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Applying Six Sigma methodology to improve performance in organizations

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ABSTRACT

BACKGROUND AND OBJECTIVES: Six Sigma is a common methodology that has been applied successfully in many organizations leading to sustainable performance improvements in products and services. However, the applied methodologies have not paid attention to Multi-Criteria decision-making models, clustering algorithms, and Balance scorecard models. The purpose of this model is to apply the six-sigma methodology in Tehran Municipality and show how the Balance scorecard model, clustering algorithm, Analytic Hierarchy Process, and Technique for Order of Preference by Similarity to Ideal Solution can be applied in the methodology.

METHODS: Define, Measure, Analyze, Improve, and Control as a common methodology of Six Sigma is applied in Tehran Municipality. Several unique elements that exist in Tehran Municipality are identified and categorized based on the Balance scorecard model into indexes, goals, and perspectives. Also, the Analytic Hierarchy Process for weight extraction and Technique for Order of Preference by Similarity to the Ideal Solution for ranking is applied. The improvement strategies are created based on the Six Sigma tolerances.

FINDINGS: The findings show that the methodology can be elevated by a balanced scorecard, Analytic Hierarchy Process, and Technique for Order of Preference by Similarity to Ideal Solution. This formulation is done and applied in Tehran Municipality and can be used in other organizations for conducting improvement strategies. Based on the arbitrary data, the best district of Tehran city is district 9 with 89.75 percent and the worst is district 18 with a 10.12 percent score. Also, Wards and K-mean clustering algorithms and Six Sigma control limits are used to cluster the districts into superior, somehow superior, moderate, somehow inferior, and inferior clusters based on their performance.

CONCLUSION: This manuscript helps to understand the way of integrating the methodology, Balance scorecard, analytic hierarchy process, technique for order of preference by similarity to an ideal solution, and Six Sigma tolerances for sustainable improvement of Tehran Municipality. The proposed formulation can be used in any organization to reach sustainable improvement.

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
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INTRODUCTION

Quality management has long been established as an important strategy for achieving competitive advantage. It has a lot of tools to reach excellence. Statistical quality control, kaizen, Quality Function Deployment, and Six Sigma are some of the widely used tools that help organizations improve their operations (Chakrabarty and Chuan Tan, 2007). Six Sigma is a methodology that can applied to both manufacturing and services (Chakrabarty and Chuan Tan, 2007). It tries to make a process free of error (3.4 defects per million opportunities) and omit variations from the average amount of a process (Chakrabarty and Chuan Tan, 2007). Different definitions of Six Sigma are available in the literature: Six Sigma is a business strategy used to improve business profitability, and the effectiveness and efficiency of all operations to meet or exceed customer needs and expectations (Kwak and Anbari, 2006). Minitab describes Six Sigma as an information-driven methodology for reducing waste, increasing customer satisfaction, and improving processes, with a focus on financially measurable results (Goh, 2002). The root of Six Sigma is back to Frederick Gauss, who introduced the concept of a normal curve or a normal distribution (Chakrabarty and Chuan Tan, 2007). Walter Shewhart in 1992 introduced three sigma for measuring and controlling variation of a process, and he stated that if the output of a process went beyond this limit, then process intervention is needed (Chakrabarty and Chuan Tan, 2007). According to Three Sigma, a process yields 99.973 percent or a defect rate of 2,600 per. Define, Measure, Analyze, Improve, and Control (DMAIC) is a reputable methodology of Six Sigma (Chakrabarty and Chuan Tan, 2007). On the other hand, performance management is essential for each company to improve performance and achieve excellence (Tomaževič *et al.*, 2017). Organizations need an integrated model to identify opportunities and problems to help them improve their processes, achieve their goals, and make steps toward their missions and visions (Mendes *et al.*, 2012). So, the main questions here arise: How DMAIC methodology can be applied in an organization as a performance management tool? How Six Sigma control limits can be used to cluster the data? How Multi Criteria Decision Making (MCDM) techniques can be applied through the DMAIC methodology? How the Balanced Score Card (BSC) can be applied in DMAIC methodology? How BSC, MCDM, and clustering algorithms can be integrated by the DMAIC methodology to introduce a more complex methodology? A clustering algorithm can help the manager to divide obtained performance into different groups. In this way, they can easily find out the strengths and weaknesses of an organization and can conduct improvement strategies. Hierarchical clustering divides the data into some groups based on some distance ((Witten and James, 2013); (Hastie *et.al*, 2009); (Lantz, 2019)). In this method, the clusters are not specified in advance but it uses dendrograms to define the number of clusters ((Witten and James, 2013); (Hastie *et.al*, 2009); (Lantz, 2019)). A dendrogram is a tree representation plot that shows how clusters are distributed ((Witten and James, 2013); (Hastie *et.al*, 2009); (Lantz, 2019)). Agglomerative hierarchical clustering (bottom-up) and divisive hierarchical clustering (top-down) are two main hierarchical clustering algorithms ((Witten and James, 2013); (Hastie *et.al*, 2009); (Lantz, 2019)). The distance measure is used to define similarity or dissimilarity between clusters ((Witten and James, 2013); (Hastie *et.al*, 2009); (Lantz, 2019)). The Euclidean distance, the Manhattan distance, the Minkowski distance, and the Pearson sample correlation distance are the most common distance calculation methods ((Witten and James, 2013); (Hastie *et.al*, 2009); (Lantz, 2019)). Maximum or complete linkage clustering, minimum or single linkage clustering, mean or average linkage clustering, centroid linkage clustering, and Ward's minimum variance method are the most common agglomeration clustering methods ((Witten and James, 2013); (Hastie *et.al*, 2009); (Lantz, 2019)). Mostly, classifications are supervised learning but clustering is unsupervised learning methods (some clustering models are for both) (Veyssieres and Plant,1998). Clustering has descriptive goals but classification has predictive (Veyssieres and Plant,1998). Forming categories of entities and assigning individuals to the proper groups within it is the main duty of clustering methods (Veyssieres and Plant,1998). Ward's is one of the hierarchical clustering methods that compute sum-of-squares as a criterion in multivariate Euclidean space, producing groups that minimize within-group dispersion at each binary fusion (Murtagh and Legendre, 2014). K-mean partitioning is a common partitioning clustering method that uses the total error sum of squares criterion (Murtagh and Legendre, 2014). The BSC first introduced by Kaplan and Norton (1992), is a framework that divides the main activities of an organization into four main perspectives: financial, customer, internal business process, and learning and growth. BSC provides coherent links between perspectives, goals, and KPIs. On the other hand, MCDM techniques are mathematical tools that might be helpful to calculate the current performance of an organization. The Analytic Hierarchy Process (AHP), as proposed by (Saaty, 1987) which reduces complex decisions to a series of pairwise comparisons and also can extract weights of indexes is a common technique in MCDM to extract the weights. Hwang and Yoon (1981) developed a Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) for the first time. The Weighted Sum Model (WSM) which also named as Simple Additive Weighting model (SAW), the Weighted Product Model (WPM), AHP with some of its variants, the ELECTRE (Elimination and Choice Translating Reality; English translation from the French original) and the TOPSIS methods are the most common techniques in MCDM models (Triantaphyllou, 2000). Jabbarzadeh (2018) presented an application of the AHP and TOPSIS in project management for contractor selection. Esfandiari and Rizvandi (2014) presented an empirical investigation to rank different business development strategies for information technology improvement based on the TOPSIS method. Wang *et al.* (2009) proposed fuzzy hierarchical TOPSIS for supplier selection. Wang and Chang (2007) proposed an application of TOPSIS in evaluating initial training aircraft under a fuzzy environment. Lin *et al.* (2008) proposed AHP and TOPSIS approaches in the customer-driven product design process. Chu (2002) proposed a fuzzy TOPSIS approach for selecting plant locations. Behzadian *et al.* (2012) surveyed TOPSIS applications. Meshram *et al.* (2020) presented the application of simple additive weights and TOPSIS in prioritizing watersheds. Afshari *et al.* (2010) presented a simple additive weighting approach to the personnel selection problem. Sahir *et al.* (2017) used a simple additive weighting method to determine the employee salary increase rate. Kaliszewski and Podkopaev (2016) introduced a Meta-model for multiple criteria decision analysis methods and proposed a framework for interpretations of rankings they produce by using simple additive weighting. Nurmalini and Rahim (2017) studied the approach of simple additive weighting for a decision support system. Chou *et al.* (2008) presented a fuzzy simple additive weighting system under group decision-making for facility location selection with objective/subjective attributes. Al-Harbi (2001) used an analytical hierarchy process to prioritize contractors of a project and select the best one to perform the project. Handfield *et al.* (2002) used the analytical hierarchy process and environmental criteria for supplier assessment. Partovi *et al.* (1990) showed the application of the analytical hierarchy process in different operation management areas like forecasting, supplier selection, facility location, choice of technology, product design, plant layout, maintenance frequency selection, and choice of logistic carrier. Palcic and Lalic (2009) used an analytical hierarchy process for selecting and evaluating projects. Fong and Choi (2000) used an analytical hierarchy process for contractor selection. Araujo *et al.* (2018) applied a two-stage approach of TOPSIS in public hospitals in 92 Rio de Janeiro municipalities. Mirfakhredini *et al.* (2013) proposed a model to assess the performance of sports organizations with BSC and TOPSIS. Azar *et al.* (2011) presented an integrated model with the BSC framework for supplier selection strategy. Kumar *et al.* (2020) prioritized attributes for successfully implementing agile manufacturing using a combined AHP and TOPSIS approach in the Indian manufacturing industry. Sehhat *et al.* (2015) have developed an evaluation model considering the indicators identified, in assessing seven insurance companies in the ranking and weighting of these criteria and companies, the AHP and TOPSIS techniques have been used. Yadav *et al.* (2018) used fuzzy AHP and TOPSIS for prioritizing solutions for Lean Six Sigma. Rathi *et al.* (2015) applied fuzzy TOPSIS for Six Sigma project selection in the automobile industry. Table 1 compares this study to the related literature.

Brilliant results can be obtained by aggregating quality management, strategic management, clustering algorithms, and MCDM models. DMAIC, a reputable methodology of Six Sigma, is a powerful tool for quality management. BSC is a significant tool for performance improvement in strategic management. AHP and TOPSIS both are widely used techniques of MCDM. K-mean and Wards are two

Table 1: Comparison of literature by study

Sources	Clustering algorithm	Six Sigma	BSC	TOPSIS/FTOPSIS	AHP/FAHP
Fong and Choi (2000)					✓
Al-Harbi (2001)					✓
Chu (2002)				✓	
Handfield *et al.* (2002)					✓
Palcic and Lalic (2009)			✓	✓	✓
Azar *et al.* (2011)					✓
Mirfakhredini *et al.* (2013)			✓	✓	
Esfandiari and Rizvandi (2014)				✓	✓
Sehhat *et al.* (2015)				✓	✓
Rathi *et al.* (2015)		✓		✓	
Araujo *et al.* (2018)				✓	
Jabbarzadeh (2018)				✓	✓
Yadav *et al.* (2018)		✓		✓	✓
Kumar *et al.* (2020)				✓	✓
This Study	✓	✓	✓	✓	✓

prominent clustering algorithms. To our knowledge, no study shows how DMAIC methodology can be integrated by BSC, AHP, and TOPSIS. So, this study has formulated the integration and shown how this can help organizations to conduct their improvement strategies more efficiently. Also, a clustering algorithm based on Six Sigma control limits is defined. Five performance clusters: superior, somehow superior, moderate, somehow inferior, and inferior are defined by Six Sigma control limits to categorize the districts. Finally, the proposed integration has been implemented at offices of plan monitoring, project control, and performance evaluation in planning, human capital development, and council affairs department at Tehran Municipality. The current study has been carried out in offices of plan monitoring, project control, and performance evaluation in planning, human capital development, and council affairs department at Tehran Municipality in Tehran in 2023.

MATERIALS AND METHODS

DMAIC methodology a well-known methodology of Six Sigma is applied. BSC is used to make a better and more hierarchical definition of indexes, goals, and perspectives. The weights of elements are calculated by AHP and TOPSIS is used to compute the rank of the districts in each element. In the define phase. A comprehensive explanation of the problem is necessary, and it is recommended to convene the deputies' agents to collectively identify the issue. The employment of BSC aids in elucidating the problem, and it is imperative to consider all the processes, inputs, outputs, outcomes, and associated impacts. It is imperative to establish clarity on the aspects of what to measure, how to measure, and the measurement system. The district's defined indexes, goals, perceptions, and final scores must be measured to ensure accurate evaluation. The AHP is utilized to determine the weights of the elements, while the TOPSIS is employed for the score calculation process. AHP involves a pairwise comparison matrix, where the criteria are compared using Saaty's 1-9 scale of pairwise comparisons (Saaty, 1987), as presented in Table 2.

All the criteria are given a score according to the comparison table in a pairwise comparison. The vector of weights $(W_1,..,W_n)$ related to A can be extracted by normalization of the geometric mean method. Let W_i denotes the weight of the element i in matrix A, Eq. 1 represents the geometric mean (Saaty, 1987):

Table 2: The scale of pairwise comparisons

Degree of Importance	Definition	Explanation
1	Equal importance	Two criteria have equal importance according to the objective.
2	Weak or slight	According to the objective, the first criterion has weak or slight importance to the second criterion.
3	Moderate importance	The first criterion has moderate importance to the second criterion according to the objective.
4	Moderate plus	Between 3 and 5
5	Strong importance	The first criterion has strong importance to the second criterion according to the objective.
6	Strong plus	Between 5 and 7
7	Very strong	The first criterion has very strong importance to the second criterion according to the objective.
8	Very, very strong	The first criterion is very important to the second criterion according to the objective.
9	Extreme importance	The first criterion has extremely strong importance to the second criterion according to the objective.

Table 3: Consistency ratio

Matrix size	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

$$W_i = \frac{\left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}}}, \quad i,j=1,\ldots,n. \tag{1}$$

Imagine C is an n-dimensional column vector describing the sum of the weighted values for the importance degrees of elements in A matrix, then: $C=[c_i]_{n*1}=A.W^T,\ i=1,\ldots,n$. The consistency value can be represented by $CV=[cv_i]_{1*n}$ where $cv_i=\frac{c_i}{w_i},\ i=1,\ldots,n$. The inconsistency index to evaluate the effectiveness of measurements can be calculated. Saaty (1987) proposed the maximum eigenvalue γ_{max} b: $\gamma_{max}=\frac{\sum_{i=1}^{n}cv_i}{n}, i=1,\ldots,n$. With the maximal eigenvalue γ_{max}, a Consistency Index (CI) can then be determined by: $CI=\frac{\gamma_{max}-n}{n-1}$ then a Consistency Ratio (CR) is defined by: $CR=\frac{CI}{RI}$. Table 3 shows the average amount of Random Index (RI) with the value obtained by different orders of the pair-wise comparison matrices. If the CR has a value below 0.1 then the matrix is considered consistent, the evaluation is rational and the weights are valid. In the case of CR>0.10, the judgments should be reviewed and improved.

TOPSIS can be used the obtained weighs to compute the ranking. TOPSIS calculates geometric distance of the alternatives from their positive ideal solution and negative ideal solution and chose the best alternative based on the shortest distance from the positive ideal solution and longest distance from the negative ideal solution. After criteria selection and weights extraction, decision matrix can be shown as ($D=[x_{ij}]_{mn}$) in which rows ($i=1,,m$) show alternatives and columns ($j=1,,n$) show criteria and each alternative give a score in each criterion named by x_{ij}. TOPSIS uses vector normalization by Eq. 2 (Hwang and Yoon, 1981).

$$R_{ij}=\frac{x_{ij}}{\sqrt{\sum_{i=1}^{m}x_{ij}^{2}}} \quad \forall i=1,,m \text{ and } \forall j=1,,n \tag{2}$$

By multiplying each normalized value R_{ij} to its corresponding weight W_j to calculate weighted normalized matrix is obtained by Eq. 3 (Hwang and Yoon, 1981).

$$V_{ij}=W_jR_{ij} \tag{3}$$

The positive ideal solution, maximum value of alternatives in each attribute, $(V^+=V_1^+,V_2^+,\ldots,V_n^+)$ and the negative ideal solution, minimum value of alternatives in each attribute $(V^-=V_1^-,V_2^-,\ldots,V_n^-)$

can be constructed. The separation measure can be calculated by Eq. 4 and Eq. 5 (Hwang and Yoon, 1981).

$$S_i^+ = \sqrt{\sum_{j=1}^{n}\left(V_{ij} - V_j^*\right)^2} \quad \forall i = 1,,,n \tag{4}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n}\left(V_{ij} - V_j^-\right)^2} \quad \forall i = 1,,,n \tag{5}$$

The relative closeness to the ideal solution is calculated by Eq. 6 (Hwang and Yoon, 1981).

$$C_i^+ = \frac{S_i^-}{S_i^+ + S_i^-} \quad \forall i = 1,,,n \tag{6}$$

The final ranking is achieved and can be used for future actions. According to the DMAIC methodology, the obtained results should be analyzed and improvement strategies should be conducted and implemented. Then the implementations should be controlled. The designed action plan should be implemented and monitored. If the implementation is not according to the plan, some corrective actions will be defined and implemented to reach the improvement goals.

RESULTS AND DISCUSSION

The fact that DMAIC is a well-known methodology, can help Tehran Municipality to make a better situation for the citizens. So, the proposed method is applied in Tehran Municipality. Tehran City is divided into 22 districts. Tehran Municipality has got 8 deputies who monitor the performance of the districts. Human capital development, project control, budgeting, and coordination of the municipality with the city council are done by the deputy of planning, human capital development, performance monitoring and assessment, and council affairs. Identifying and collecting income and economic issues are related to the deputy of finance and urban economics. All the districts should be coordinated by the Tehran Municipality and have proper performance so, the deputy of coordination and affairs monitor the coordination. City construction and technical planning are done by the deputy of Technical and construction. Public transportation and traffic safety issues are related to the deputy of Traffic transportation. Women's affairs, citizenship training, general directorate of health, general directorate of urban planning and development, and social and cultural developments are done by the deputy of social and cultural affairs. The deputy of urban services and environment has the following duties: general directorate of urban and development of urban services affairs and development of environment and general direction of municipal services. The general directorate of privacy, general directorate of regulations, supervision and licensing, general directorate of architecture and building, secure historical monuments of Tehran, and development of urban planning and architecture affairs are done by the deputy of urban planning and architecture. The performance of the districts should be monitored and improved to obtain sustainable improvement. DMAIC methodology that is elevated by BSC, AHP, TOPSIS, and clustering algorithms is applied to Tehran Municipality. Six sigma experts of each deputy are gathered together to define proper measures and design the BSC of Tehran Municipality. Outcome measures (lagging indicators) as objectives and performance drivers (leading indicators) as sub–measures of these outcomes are the essential points that should be considered in a proper BSC. Performance drivers and outcome measures help organizations implement selected strategies, improve operations, obtain financial goals, and achieve proper outcomes. KPIs are the performance drivers that are used to measure the level of achievement of the outcome measures (objectives). The proposed BSC is composed of 4 separate, 3 hierarchy levels. Each level represents an important perspective of a Tehran Municipality and inside the perspective, related goals and measures of the perspective are presented. The 4 perspectives are as follows:

- Learning and growth,
- Internal processes,
- Urban development,
- Financial

Each perspective has a strategic goal and some objectives. Each objective can be calculated by some KPIs. So, as a hierarchical performance assessment system, top-level or level one is considered strategic goals, level two has consisted of outcomes as objectives, and the third level is composed of performance drivers as KPIs. Therefore as a hierarchical performance assessment system (Goal,

Table 4: BCS for Tehran Municipality

Perception	Strategic goal		Objective goals	
Financial	Reaching financial growth	KPI	Increase Municipality income Increase productivity Increase municipal incomes Entrepreneurship	Reduce cost Reduce operational costs Control wages Minimize usage cost of public facilities
Urban development	Develop city's structures and infrastructures	KPI	Increase clean transportation Decrease price of bicycle Increase green public transportation Upgrade transportation equipment	Increase city resilience create and maintain safeguards for citizens Social stability Minimal vulnerability of citizens
Internal processes	Achieving matured processes	KPI	Strengthening internal control Promote state supervision Drawing process flow charts Drawing organization functional charts	Reaching an excellent level of operation Upgrade internal equipment's Level of Funds Employed Staff training
Learning and growth	Increase efficiency of employees	KPI	Increase knowledge of employees Access to Information/Knowledge Increase workshops Increase seminars Increase educational classes	Increase motivation of employees Moral Award Prize money Self-Motivation Evaluation

objectives, KPIs) at first, four separate perspectives are defined with the help of BSC and then are customized for Tehran Municipality. Then strategic goal of each perspective is defined, some related outcomes as objectives for each perspective are defined and in the next step, performance measures for the defined objects are defined.

Perspective: Learning and growth

• Strategic goal: Increase efficiency of employees

• Objective goals:

• Increase knowledge of employees

• Increase the motivation of employees

Perspective: Internal processes

• Strategic goal: Achieving matured processes

• Objective goals:

• Strengthening internal control

• Reaching an excellent level of operation

Perspective: Urban development

• Strategic goal: Develop city's structures and infrastructures

• Objective goals:

• Increase clean transportation

• Increase city resilience

Perspective: Financial

• Strategic goal: Reaching financial growth

• Objective goals:

• Increase Municipality income

• Reduce cost

Table 4 shows the BCS for Tehran Municipality.

AHP is used to calculate the weights of elements on BSC for each distinct and TOPSIS is applied to compute the rank and score of each distinct in each element. Concerning security issues, no real data has been used. Tables 5 and 6 show the weight, score, and rank for an imaginary district by arbitrary data and Table 7 shows the final ranking.

Discussion

If managers can divide their activities based on different KPIs into different groups, they might be able to improve the situation of the organization efficiently. For this purpose, clustering techniques are the most appropriate methods. They can help managers to better understand their current situations, strengths, and weaknesses and conduct the right strategies for each group to attain sustainable improvement. Wards and K-mean algorithms, as two prominent clustering algorithms, with the help of Statistical Package for the Social Sciences (SPSS) are used here for cluster analysis. The number of clusters is equal to 5. Inferior (I), Somewhat Inferior (SI), Moderate (M), Somewhat Superior (SS) and Superior (S) are the names of the clusters. Each district can be put on a cluster based on its performance score. Table 8 shows the results.

Clustering algorithms try to minimize within-group variances and maximize between-group

Table 5: Weights of indexes for a district

Perception	Weights		Objective goals	Weights	Objective goals	Weights
Financial	25 percent (%)	KPI	Increase Municipality income	70%	Reduce cost	30%
			Increase productivity	20%	Reduce operational costs	30%
			Increase municipal incomes	40%	Control wages	50%
			Entrepreneurship	40%	Minimize usage cost of public facilities	20%
Urban development	20%	KPI	Increase clean transportation	20%	Increase city resilience	80%
			Decrease price of bicycle	15%	create and maintain safeguards for citizens	25%
			Increase green public transportation	35%	Social stability	45%
			Upgrade transportation equipment	50%	Minimal vulnerability of citizens	30%
Internal processes	35%	KPI	Strengthening internal control	45%	Reaching an excellent level of operation	55%
			Promote state supervision	10%	Upgrade internal equipment's	10%
			Drawing process flow charts	40%	Level of Funds Employed	45%
			Drawing organization functional charts	50%	Staff training	45%
Learning and growth	20%	KPI	Increase knowledge of employees	40%	Increase motivation of employees	60%
			Access to Information/Knowledge	60%	Moral Award	5%
			Increase workshops	20%	Prize money	20%
			Increase seminars	10%	Self-Motivation	45%
			Increase educational classes	10%	Evaluation	30%

Table 6: Performance and rank for a district

Perception	Rank (score)	Objective goals	Rank (score)	Objective goals	Rank (score)
Financial	15 (35%)	Increase Municipality income	12 (50%)	Reduce cost	17 (41%)
		Increase productivity	15 (30%)	Reduce operational costs	18 (25%)
		Increase municipal incomes	18 (19%)	Control wages	20 (19%)
		Entrepreneurship	17 (35%)	Minimize usage cost of public facilities	12 (52%)
Urban development	10 (50%)	Increase clean transportation	9 (55%)	Increase city resilience	12 (50%)
		Decrease the price of bicycle	8 (50%)	Create and maintain safeguards for citizens	15 (32%)
		Increase green public transportation	5 (75%)	Social stability	10 (57%)
		Upgrade transportation equipment	10 (59%)	Minimal vulnerability of citizens	3 (85%)
Internal processes	3 (85%)	Strengthening internal control	1 (90%)	Reaching an excellent level of operation	5 (70%)
		Promote state supervision	1 (75%)	Upgrade internal equipment	1 (87%)
		Drawing process flow charts	5 (79%)	Level of Funds Employed	2 (85%)
		Drawing organization functional charts	3 (89%)	Staff training	7 (50%)
Learning and growth	22 (5%)	Increase knowledge of employees	21 (8%)	Increase the motivation of employees	22 (4%)
		Access to Information/Knowledge	15 (25%)	Moral Award	22 (3%)
		Increase workshops	18 (30%)	Prize money	21 (7%)
		Increase seminars	19 (4%)	Self-Motivation	19 (12%)
		Increase educational classes	20 (7%)	Evaluation	18 (5%)

variances. Finding clusters with meaningful groups embedded is a critical issue in clustering algorithms. Now, a criterion is needed to choose the proper and meaningful clustering algorithm. An expert's idea is used here. Concerning Table 8, the expert's perceptions of the performance of the districts are not

Table 7: Final rank of the districts

District	Score	Rank
District 9	89.75%	1
District 16	76.36%	2
District 8	74.52%	3
District 13	69.45%	4
District 7	63.09%	5
District 17	53.04%	6
District 14	53.04%	7
District 4	51.62%	8
District 20	51.38%	9
District 6	51.02%	10
District 5	50.92%	11
District 3	50.19%	12
District 21	46.85%	13
District 15	46.26%	14
District 2	43.73%	15
District 19	43.63%	16
District 11	41.57%	17
District 12	36.92%	18
District 10	34.19%	19
District 22	30.43%	20
District 1	14.15%	21
District 18	10.12%	22

aligned with the results of the clustering algorithms. So, they might want another clustering of the data. Six Sigma defines upper and lower control limits that might be used as a clustering algorithm. Here, those limits are adopted to define some clusters as follows:

Imaging is μ the average of the final scores and σ is their standard deviation. By applying Six Sigma as a clustering algorithm following clusters are proposed: If the performance of a district is between [$\mu-\sigma$, $\mu+\sigma$) so, it has the same performance in comparison with other districts. If the performance of a district is between [$\mu+\sigma$, $\mu+2\sigma$) so, it has a somewhat superior performance in comparison with other districts. If the performance of a district is between [$\mu+3\sigma,+\infty$) so, it has a superior performance in comparison with other districts. If the performance of a district is between [$\mu-2\sigma$, $\mu-\sigma$) so, it has a somewhat inferior performance in comparison with other districts. If the performance of a district is between ($-\infty$, $\mu-2\sigma$) so, it has inferior performance in comparison with other districts. By applying the six-sigma clustering method to the final scores of districts, 3 clusters are composed. Therefore, the K-mean and Wards algorithm by 3 clusters is applied to the data. Table 9 shows the comparison of the results. According to the table, district 7 puts on a Moderate cluster by the Six Sigma algorithm, but it puts on a Somewhat Superior cluster by K-mean and Wards. Also, district 22 puts on the Somewhat Inferior cluster by the Six Sigma algorithm, but it puts on the Inferior cluster by K-mean and Wards.

According to the expert's idea, achieved clusters

Table 8: K-man and Wards clustering (5 clusters)

District	score	K-mean (5 clusters)	Wards (5 clusters)
District 9	0.8975	S	S
District 16	0.7636	SS	S
District 8	0.7452	SS	S
District 13	0.6945	SS	S
District 7	0.6309	SS	S
District 17	0.5304	M	SS
District 14	0.5304	M	SS
District 4	0.5162	M	SS
District 20	0.5138	M	SS
District 6	0.5102	M	M
District 5	0.5092	M	M
District 3	0.5019	M	M
District 21	0.4685	M	SI
District 15	0.4626	M	SI
District 2	0.4373	SI	SI
District 19	0.4363	SI	SI
District 11	0.4157	SI	SI
District 12	0.3692	SI	SI
District 10	0.3419	SI	SI
District 22	0.3043	SI	SI
District 1	0.1415	I	I
District 18	0.1012	I	I

by six sigma limits were accepted for the improvement phase. By regarding the weighted standard score of the indexes of each district, improvement priority can be obtained. Then, the roots of the low score should be found to be used in the improvement phase. All the districts are sorted according to their final TOPSIS score and the following thresholds are used to classify their performance: According to the thresholds, no district has the superior performance. 4 districts have somehow superior performance. 15 districts put on moderate performance cluster. 3 districts have somehow inferior performance. Roots of the low score of each district in the perspectives, goals, and indexes should be found. Then an action plan for each district should be defined. For instance, imagine that district one has got a low mark in staff training, therefor probably some high-quality courses should be defined and executed for the staff to promote their capability to reach to excellent level of operation. As another example, imagine district two has got a very low mark in clean transportation goal and the main reason for the score is the price of bicycles, therefore the mayor should find a way to solve the problem maybe by renting bicycles to the citizens or distributing some low-price bicycles. It is worth noting that cost and benefit analysis should be done in this step and some improvement projects that are not feasible should be omitted. A lot of corrective actions have been defined in the improvement phase. So, the actions should be done and controlled to make progress and improvement for the city. Some new indexes or goals can be defined here to control the improvement of the district. The owner of each corrective action by the related duration, start and

Table 9: Six sigma, K-man, and Wards clustering (3 clusters)

District	score	Sig Sigma	K-mean (3cluster)	Wards (3 cluster)
District 9	0.8975	SS	SS	SS
District 16	0.7636	SS	SS	SS
District 8	0.7452	SS	SS	SS
District 13	0.6945	SS	SS	SS
District 7	0.6309	M	SS	SS
District 17	0.5304	M	M	M
District 14	0.5304	M	M	M
District 4	0.5162	M	M	M
District 20	0.5138	M	M	M
District 6	0.5102	M	M	M
District 5	0.5092	M	M	M
District 3	0.5019	M	M	M
District 21	0.4685	M	M	M
District 15	0.4626	M	M	M
District 2	0.4373	M	M	M
District 19	0.4363	M	M	M
District 11	0.4157	M	M	M
District 12	0.3692	M	M	M
District 10	0.3419	M	M	M
District 22	0.3043	SI	M	M
District 1	0.1415	SI	SI	SI
District 18	0.1012	SI	SI	SI

finish time and proper budget should be clarified. On the other hand, Choosing the right MCDM technique is a vital decision in ranking and improvement strategy making. TOPSIS is one of the most prevalent technique in MCDM. TOPSIS use vector normalization to normalize the scores. Linear scale transformation (sum), linear scale transformation (max), linear scale transformation (max-min), and also standardization to standardize the data are other ways that can be used to normalize the data and rank the distinct. Linear scale transformation (sum) use $a_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}$ to normalize the data, linear scale transformation (max) as: $a_{ij} = \frac{x_{ij}}{x_j^{max}}$ for benefit attribute and $a_{ij} = 1 - \frac{x_{ij}}{x_j^{max}}$ for cost attribute as x_j^{max} is the maximum performance rating among alternatives for the jth attribute; linear scale transformation (max-min) as $a_{ij} = \frac{x_{ij} - x_j^{min}}{x_j^{max} - x_j^{min}}$ for benefit attribute and $a_{ij} = \frac{x_j^{max} - x_{ij}}{x_j^{max} - x_j^{min}}$ for cost attribute as x_j^{min} is the minimum performance rating among alternatives for the jth attribute, standardization use mean (μ) and standard division (σ) of data by the following formula $a_{ij} = \frac{x_{ij} - \mu}{\delta}$ to make the data dimensionless and comparable. Simple Weighted Method (SWM) is another well-known MCDM technique. SWM calulates the score of each alternative by the following formula $fo\ all\ i = 1,,,m$ by $A_{i-score} = \sum_{j=1}^{n} W_j a_{ij}$ and ranks the alternatives according to the heights score. This section compares TOPSIS and SWM ranking to find out the best technique for an imaginary problem. Table 10 presents imaginary data for the district in four aspects.

Tables 11 and 12 present the results of SWM and TOPSIS techniques by different normalization and standardization methods.

10 different solutions now are available and the main question here arises which one should be

Table 10: Imaginary data for the district in four aspects

Aspects	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Financial	48	25	12	87	46	55	4	24	12	96	21	42	90	97	40	34	46	47	58	18	23	22
Urban development	17	37	10	25	22	22	28	52	65	27	28	60	51	98	55	61	66	36	87	51	54	90
Internal processes	57	53	99	32	95	99	89	53	57	66	70	55	82	19	48	46	19	19	10	7	24	8
Learning and growth	67	13	62	62	7	14	2	69	61	19	79	61	63	78	31	81	39	86	47	76	80	64

Table 11: Results of TOPSIS technique by different normalization and standardization methods

	Vector Normalization		Standardization $a_{ij}=\frac{x_{ij}-\mu}{\delta}$		Linear Scale Transformation (Sum) $a_{ij}=\frac{x_{ij}}{\sum_{i=1}^{m}x_{ij}}$		linear Scale Transformation (Max)as: $a_{ij}=\frac{x_{ij}}{x_j^{max}}$		Linear Scale Transformation (Max-Min) as: $a_{ij}=\frac{x_{ij}-x_j^{min}}{x_j^{max}-x_j^{min}}$	
Districts	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1	0.27	10	0.47	9	0.47	8	0.49	7	0.48	7
2	0.08	21	0.23	21	0.23	20	0.22	21	0.22	21
3	0.16	20	0.26	20	0.23	21	0.28	20	0.27	20
4	0.64	4	0.70	3	0.74	3	0.73	3	0.72	3
5	0.21	16	0.37	16	0.39	13	0.37	17	0.37	16
6	0.28	7	0.44	11	0.47	7	0.44	11	0.44	11
7	0.07	22	0.09	22	0.09	22	0.09	22	0.09	22
8	0.20	17	0.37	15	0.33	16	0.38	15	0.38	15
9	0.19	18	0.32	19	0.27	19	0.32	19	0.32	19
10	0.67	3	0.66	4	0.71	4	0.66	4	0.66	4
11	0.22	14	0.35	18	0.31	17	0.37	16	0.36	17
12	0.25	12	0.48	7	0.46	10	0.48	8	0.48	8
13	0.71	2	0.79	2	0.81	2	0.80	2	0.79	2
14	0.91	1	0.93	1	0.93	1	0.92	1	0.92	1
15	0.19	19	0.40	13	0.40	12	0.39	14	0.40	14
16	0.28	9	0.46	10	0.43	11	0.47	9	0.47	10
17	0.25	11	0.47	8	0.47	9	0.47	10	0.47	9
18	0.33	6	0.52	6	0.50	6	0.54	6	0.53	6
19	0.41	5	0.60	5	0.60	5	0.59	5	0.60	5
20	0.22	15	0.35	17	0.31	18	0.36	18	0.36	18
21	0.25	13	0.39	14	0.35	15	0.40	12	0.40	13
22	0.28	8	0.41	12	0.36	14	0.40	13	0.40	12

considered the best one? One answer can be reached by calculating the sum of the absolute difference between the rank of the district in each technique by the others. According to Table 13 Linear Scale Transformation (Sum) is the most robust solution for the mentioned example.

It is worth answering the mentioned questions here: How DMAIC methodology can be applied in an organization as a performance management tool? Defining Tehran Municipality is done based on its deputies. In this way, all the activities, inputs, processes, outputs, and outcomes are defined by each deputy. Then a hierarchical performance assessment system (Goal, objectives, KPIs) is applied for a more accurate definition of the problem. AHP and TOPSIS are used in the measurement phase to calculate the

Table 12: Results of SWM technique by different normalization and standardization methods

	Vector Normalization		Standardization $a_{ij} = \frac{x_{ij}-\mu}{\delta}$		Linear Scale Transformation (Sum) $a_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}$		linear Scale Transformation (Max)as: $a_{ij} = \frac{x_{ij}}{x_j^{max}}$		Linear Scale Transformation (Max-Min) as: $a_{ij} = \frac{x_{ij}-x_j^{min}}{x_j^{max}-x_j^{min}}$	
Districts	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1	9.70	10	-0.02	11	0.05	10	0.51	9	0.47	9
2	3.07	21	-0.79	21	0.03	21	0.27	21	0.23	21
3	5.65	20	-0.71	20	0.03	20	0.31	20	0.27	20
4	19.99	4	0.67	3	0.07	3	0.70	3	0.67	3
5	6.50	19	-0.52	19	0.03	19	0.35	19	0.32	19
6	8.68	13	-0.28	16	0.04	13	0.42	17	0.39	17
7	2.11	22	-1.29	22	0.01	22	0.13	22	0.09	22
8	8.20	14	-0.15	13	0.04	15	0.46	13	0.43	13
9	7.65	17	-0.33	18	0.03	18	0.40	18	0.37	18
10	20.97	3	0.50	4	0.06	4	0.64	4	0.62	4
11	8.09	15	-0.28	17	0.04	16	0.43	15	0.40	15
12	10.50	9	0.17	8	0.05	7	0.54	8	0.52	8
13	23.84	2	1.04	2	0.07	2	0.79	2	0.78	2
14	32.95	1	1.60	1	0.09	1	0.94	1	0.93	1
15	7.06	18	-0.20	14	0.04	14	0.43	14	0.40	14
16	11.73	7	0.21	7	0.05	8	0.56	7	0.53	7
17	9.36	11	0.03	9	0.05	9	0.49	10	0.47	10
18	12.41	6	0.24	6	0.05	6	0.58	6	0.55	6
19	15.13	5	0.48	5	0.06	5	0.62	5	0.60	5
20	8.00	16	-0.28	15	0.04	17	0.42	16	0.39	16
21	9.34	12	-0.10	12	0.04	12	0.47	12	0.44	12
22	11.24	8	0.01	10	0.04	11	0.49	11	0.46	11

Table 13: Sum of the absolute difference between the ranks of the district in each technique by the others

Technique	Method	Sum of absolute differences
TOPSIS	Vector Normalization	312
	Standardization	208
	Linear Scale Transformation (Sum)	312
	linear Scale Transformation (Max)as	184
	Linear Scale Transformation (Max-Min)	188
SWM	Vector Normalization	238
	Standardization	202
	Linear Scale Transformation (Sum)	168
	linear Scale Transformation (Max)as	188
	Linear Scale Transformation (Max-Min)	188

weights of the elements and the scores of the districts. K-mean, wards, and Six Sigma control limits are used for analyzing phase. The improvement phase is done by finding the roots of weaknesses in the previous step. Once the implementation of enhancement strategies has been completed, it is crucial to proceed with the control step. To effectively cluster the data, the utilization of six-sigma control limits can prove to be highly beneficial. The discussion section provides a comprehensive answer to how these control limits can be employed for this purpose. The application of MCDM techniques within the DMAIC methodology involves utilizing AHP for determining the weights of various elements, followed by the implementation of TOPSIS to rank the different districts based on the established criteria. The application of the Balanced Scorecard (BSC) within the DMAIC methodology can be explored by considering its implementation in the define phase, specifically concerning the hierarchical performance assessment system. This system encompasses the establishment of goals, objectives, and key performance indicators (KPIs). By incorporating the BSC, a different approach can be taken to enhance the effectiveness of this assessment system, allowing for a more comprehensive evaluation of performance within the DMAIC framework. The DMAIC methodology can be enhanced by integrating the BSC, MCDM, and clustering algorithm to introduce a more intricate approach. In the defining phase, the BSC is utilized to establish a clear framework. During the measurement phase, AHP and TOPIS are employed to gather relevant data. Finally, in the analysis phase, clustering algorithms are applied to analyze the collected information and identify patterns or groups. By combining these different techniques, the DMAIC methodology can provide a comprehensive and robust solution to complex problems.

CONCLUSION

This study showed how DMAIC methodology as a reputable methodology of Six Sigma can be applied in Tehran Municipality. The methodology has been elevated by BSC, TOPSIS, AHP, and clustering algorithms. 1) The define phase is based on BSC and is done at 3 hierarchy levels. Learning and growth, Internal processes, Urban development, and Financial are four defined perspectives. Each perspective has a strategic goal, and some objectives, and each object can be calculated by some key performance indicators. 3) The measure phase is done by AHP and TOPSIS. Weights of the elements of BSC are calculated based on AHP and district ranking is done by TOPSIS. 2) Wards and K-mean algorithms as two prominent clustering algorithms are used in the analysis phase. Moreover, by applying Six Sigma as a clustering algorithm following clusters are proposed: The performance tolerances are defined based on the standard deviation of data. If the performance of a district is between [$\mu-\sigma$, $\mu+\sigma$) so, it has the same performance in comparison with other districts. If the performance of a district is between [$\mu+\sigma$, $\mu+2\sigma$) so, it has a somewhat superior performance in comparison with other districts. If the performance of a district is between [$\mu+3\sigma$, $+\infty$) so, it has a superior performance in comparison with other districts. If the performance of a district is between [$\mu-2\sigma$, $\mu-\sigma$) so, it has a somewhat inferior performance in comparison with other districts. If the performance of a district is between $-\infty$, $\mu-2\sigma$), it has inferior performance in comparison with other districts. 4) The improvement phase traces back to the BSC levels and finds out the strengths and weaknesses of the districts based on the weights and performance and defines improvement plans. 5) The control phase tries to control the execution of improvement plans. Moreover, 4 different normalization ways linear scale transformation (sum), linear scale transformation (max), linear scale transformation (max-min), vector normalization, and also standardization to standardize the data, and TOPSIS and SWM techniques are used to normalize the data and rank the distinct. In this way, 10 different solutions are obtained and a criterion is proposed to select the most suitable solution. For further research, providing statistical analysis can be used to test the stability of the clusters and group the scores into meaningful clusters.

AUTHOR CONTRIBUTIONS

K. Fahimi performed the literature review, conducted the conceptual model, and numerical results, compiled the data, analyzed and interpreted the data, and prepared the manuscript text, and manuscript edition. M. Amirabadi performed the literature review and applied the model in Tehran Municipality.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the authors have completely witnessed the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy.

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ABBREVIATIONS

%	Percent
AHP	Analytical Hierarchical Process
ANOVA	Analysis of variance
BSC	Balanced Score Card
CI	Consistency Index
CR	Consistency Ratio
FTOPSIS	Fuzzy Technique for Order of Preference by Similarity to Ideal solution
FAHP	Fuzzy analytical hierarchical process
MBNQA	Malcolm Baldrige National Quality Award
MCDM	Multi-Criteria Decision-Making
RI	Random Index
SPSS	Statistical Package for the Social Sciences
SWM	Sample Weighted Method
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
TQM	Total Quality Management
$A=\left[a_{ij}\right]$	Pairwise comparison matrix.
a_{ij}	Amount of preference of element i to element j.
$(W_1,..,W_n)$	Vector of weights.
C	An n-dimensional column vector.
$CV=\left[cv_i\right]_{1*n}$	Consistency value.
γ_{max}	Maximum eigenvalue.
CI	Consistency index.
RI	Average random index.
$D=\left[x_{ij}\right]_{mn}$	Decision matrix.
x_{ij}	Score of alternatives i in criteria j.
R_{ij}	Normalized amount of x_{ij}.
V_{ij}	Weighted normalized amount of x_{ij}.
$(V^+=V_1^+,V_2^+,\ldots,V_n^+)$	The maximum value of alternatives in each attribute.
$(V^-=V_1^-,V_2^-,\ldots,V_n^-)$	The minimum value of alternatives in each attribute.
S_i^+	Positive separation measure.
S_i^-	Negative separation measure.
C_i^+	Relative closeness to the ideal solution.
μ	Average of the final scores.
σ	Standard deviation of the final scores.

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