Next, the top manager determines a voting power weight to each of the members of the Lean and Six Sigma e-Health teams as follows:

\[
W_{E-health}(I) = [w(T_1(I)), w(T_2(I)), \ldots, w(T_m(I))]
\]  
(3)

\[
W_{E-health}(6\sigma) = [w(T_1(6\sigma)), w(T_2(6\sigma)), \ldots, w(T_m(6\sigma))]
\]  
(4)

**Phase 2: Identification of the e-Health reference architectures**

In this phase, the Lean and Six Sigma e-Health teams identify alternative e-Health reference architectures. Let us assume that the Six Sigma e-Health team has identified \( n \) e-Health reference architectures:

\[ A = [A(1), A(2), \ldots, A(i), \ldots, A(n)] \]  
(5)

**Step 2-1: Identification of core e-Health layers of e-Health reference architectures**

In this step, the Lean and Six Sigma e-Health teams identify the core e-Health layers of e-Health reference architectures. Let us assume that they have identified \( q \) core e-Health layers as follows:

\[ A = [L_1, L_2, \ldots, L_h, \ldots, L_q] \]  
(6)

**Step 2-2: Identification of core e-Health modules of each e-Health layer**

In this step, the Lean and Six Sigma e-Health teams identify the core e-Health modules of each e-Health layer. Let us assume that they have identified \( M_h \) core e-Health Modules for the \( h \)th e-Health layer as follows:

\[ L_h = [M_{1h}, M_{2h}, \ldots, M_{ih}, \ldots, M_{qh}] \quad h = 1, 2, \ldots, q \]  
(7)

**Phase 3: Identification of the Lean and Six Sigma criteria**

In this phase, Lean and Six Sigma criteria are identified. This phase is divided into the following two steps:

**Step 3-1: Identification of the Lean criteria**

From a Lean perspective, a non-value-added complexity should be eliminated. Lean e-Health focuses upon eliminate non required elements from the e-Health module & improve e-Health module on aspects of efficiency and effectiveness.

In this step, the Lean e-Health team identifies a list of Lean criteria. Let us assume that we have the Lean criteria:

\[ c_1(I), c_2(I), \ldots, c_{r_l}(I) \]

**Step 3-2: Identification of the Six Sigma criteria**

The objective of Six Sigma is to reduce variation and elimination of defects in the e-Health module and provide near perfect e-Health services that will satisfy customers. In this step, the Six Sigma E-Health team identifies a list of Six Sigma criteria. Let us assume that we have the Six Sigma criteria:

\[ c_1(6\sigma), c_2(6\sigma), \ldots, c_{r_\sigma}(6\sigma) \]

**Phase 4: Constructing the fuzzy individual decision matrices from Lean and Six Sigma perspectives**

In this phase, the fuzzy Individual decision matrices are constructed from Lean and Six Sigma perspectives. This phase is divided into the following two steps:

**Step 4-1: Constructing the fuzzy individual decision matrices from Lean perspectives**
In this step, the fuzzy individual decision matrices evaluated by the members of the Lean e-Health team will be determined, given in Table 1:

<table>
<thead>
<tr>
<th>Lean criteria</th>
<th>$w(L_1)$</th>
<th>...</th>
<th>$w(L_q)$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$w(M_1^1)$</td>
<td>...</td>
<td>$w(M_q^1)$</td>
</tr>
<tr>
<td>$c_1(l)$</td>
<td>$A(1)$</td>
<td>...</td>
<td>$A(1), c_1(l)$</td>
</tr>
<tr>
<td></td>
<td>$r_{11}^k [A(1), c_1(l)]$</td>
<td>...</td>
<td>$r_{g_k}^k [A(1), c_1(l)]$</td>
</tr>
<tr>
<td></td>
<td>$r_{g_1}^k [A(1), c_1(l)]$</td>
<td>...</td>
<td>$r_{g_k}^k [A(1), c_1(l)]$</td>
</tr>
<tr>
<td>$c_{q_1}(l)$</td>
<td>$A(1)$</td>
<td>...</td>
<td>$A(1), c_{q_1}(l)$</td>
</tr>
<tr>
<td></td>
<td>$r_{11}^k [A(1), c_{q_1}(l)]$</td>
<td>...</td>
<td>$r_{g_k}^k [A(1), c_{q_1}(l)]$</td>
</tr>
<tr>
<td></td>
<td>$r_{g_1}^k [A(1), c_{q_1}(l)]$</td>
<td>...</td>
<td>$r_{g_k}^k [A(1), c_{q_1}(l)]$</td>
</tr>
</tbody>
</table>

Table 1: The fuzzy individual decision matrix for the e-Health reference architecture from Lean perspective

Furthermore, assume $\phi = \{(k_1, l_1)\}$ denote a set of ordered pairs $(k_1, l_1)$ where $k_1$ designates the preferred e-Health reference architecture on a forced choice basis resulting from a paired comparison involving $k_1$ and $l_1$ from Lean perspective.

**Step 4-2: Construction of the fuzzy individual decision matrices from Six Sigma perspective**

In this step, the fuzzy individual decision matrices evaluated by the members of the Six Sigma e-Health team will be determined, given in Table 2:

<table>
<thead>
<tr>
<th>Six sigma criteria</th>
<th>$w(L_1)$</th>
<th>...</th>
<th>$w(L_q)$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$w(M_1^1)$</td>
<td>...</td>
<td>$w(M_q^1)$</td>
</tr>
<tr>
<td>$c_1(6\sigma)$</td>
<td>$A(1)$</td>
<td>...</td>
<td>$A(1), c_1(6\sigma)$</td>
</tr>
<tr>
<td></td>
<td>$r_{11}^k [A(1), c_1(6\sigma)]$</td>
<td>...</td>
<td>$r_{g_k}^k [A(1), c_1(6\sigma)]$</td>
</tr>
<tr>
<td></td>
<td>$r_{g_1}^k [A(1), c_1(6\sigma)]$</td>
<td>...</td>
<td>$r_{g_k}^k [A(1), c_1(6\sigma)]$</td>
</tr>
<tr>
<td>$A(n)$</td>
<td>$A(n)$</td>
<td>...</td>
<td>$A(n), c_1(6\sigma)$</td>
</tr>
<tr>
<td></td>
<td>$r_{11}^k [A(n), c_1(6\sigma)]$</td>
<td>...</td>
<td>$r_{g_k}^k [A(n), c_1(6\sigma)]$</td>
</tr>
<tr>
<td></td>
<td>$r_{g_1}^k [A(n), c_1(6\sigma)]$</td>
<td>...</td>
<td>$r_{g_k}^k [A(n), c_1(6\sigma)]$</td>
</tr>
</tbody>
</table>

Six sigma criteria | $w(L_i)$ | ... | $w(L_q)$
|---|---|---|---|
| $w(M^i_1)$ | $w(M^g_{s_i})$ | ... | $w(M^q_1)$ | $w(M^q_{s_q})$

$c_0 (6\sigma)$

| $A(n)$ | $\tilde{r}_{i1}[A(n),c_1 (6\sigma)]$ | $\tilde{r}_{i2}[A(n),c_1 (6\sigma)]$ | $\tilde{r}_{i3}[A(n),c_1 (6\sigma)]$ | $\tilde{r}_{qs_1}[A(n),c_1 (6\sigma)]$

| $A(n)$ | $\tilde{r}_{i1}[A(n),c_1 (6\sigma)]$ | $\tilde{r}_{i2}[A(n),c_1 (6\sigma)]$ | $\tilde{r}_{i3}[A(n),c_1 (6\sigma)]$ | $\tilde{r}_{qs_1}[A(n),c_1 (6\sigma)]$

| $A(n)$ | $\tilde{r}_{i1}[A(n),c_1 (6\sigma)]$ | $\tilde{r}_{i2}[A(n),c_1 (6\sigma)]$ | $\tilde{r}_{i3}[A(n),c_1 (6\sigma)]$ | $\tilde{r}_{qs_1}[A(n),c_1 (6\sigma)]$

| $A(n)$ | $\tilde{r}_{i1}[A(n),c_1 (6\sigma)]$ | $\tilde{r}_{i2}[A(n),c_1 (6\sigma)]$ | $\tilde{r}_{i3}[A(n),c_1 (6\sigma)]$ | $\tilde{r}_{qs_1}[A(n),c_1 (6\sigma)]$


Table 2: The fuzzy individual decision matrix for the e-Health reference architecture from Six Sigma perspective.

Furthermore, assume $\phi_2 = \{(k_2, l_2)\}$ denote a set of ordered pairs $(k_2, l_2)$ where $k_2$ designates the preferred e-Health reference architecture on a forced choice basis resulting from a paired comparison involving $k_2$ and $l_2$ from Six Sigma perspective.

**Phase 5: Constructing the fuzzy weighted collective decision matrices from Lean and Six Sigma perspectives**

In this phase, the fuzzy weighted collective decision matrices are constructed from Lean and Six Sigma perspectives. This phase is divided into the following two steps:

**Step 5-1: Constructing the fuzzy weighted collective decision matrix from Lean perspectives**

In this step, the fuzzy weighted collective decision matrix evaluated by the members of the Lean e-Health team will be determined, given in Table 3:

| Lean criteria | $w(L_i)$ | ... | $w(L_q)$
|---|---|---|---|
| $w(M^i_1)$ | $w(M^g_{s_i})$ | ... | $w(M^q_1)$ | $w(M^q_{s_q})$

$c_1 (I)$

| $A(I)$ | $\tilde{r}_{i1}[A(I),c_1 (I)]$ | $\tilde{r}_{i2}[A(I),c_1 (I)]$ | $\tilde{r}_{i3}[A(I),c_1 (I)]$ | $\tilde{r}_{qs_1}[A(I),c_1 (I)]$

| $A(I)$ | $\tilde{r}_{i1}[A(I),c_1 (I)]$ | $\tilde{r}_{i2}[A(I),c_1 (I)]$ | $\tilde{r}_{i3}[A(I),c_1 (I)]$ | $\tilde{r}_{qs_1}[A(I),c_1 (I)]$

| $A(I)$ | $\tilde{r}_{i1}[A(I),c_1 (I)]$ | $\tilde{r}_{i2}[A(I),c_1 (I)]$ | $\tilde{r}_{i3}[A(I),c_1 (I)]$ | $\tilde{r}_{qs_1}[A(I),c_1 (I)]$

| $A(I)$ | $\tilde{r}_{i1}[A(I),c_1 (I)]$ | $\tilde{r}_{i2}[A(I),c_1 (I)]$ | $\tilde{r}_{i3}[A(I),c_1 (I)]$ | $\tilde{r}_{qs_1}[A(I),c_1 (I)]$


Table 3: The fuzzy weighted collective decision matrix for the e-Health reference architecture from Lean perspective.

Where:
\[
\tilde{r}_{g_k} \left[ A(i), c_j (l) \right] = \frac{\sum_{k=1}^{m} w(T_k (l)) \left[ \tilde{r}^k_{g_k} \left[ A(i), c_j (l) \right] \right]}{\sum_{k=1}^{m} w(T_k (l))}
\]  

(8)

**Step 5-2: Construction of the fuzzy weighted collective decision matrix from Six Sigma perspective**

In this step, the fuzzy weighted collective decision matrix evaluated by the members of the Six Sigma e-Health team will be determined, given in Table 4:

<table>
<thead>
<tr>
<th>Six sigma criteria</th>
<th>( w(L_1) )</th>
<th>( \cdots )</th>
<th>( w(L_q) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L_i )</td>
<td>( \cdots )</td>
<td>( \cdots )</td>
<td>( \cdots )</td>
</tr>
<tr>
<td>( w(M^1_i) )</td>
<td>( \cdots )</td>
<td>( \cdots )</td>
<td>( \cdots )</td>
</tr>
<tr>
<td>( M^1_i )</td>
<td>( \cdots )</td>
<td>( \cdots )</td>
<td>( \cdots )</td>
</tr>
<tr>
<td>( c_1(6\sigma) )</td>
<td>( \tilde{r}_{11} [A(l), c_1(6\sigma)] )</td>
<td>( \cdots )</td>
<td>( \tilde{r}_{q_k} [A(n), c_1(6\sigma)] )</td>
</tr>
<tr>
<td>( A(n) )</td>
<td>( \tilde{r}_{11} [A(i), c_1(6\sigma)] )</td>
<td>( \cdots )</td>
<td>( \tilde{r}_{q_k} [A(n), c_1(6\sigma)] )</td>
</tr>
<tr>
<td>( c_q(6\sigma) )</td>
<td>( \tilde{r}_{11} [A(l), c_q(6\sigma)] )</td>
<td>( \cdots )</td>
<td>( \tilde{r}_{q_k} [A(n), c_q(6\sigma)] )</td>
</tr>
<tr>
<td>( A(n) )</td>
<td>( \tilde{r}_{11} [A(i), c_q(6\sigma)] )</td>
<td>( \cdots )</td>
<td>( \tilde{r}_{q_k} [A(n), c_q(6\sigma)] )</td>
</tr>
</tbody>
</table>

Table 4: The fuzzy weighted collective decision matrix for the e-Health reference architecture from Six Sigma perspective

Where:

\[
\tilde{r}_{g_k} \left[ A(i), c_j (6\sigma) \right] = \frac{\sum_{k=1}^{m} w(T_k (6\sigma)) \left[ \tilde{r}^k_{g_k} \left[ A(i), c_j (6\sigma) \right] \right]}{\sum_{k=1}^{m} w(T_k (6\sigma))}
\]  

(9)

**Phase 6: Prioritization of the e-Health reference architectures with regard to Lean and Six Sigma criteria**

In this phase, the e-Health reference architectures are prioritized based on Lean and Six Sigma criteria. This phase is divided into the following two steps:

**Step 6-1: Prioritization of the e-Health reference architectures with respect to the Lean criteria**

In this step, the e-Health reference architectures with respect to the Lean criteria are prioritized, given in Table 5:
Table 5: The scores of the e-Health reference architectures from Lean perspective

Where:

\[
\tilde{s}
\left[ A(i), c_j(l) \right] = \frac{\sum_{h=1}^{q} w(M_h) \sum_{j=1}^{g} w(P_{jh}) \tilde{r}_{jh} \left[ A(i), c_j(l) \right]}{\sum_{h=1}^{q} w(M_h) \sum_{j=1}^{g} w(P_{jh})} \tag{10}
\]

Step 6-2: Prioritization of the e-Health reference architectures with respect to the Six Sigma criteria

In this step, the e-Health reference architectures with respect to the Six Sigma criteria are prioritized, given in Table 6:

Table 6: The scores of the e-Health reference architectures from Six Sigma perspective

Where:

\[
\tilde{s}
\left[ A(i), c_j(6\sigma) \right] = \frac{\sum_{h=1}^{q} w(M_h) \sum_{j=1}^{g} w(P_{jh}) \tilde{r}_{jh} \left[ A(i), c_j(6\sigma) \right]}{\sum_{h=1}^{q} w(M_h) \sum_{j=1}^{g} w(P_{jh})} \tag{11}
\]
Phase 7: Selection of the best practice Lean Six Sigma e-Health reference architecture

Finally, in this phase, the best practice Lean Six Sigma e-Health reference architecture is selected using the proposed fuzzy bi-objective LINMAP model as follows:

Min \( \sum_{(k_1, b_1) \in B_1} z_{k_1b_1}(l) \)  
(Fuzzy Group Bi-Objective LINMAP model)

Min \( \sum_{(k_2, b_2) \in B_2} z_{k_2b_2}(6\sigma) \)

St:

\[ \sum_{j=1}^{m_1} w_j(l) \left[ \tilde{s} \left( A(k), c_j(l) \right) - \tilde{s} \left( A(b), c_j(l) \right) \right] + z_{k_1b_1}(l) \geq 0 \text{ for } (k_1, b_1) \in B_1 \]

\[ \sum_{j=1}^{m_1} w_j(l) \sum_{(k_1, A_1) \in B_1} \left[ \tilde{s} \left( A(k), c_j(l) \right) - \tilde{s} \left( A(b), c_j(l) \right) \right] = 1 \]

\[ \sum_{j=1}^{m_2} w_j(6\sigma) \left[ \tilde{s} \left( A(k), c_j(6\sigma) \right) - \tilde{s} \left( A(b), c_j(6\sigma) \right) \right] + z_{k_2b_2}(6\sigma) \geq 0 \text{ for } (k_2, b_2) \in B_2 \]

\[ \sum_{j=1}^{m_2} w_j(6\sigma) \sum_{(k_2, b_2) \in B_2} \left[ \tilde{s} \left( A(k), c_j(6\sigma) \right) - \tilde{s} \left( A(b), c_j(6\sigma) \right) \right] = 1 \]

\( w(l) \geq 0 \text{ for } j = 1, 2, \ldots, m_1 \)

\( z_{k_1b_1}(l) \geq 0 \text{ for } (k_1, b_1) \in B_1 \)

\( w(6\sigma) \geq 0 \text{ for } j = 1, 2, \ldots, m_2 \)

\( z_{k_2b_2}(6\sigma) \geq 0 \text{ for } (k_2, b_2) \in B_2 \)

The optimal solution for the above proposed fuzzy bi-objective LINMAP model is the best practice Lean Six Sigma e-Health reference architecture. In the next section, we present a case study to demonstrate the applicability of the proposed framework and exhibit the efficacy of the procedures and algorithms.

CASE STUDY

An U.S. hospital has decided to implement a lean six sigma e-Health reference architecture in order to improve health care quality (reduce medication errors, reducing patient wait times,…) and decrease the cost of medical care. After a careful analysis of the problem, the consultants suggested to use the framework proposed in this study:

In the first phase, the top manager established Lean and Six Sigma e-Health teams to evaluating core e-Health modules and layers of each e-Health reference architecture as follows:

\[ T_{E-health}(l) = \{ \text{Chief Executive Officer, Chief Operating Officer, Chief Medical Officer} \} \]

\[ T_{E-health}(6\sigma) = \{ \text{Clinical Services Director, Director of Nursing, Special Assistant} \} \]

Next, the top manager determined a voting power weight to each of the members of the Lean and Six Sigma e-Health teams as follows:

\[ w[T_{E-health}(l)] = [0.4, 0.3, 0.3] \]

\[ w[T_{E-health}(6\sigma)] = [0.35, 0.35, 0.3] \]

In the second phase, the Lean and Six Sigma e-Health teams identified the following e-Health reference architectures, given in Figures 3-5: