approach in the organisations, researchers such as James and Bruce (2015) assessed the improvement aspects of the necessities and opportunities available in universities considering four parts of learning programs: business and auxiliary services, research about admissions enrolment, management and marketing, and curriculum delivery. It challenges the improvement path by considering students as customers and assessing cultural changes.

In a case study on the university library, Sunder (2016) assessed the LSS implementation regarding the HEI promotion. It was found that applying the key performance indicators (KPIs) could provide reasonable levels in selecting appropriate LSS projects. After approving the efficiency of LSS in HEIs, Sunder and Antony (2018) introduced a perspective model containing a consecutive six-stage framework to establish LSS approach in different departments of HEIs. They developed a mental conception matrix for selecting LSS projects where the concrete criteria were not concerned. They recommended that the process adjustment must go beyond the university teaching process or the educational system and enter the university management system.

Haerizadeh and Sunder (2019) found that the efficiency and effectiveness of the established LSS led to the improvement of one of the major universities in Iran. The conceptual model introduced by Sunder and Antony (2018) applied to measure credibility. They emphasised that applying the LSS approach is promising in improving the educational system towards the defined objectives.

A five-stage approach was proposed by Duarte et al. (2012) to identify and select the LSS projects. They applied a structural supportive model in determining and prioritising the project appropriate for LSS in an IT firm. They found that clustering method could be applied in grouping similar projects in any organisation. Herku (2016) suggested five appropriate methods for identifying projects according to their difficulty and effectiveness. The methods included asking the employees and stakeholders, analysing the operational performance indicators, comparing the performance with the organisation plan, benchmarking, and down working strategic flow. According to Herku, for a better identification of the opportunities, a combination of the five mentioned methods is usually adopted.

In one of the chapters of their book, Antony et al. (2019), after expressing the importance of aligning the strategy of LSS projects as a project of continuous

improvement and the strategy of the organisation, they used Hoshin Kanri theory to identify the opportunities for project selection considering pure Six Sigma condition. According to the authors, the actions resulting from short-term goals represent opportunities for Six Sigma projects during a year. However, not all of the goals derived from Hoshin Kanri's X-matrix are suitable to be used as LSS projects, and the impact of their implementation on the organisation's strategy should be considered. Sreedharan et al. (2020), after stating the importance of implementing Six Sigma projects in leading organisations, provided suggestions for the implementation of LSS projects. They found that selecting those projects that can result in rapid cost savings can have excellent results. Al-Akel and Marian (2020) proposed a LSS algorithm with the aim of reducing the failure rate of continuous improvement projects in DMAIC standard phases and with special tools of lean and Six Sigma production. The results of their proposed algorithm were examined in a pharmaceutical company in an 18-month interval.

Identifying and selecting a LSS project is a difficult task due to the lack of a systematic and suitable method for the HEIs and because of their various natures. While the available models are too abstract in nature, the concrete and constructive criteria would meet the LSS project requirements. In this study, an attempt is made to identify the best opportunities by applying LSS approach using the clustering method in one of the universities of Iran, i.e., University of Isfahan.

2 Literature review

2.1 Lean Six Sigma

Survival is very difficult in the global market due to fierce competition from world-class and high-quality organisations (Ahuja et al., 2018). The concept of the LSS approach was first introduced by Laura Meade in 1997 (Pepper and Spedding, 2010). According to Haerizadeh and Sunder (2019), LSS is a comprehensive and flexible system applied in accessing, stabilising, and maximising the operational success in the trade closely related to the customer demand, regularity in the real data, and statistical analyses therein, making the enthusiastic sub-management to be led by the improved new trade process. The advantage of LSS compared to its similar aspects is in its applicability in overcoming the changes in the trade process, while applying the lean principles in reducing the waste in the trade, and hence, increasing customer satisfaction. Establishing the LSS approach leads to outstanding effects as to the principal mission of a trade (Hilton and Sohal, 2012).

Where LSS is well established, organisations are able to surpass their competitors in various indicators such as increasing customer satisfaction, revenue growth, providing high quality products/services, as well as increasing productivity and efficiency. Of course, not all organisations can really benefit from the implementation of Six Sigma projects. Improper attempts to deploy LSS can make it ineffective (Sreedharan et al., 2020).

2.1.1 LSS in HEIs

According to Feigenbaum, education quality is a key factor in the hidden competition worldwide formed through products and services in every country regarding the

mentality, decision making procedures, and the performance of managers, educators, economists, engineers, and the other education groups (James and Bruce, 2015). Establishing LSS in HEIs provides the opportunity to learn based on the activities. In the HEIs context, the LSS has its unique interpretation due to the ambiguity in defining the terms customer, nature of duties upon HEIs, and lack of specified definition for *faulty and successful measuring* (Quinn et al., 2009; Sunder, 2016). Consequently, the LSS approach in HEIs requires a strong aspiration with top-bottom orientation in university management as an evolutionary measure in the cultural setup (Haerizadeh and Sunder, 2019).

Implementing LSS in a university is a serious challenge, and it would be highly contributive in accomplishing organisational objectives in case of the long-term strategic planning. This issue necessitates responsive executive university management, organisational training at all levels, and significant changes in the operating locations. It is evident that local improvements do promote quality, but regarding the overall organisational efficiency, no considerable effect is evident (Sunder, 2016).

2.1.2 Identifying LSS projects

Similar to Six Sigma, the problem of selecting both the subjects and projects with higher priorities in an organisation is evident in LSS (Vinodh and Swarnakar, 2015). It indicates that not all the projects can be the candidate for LSS (Sunder, 2016). Implementing a wrong project would lead to negative outcomes, where the main organisation problems will not be solved, no serious devotion of the management would be observed, no aspiration would be exhibited as to sustainability, the time required would be doubled or tripled, more cost would be incurred, the project outcome would be low or inefficient, and finally if the organisation is lucky, the project would be nullified (Herku, 2016).

2.2 Clustering

The data and patterns constitute the most important indices in the information realm. Clustering is one of the best approaches in working with the data. Clustering is the process of organising the elements and data into groups where members are of similar features with respect to their properties in a few criteria. The clustering algorithms are of advantages which identify the non-identified credible and correct patterns in big datasets and are able to be applied for the data with non-specific structure (Duarte et al., 2012; Ahmed et al., 2015).

Clustering has two essential criteria:

1 The points in the cluster are quite similar and in a space with ‘n’ dimensions, not very distant from one another, while the two clusters must be of low similarity and the distance between them should be long.

2 Determining the similarity criteria and assessing the distance in clustering is highly essential (Duarte et al., 2012). Due to the absence of a definite clustering method, its application will be more difficult than supervised data-mining (Saxena et al., 2017).

The K-means clustering algorithm is one of the well-known and practical techniques. To determine the cluster count and the initial states in K-means, it is particularly necessary to define the cluster count K. Then, the cluster with the shortest distance from

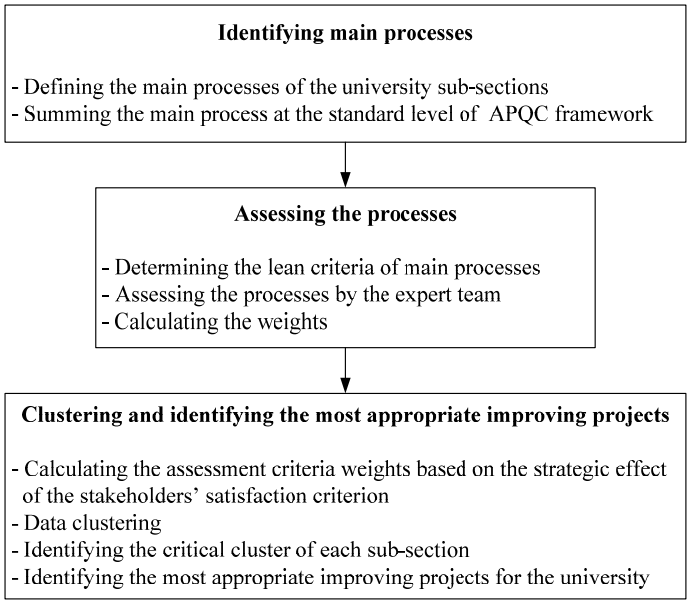
each input is determined to which the cluster is assigned. The cluster centres at each stage become updated after the inputs are added. This process is run until a change is observed in the cluster structure (Moslehi et al., 2019).

3 Research methodology

Although universities are highly contributive in training human resources in any country, few studies exist about the adopted LSS projects. University of Isfahan is one of the top universities in Iran with 15 faculties, 55 departments, and 362 disciplines. Despite the quantitative developments, its qualitative aspects in relation to internationally renowned universities require adequate promotion. With this goal, the focus is on the LSS projects in this university. This study is typically applied and qualitative in terms of purpose and is descriptive-survey in terms of data collection method. The research process is illustrated in Figure 1.

To begin with, the four zones of educational management, research and technology, student non-academic affairs, and administrative-financial sub-sections were chosen for assessment and defining improvable projects.

Figure 1 Research process



In this study, 28 professionals and managers were invited. After the expert team was formed, the main process regarding the concerned four sub-sections items was identified by completing a questionnaire. In the next step, processes were summed up according to the framework of American Productivity and Quality Center (APQC).

The outcome indicated 56 main processes in educational management, 31 main processes in research and technology, 24 main processes in administrative-financial management, and 22 main processes in student non-academic affairs. The customised

processes of the university were not published in order to observe the required confidentiality.

Table 1 The assessment criteria of the process

Assessment criterion	*Score*	*Definition*
Complexity	1	Proper standardisation of the process/lack of ambiguities in running the process
	2	Proportional standard for the process/lack or no ambiguities in running the process
	3	Standardisation of some processes/the ambiguity related to personal decisions
	4	Running the process is subject to personal decisions
	5	No standard exists in running the process
Process implementation time	1	The whole process runs in less than a working day
	2	The whole process runs in more than one day or within a week
	3	The whole process runs in a week or within a month
	4	The whole process runs in one semester
	5	The whole process requires more than a semester time
The extra activities or stages in the process	1	Lack of the extra/parallel or the reworking stage in the process
	2	Presence of one extra/parallel or reworking stage in the process
	3	Presence of two extra/parallel or reworking stages in the process
	4	Presence of three extra/parallel or reworking stages in the process
	5	Presence of more than three extra/parallel or reworking stages in the process
Available resources applied hr/Rls	1	The lowest level of resource consumption in relation to other processes in the sub-section
	2	In this process, less resources are consumed in relation to other processes in the sub-section
	3	Resource consumption of this process equals to the average of other processes in the sub-section
	4	Resource consumption of this process is more than the average of other processes in the sub-section
	5	Resource consumption in relation to other processes in the domain is very high
Process frequency (iteration)	1	The process runs within seasonal-annual time intervals
	2	The process runs once during a semester
	3	The process runs at least once a month
	4	The process runs once or more during one week
	5	The process runs on a daily basis

By resorting to available resources, the assessing of lean features, applying balance score card (BSC), and having interviews with the professionals in the administrative departments, the six criteria regarding assessing, scoring, and clustering of the process were selected. The criteria included 'complexity of process implementation', 'process implementation time', 'the extra/non-essential stages or activities in the process', 'process frequency', 'strategic effect of the process on the satisfaction of the stakeholders', and 'available resources applied hr/Rls'. Apart from the strategic effect of the process on the stakeholders' satisfaction, by which the importance of the process was expressed, such criteria used to measure the existing situation of the process. This was followed by weighing the five criteria via measuring each criterion related to the satisfaction of stakeholders by the expert team and convergence with Shannon's entropy. With the process score of each criterion, the higher value indicated the priority in allocating the improved projects. At this stage, the processes in each sub-section were scored according to the expert views based on the five Likert spectrum. The assessment criteria are defined in Table 1.

Any mistake in scoring would lead to the wrong grouping of the processes. The scoring takes place in the presence of all the managers of each sub-section. The process clustering, with respect to their features and the weighted criteria, runs through SPP Clementine 12.0 version S/W. The Davies-Bouldin index was applied to assess the obtained clusters.

4 Findings

The findings are tabulated in Tables 2, 3, 4, and 5, wherein any observed difference is due to every expert's opinion and process nature. Note that calculating the weight of criteria in this method increases the validity of the weights in data clustering. After calculating the assessment criteria and the weights in each sub-section, and balancing the main process in the four sections, clustering runs due to lean criteria in SPSS software (Clementine 12.0 S/W). The clustering results are presented in Table 6.

Table 2 Assessment of the weighted criteria in the educational management sub-section

Criteria	*Complexity*	*Time*	*Extra stages*	*Consumable resources*	*Frequency*
Shannon entropy	0.2197	0.1800	0.2654	0.1491	0.2158
Expert team opinion	0.2778	0.2778	0.2222	0.1111	0.1111
Integrated weight	0.3018	0.2061	0.2916	0.0819	0.1186

Table 3 Assessment of the weighted criteria in the administrative-financial sub-section

Criteria	*Complexity*	*Time*	*Extra stages*	*Consumable resources*	*Frequency*
Shannon entropy	0.2198	0.2174	0.2698	0.1662	0.1268
Expert team opinion	0.2381	0.2381	0.1905	0.1905	0.1428
Integrated weight	0.2550	0.2522	0.2504	0.1542	0.0882

Table 4 Assessment of the weighted criteria in the research and technology sub-section

Criteria	*Complexity*	*Time*	*Extra stages*	*Consumable resources*	*Frequency*
Shannon entropy	0.1436	0.1188	0.2800	0.0716	0.3860
Expert team opinion	0.2222	0.2222	0.2778	0.1667	0.1111
Integrated weight	0.1671	0.1383	0.4074	0.0626	0.2246

Table 5 Assessment of the weighted criteria in the student non-academic affairs sub-section

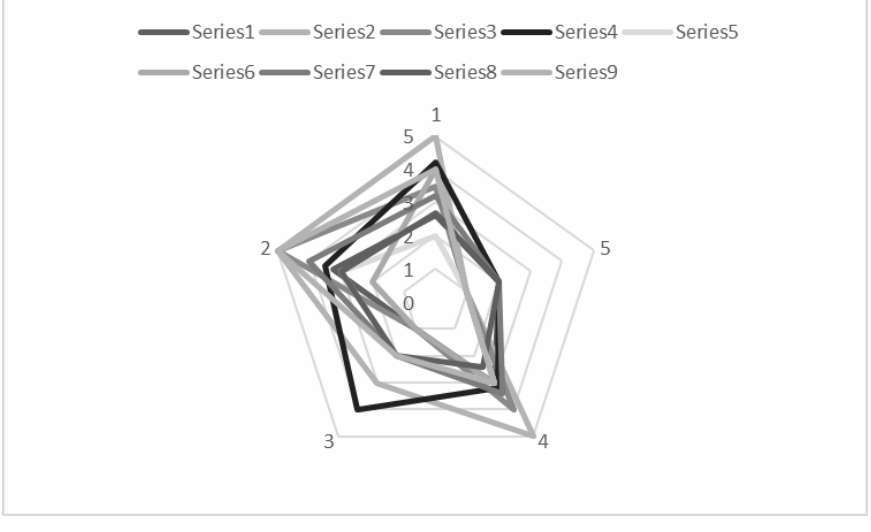
Criteria	*Complexity*	*Time*	*Extra stages*	*Consumable resources*	*Frequency*
Shannon entropy	0.1585	0.3218	0.1959	0.1876	0.1362
Expert team opinion	0.2353	0.2353	0.2941	0.0588	0.1765
Integrated weight	0.1813	0.3681	0.2801	0.0537	0.1168

Table 6 Clustering results

Zones	*Main process count*	*Optimal cluster count*	*Optimal process cluster count*	*The optimal cluster**
Educational management	56	8	8	(3.6, 4, 3.5, 3.5, 4.2)
Administrative-financial	24	6	5	(3.6, 4.8, 4.8, 4.8, 4.2)
Research and technology	31	9	5	(2, 3.5, 4, 3.2, 4.2)
Student non-academic affairs	22	7	1	(2, 3, 4, 3.5, 4)

Note: *complexity, process time, existing extra stages, resource consumption and frequency.

Figure 2 The radar diagram in the research and technology sub-section



Among the assessed criteria, the strategic effect of process is quite effective in selecting the critical cluster (e.g., the two clusters of research and technology at 1, 5, 3, 5, 5 and 2, 3.5, 4, 3.2, 4.2, respectively). Although the first cluster has the highest weight in the three criteria (due to its improvement) and the high weight (0.4074) (due to the extra stages), the second cluster with the average score of 3.442 is more critical compared to the first cluster with 3.289 average weight. The radar diagram of the research and technology sub-section clustering is illustrated in Figure 2.

According to Figure 2, the lack of an orderly method would not allow the main and critical process to be identified with the aim of determining the LSS projects, and the intervals between the process are not properly specified due to their conditions in the lean criteria. Consequently, the correct implementation of the method developed in this study can be a guide in organisational management and decision-making to promote their qualitative aspects.

It is important to note that due to the assessment of processes in different sections by the managers of each department, different judgments of managers in assessing the processes in mental criteria sometimes causes a significant difference in the coordinates of the critical cluster centre in different departments/sections. For example, consider the 'the extra activities or stages in the process' criterion weight in the four critical clusters of Table 6.

5 Discussion and conclusions

The economic competition among different countries, led to adopting and applying advanced quality management approaches with a vital and inevitable necessity and highly equipped component (Gremyr and Fonquect, 2012). Continuous process improvement is a common goal for any organisation that is motivated to create and maintain a competitive advantage in the global market. In this competitive environment, LSS acts as a strong management strategy that increases process performance, and therefore many organisations achieve quality excellence through LSS (Al-Akel and Marian, 2020).

Although the deployment of LSS in organisations is done with significant investment, it has many benefits, of which participatory leadership, continuous improvement, and employee participation are the least benefits in terms of quality excellence. Therefore, it is important to look at the deployment of LSS from a strategic point of view. Thus, the active participation of senior managers is essential for the success of LSS in any organisation, regardless of the type of industry, their nature and size (Antony et al., 2019).

Considering all components involved and by recognising the purpose and the objective of HEIs, it is necessary to apply a systematic and constructive measure to promote the process, such as the quality of education in the university environment. This requirement necessitates adopting a standard to measure the advantages and disadvantages. However, the different nature of HEIs makes it difficult to measure and evaluate them correctly.

It is assumed that the most difficult stage in this endeavour is the identification of the improved projects. Identifying an appropriate project requires the precise analysis of the data to make all the selected projects in line with the organisation strategy objectives with the least uncertainty rate in implementation. The financial and human resources as well as time, and proper scheduling are the major constitutes, though the issues that have made

LSS fail in yielding the accepted results also exist. In reality, the issue is not merely the application of LSS but also the successful implementation of the best improving project. The proper LSS project identification, due to lack of a systematic and adopted method in HEIs considering the different nature of institutions and processes is a different subject.

The available patterns are confined in the theoretical format consisting of perceptive, mental conception, and complex models, where lack of concrete and constructive criteria in proper LSS project identification is missing. An attempt was made in this study to identify the best improvement opportunities through the LSS approach, together with the clustering method in the University of Isfahan. In this context, among the 133 main processes in four zones of the university, a total of 19 critical processes were identified, which was something not applicable by the subject of university management at the beginning. Despite the apparent complexities, clustering is a dynamic and efficient approach in identifying the best project opportunities with respect to LSS projects in HEIs.

Although the results were provoking for the senior university administrators, it was very difficult to identify and decide to implement the LSS projects among the many processes of different natures in different departments without having a scientific and structured method. However, by this study, this objective was accomplished.

Because the criteria vary and their values are more than the concerned values in this study in the real applications, it is recommended to involve the factorial analysis and to select more important criteria to assess the process. In determining the weight of criteria, it is recommended to compare them with the available weighing methods and to determine the sensitivity of the LSS projects by these methods.

Considering the subjectivity of the two process assessment criteria and the different judgments of managers in different departments, a process that is known in one critical area may, in fact, be a lower priority for improvement than an unselected process in another area. It is suggested to researchers to perform further study to solve such a problem.

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