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In 50 Words Or Less

- Decision making often involves balancing competing objectives.
- A new five-step process—define, measure, reduce, combine and select (DMRCS)—can help you measure and balance trade-offs.
- DMRCS ultimately provides the structure to combine different facets of a decision and reach a coherent, justifiable final choice.

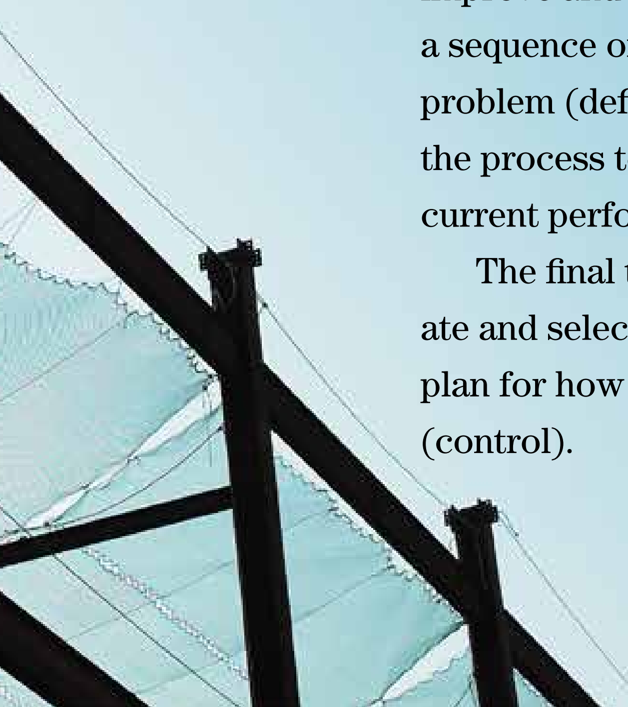
Needed CTURE

A new 5-step **decision-making process** helps you evaluate, balance competing objectives

by Christine M. Anderson-Cook and Lu Lu

AT THE HEART of Six Sigma is an approach to structured problem solving. The define, measure, analyze, improve and control (DMAIC) method guides users through a sequence of steps to determine the right scope for their problem (define), select the correct metrics to characterize the process to be improved (measure) and understand its current performance (analyze).

The final two steps use design of experiments to evaluate and select a best path forward (improve) and formulate a plan for how to sustain the gains introduced into the process (control).



One of the keys to DMAIC success is how it takes an often complex and unstructured problem-solving situation and translates the solution to a series of steps for which tools and approaches can be readily described.

Another scenario common in organizations is making decisions when you must balance multiple competing objectives. If a decision involves optimizing just a single objective, this is typically straightforward and can be done without much complication. Where things can get difficult are situations in which you have multiple facets to consider and no clear way of prioritizing the values of different aspects of the decision.

Think about some of the most recent difficult decisions you have wrestled with. Weren't the difficult parts about how to measure and choose among trade-offs? For example:

- Spend more for better quality or save money at the expense of reduced quality.
- Pay a little extra or sacrifice a bit of quality to save some time.

The critical part of these decisions is coming to grips with how cost, quality and time are valued relative to one another. This can be greatly complicated by dimensions being measured in different units and having different values to you in different situations.

In today's world, where expertise is distributed among many stakeholders, you're often making these challenging decisions as part of a team, where consensus is needed, along with decisions about how to balance these trade-offs between alternative potential solutions.

New, structured process

We've devised a new five-step process to evaluate and balance competing objectives in a structured and defensible way, while still allowing the flexibility to incorporate and evaluate different subjective weightings of the facets of the decision. Similar to DMAIC, this complex process is arranged into five manageable steps: define, measure, reduce, combine and select (DMRCS, which can be pronounced as "dem-recks").

Define: As with the DMAIC process, the first step is to clarify the scope of the exercise, which involves identifying the problem to be solved, the facets of the decision that are valued and what potential solutions might exist. This step is critical for framing key components of the decision to ensure the correct problem is solved.

Measure: Also a step common to DMAIC, you should be confident you have high-quality data on which to base your decision. The facets of the decision must be translated into quantitative metrics with precise definitions to allow fair and consistent comparisons between potential solutions for a given facet. If high-quality quantitative measurements of the characteristics of importance cannot be used, the quality of the decision may be compromised.

Reduce: Triage of the identified criteria may lead to some metrics being deemed secondary to the decision's primary objectives. In addition, some choices based on the primary criteria from a collection of potential solutions can be eliminated from further consideration based on their objective inferiority to other available options. Would you ever buy a more expensive, lower-quality item?

A Pareto front[1,2] can be constructed that includes only those options that represent rational good choices. These are the only options you should consider in subsequent stages. Trimming the number of solutions allows more meaningful exploration of the alternatives, but it is essential that no worthwhile solutions are spuriously eliminated.

Combine: Next, consider ways of combining the different metrics—often measured on different scales—into comparable forms. This allows you to examine leading contenders while incorporating and evaluating your priorities for a good final solution. Finding ways of examining different metrics in comparable ways is the key to understanding the important trade-offs.

Select: Finally, examine your prioritized solutions, compare them to close competitors and select a final choice that matches your priorities. Using graphical tools to help understand the relative merits and weaknesses of the alternatives can help build team consensus and allow you to formulate a coherent, justifiable explanation for your particular choice.

Job search example

Walking through the DMRCS process using a job search example will illustrate the power of this method. Susan has unique skills that are highly sought by several employers. After an extensive job search, Susan received 25 job offers that are different in many important ways. Knowing the importance of choosing the best job for her, she wants to make a decision based on a quantitative evaluation of the options (job offers) and their relative trade-offs.

Define: The goal is to select the best job offer from the 25 received. By following the five-step process, Susan begins with identifying the facets of the decision that are valued—that is, the criteria or valuable features of interest. After evaluating the aspects thought most exciting about some jobs or least appealing about others, the following seven criteria were identified:

1. Salary.
2. Work environment.
3. Location.
4. Potential for promotion.
5. Short or long-term staying potential.
6. Schedule.
7. Benefits.

In reviewing which characteristics to focus on, it was essential to consider those that had data available and could summarize a job's appeal to her. It also is important to think broadly about diverse aspects of a decision, while not having multiple metrics for similar dimensions.

Measure: In the measure step, appropriate metrics are chosen for the listed criteria to quantify the performance of the candidate solutions—job offers—for all criteria under consideration. Annual salary is natural to measure as a numerical criterion, with values ranging between $42,000 and $90,000 for her available choices.

By defining a scale between zero (worst) and 10 (best), with particular characteristics associated with different scores,[3] the desirability of characteristics two, three, four, six and seven can be quantified.

Note that for some attributes, such as location, it is possible to finely distinguish between choices. For other characteristics, such as potential for promotion, the options have less distinction with many choices sharing common scores. Short or long-term staying potential is naturally categorical with only two values.

The scoring process to assign values for all of the jobs is vitally important to making a good decision. All subsequent steps hinge on having the sequence of the alternatives in each of the criteria correct and representative of how valued a job is in that category.

Table 1 summarizes the criteria values for the job offers.

Reduce: Next, in the reduce step, Susan wants to cut the possible options by eliminating obviously inferior offers. After careful consideration, Susan first decides salary and short term are deal-breakers for her.

Given a rich set of alternatives, she decides accepting a short-term position would not be satisfying. In addition, given the range of salaries being offered, she eliminates those jobs with a yearly salary lower than

Data for the job search example / TABLE 1

Job No.	Term	Salary	Location	Potential for promotion	Benefits	Schedule	Work environment
1	**Long**	**70**	**7.5**	**10**	7	8	7
2	**Long**	**66**	**8.5**	**5**	8	10	3
3	Short	80	6	10	9	8	5
4	**Long**	**75**	**7**	**7**	9	8	9
5	Long	42	9.5	7	6	8	10
6	Long	55	9	7	6	8	4
7	**Long**	**68**	**8**	**7**	7	10	6
8	**Long**	**84**	**4**	**10**	7	4	6
9	Long	78	6	5	10	8	5
10	Long	72	7	5	8	8	6
11	Short	90	3	10	8	4	8
12	Short	86	4.5	10	10	8	7
13	Long	64	7	7	7	10	10
14	Long	69	6	5	9	8	9
15	Long	73	7	7	10	8	8
16	Long	62	9	7	7	10	9
17	**Long**	**83**	**6**	**7**	8	8	6
18	Short	79	5	7	9	10	8
19	Long	57	7	7	9	8	8
20	Long	76	6.5	7	7	8	7
21	Long	63	7	5	8	10	8
22	**Long**	**80**	**6.5**	**10**	8	8	9
23	Long	65	8	7	7	10	5
24	**Long**	**81**	**6**	**10**	7	8	7
25	Long	57	7	7	6	8	8

Note: Term is categorical with two levels (short vs. long). Salary is measured in thousands of U.S. dollars per year. The remaining five criteria are all measured in a 0-10 scale—0 being the worst and 10 the best. The entries shaded in gray are excluded considering the deal-breaker criteria (short term or salary < $65,000). The eight offers identified on the Pareto front are shaded in blue.

$65,000. Hence, 11 offers (shown in gray in Table 1) are excluded from further consideration.

Second, not all of the criteria are of equal importance. Susan thinks that what makes a job offer stand out are salary, location and potential for promotion. These, she decides, are the most important characteristics on which she wishes to focus. The remaining three criteria (benefits, schedule and work environment) are considered less important and can be used as supplementary tie-breaking criteria when making a final decision among a few most promising options.

Having too many criteria designated as of primary interest can lead to mediocre values for individual criteria for the best solutions if there are strong trade-offs between objectives. Being selective about what to consider the top priorities is therefore recommended.

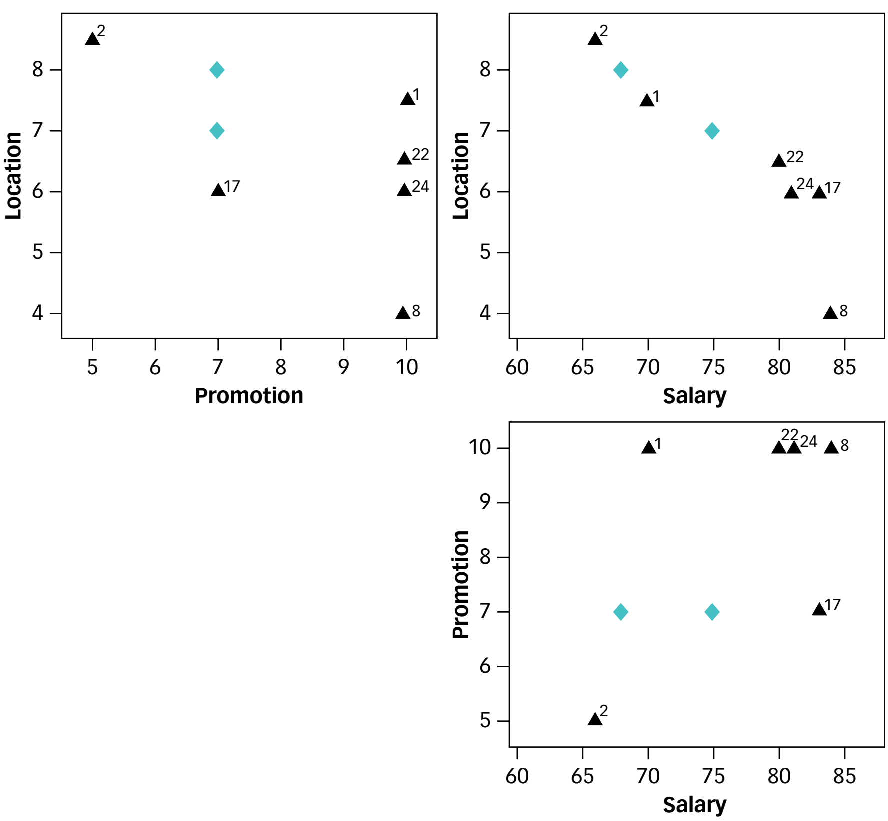
Focusing on the 14 remaining offers, Susan now wants to further eliminate some offers that have at least one better option (that is, as good for all criteria and strictly better for at least one criterion) based on the three most important criteria.

After eliminating the inferior options, the remaining set comprises the Pareto front. For any offer on the Pareto front, there is no alternative that is strictly better for all three primary criteria. The Pareto front thus offers an objective set of superior choices before considering the subjective choices of user priorities between criteria.

From the 14 offers remaining—after elimination based on the deal-breakers—eight are identified on the Pareto front (shown in blue in Table 1). Any offer not on the front can be outperformed by a solution from the front.

Offer 20 (not on the front) is beaten, for example, by offer 22 (on the front) because they tie with the same score on location, but offer 22 is better for salary and potential for promotion.

Pairwise scatter plots for the eight job offers on the Pareto front / FIGURE 1



Note: The six offers selected as best for at least one set of weight combination are highlighted in black symbols. The remaining offers that belong to the front but not selected in the mixture plot are shown in blue symbols.

The pairwise scatter plots of the points on the Pareto front are shown in Figure 1. The top-right corner of each panel represents the ideal solution based on each pair of criteria. The farther away the points on the front are to the ideal, the more trade-off there is between the criteria. Among the three pairs of criteria, it can be observed that the most trade-off exists between salary and location, and there is the least trade-off between salary and promotion.

At the conclusion of this step, Susan has cut the number of choices to be considered from the original 25 to eight. If she has identified her characteristics of interest and quantified the performance of each job on these characteristics, this set of eight jobs represents an indisputable set of superior choices from which she can start selection based on her priorities and preferences. This more manageable set is less overwhelming and allows more careful consideration of the alternatives.

Combine: Next, in the combine step, the Pareto front solutions are examined further to identify some leading contenders. In this stage, it's important how you value the different characteristics and how you are willing to tolerate poor scores on one metric if the performance of other metrics is exceptional.

Because multiple facets are simultaneously considered for capturing the solution's diverse attributes, you should integrate multiple metrics into the overall decision. There are different ways to achieve that.

One way is to use the threshold approach, which tackles the relative importance of individual criteria one by one. Specifically, it may start with the most important criterion to determine the threshold below—or above (if minimizing)—which you are unwilling to accept values. This eliminates a subset of the choices. The process is repeated with the next most important criterion until all are examined.

The advantage of this approach is being able to work with the raw data. The determination of the thresholds, however, is often quite subjective, and the final decision can be highly sensitive to the choice of the thresholds. As the number of criteria considered grows, it becomes easy to end with an empty set of contenders if too ambitious thresholds are selected.

An alternative is to use the utopia point approach[4]—which is closely related to the desirability function approach.[5] The idea is to rank all the points (offers) on the Pareto front based on their proximity to a utopia point, which represents an ideal solution that simultaneously has best values for all criteria (corresponding to the top-right corner in each panel in Figure 1) and often exists only in theory.

Preferred solutions are those that are closest to the ideal solution. The proximity measurement is based on combining different metrics for multiple criteria into an overall summary. This requires scaling different criteria values' comparable scales and choosing the appropriate weighting and metric form to combine different criteria together. Given the identified Pareto front, this approach allows the quick examination of different weighting, scaling and metric forms, plus their potential impact on the decision.

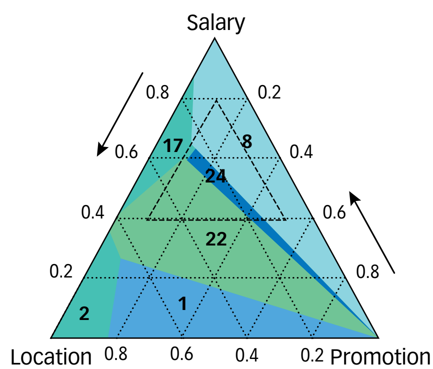
Figure 2 shows a mixture plot,[6] one of the graphical tools that can be used to evaluate the impact of subjective choices and facilitate decision-making. It displays the best solutions (offers) for all possible weighting choices for certain selected scaling and metric forms. Here, Susan decides to linearly scale the criteria values based on the range of values on the Pareto front.

The worst criterion value on the front is scaled to zero (least desirable), and the best is scaled to one (most desirable). She also has chosen the metric in the form of $DF_i = w_S S_i + w_L L_i + w_P P_i$ for combining all three criteria, in which S_i, L_i and P_i represent the scaled criteria values for salary, location and promotion potential for the ith job offer, and w_S, w_L and w_P are the weights for these three criteria. This metric is often referred to as an additive desirability function.

This metric form does not place an extra penalty on poor performance and hence allows good performance on one criterion to overcome poor performance on another. In the mixture plot, each point in the triangle represents a weight combination. Vertices indicate all the weight on a single objective, edges consider two of the three objectives, while interior points consider non-zero weights for all three objectives. The centroid of the triangle represents equal weight for all criteria. Different shades of gray distinguish different regions for different best solutions.

Among the eight points on the Pareto front, six solutions are selected as best for some weight combinations. Offer 22 is optimal for 34% of the weights when salary and location are valued at approximately equal importance. Offer eight is optimal for 25.5% of the weights when salary is considered more important than location. Offer one is optimal for 21.5% of the weights when location is valued more than salary. Offer 24 is optimal for 4.6% of the weights when salary and location are important, but salary is valued slightly

Mixture plot for showing the six best job offers for different weighting choices / FIGURE 2



Note: The focused weight region with $0.5 \le w_S \le 0.8$, $0.1 \le w_L \le 0.4$, and $0.1 \le w_P \le 0.4$, that is of primary interest to Susan is shown as the triangular area surrounded by the dash lines.

more than location. Offers two and 17 are best choices when promotion is considered less important.

After thinking carefully about the value of the three facets, Susan decides salary is more important than location and promotion, and she chooses to weigh salary between 50 to 80%, with each remaining two criteria receiving at least some consideration with at least 10% of the overall weight.

The more focused weighting region is highlighted with the triangular area surrounded by the dash line in the mixture plot (Figure 2, p. 47). Four offers are identified as best for at least some weight combinations in the focused region. Offers eight and 22 are best for large areas of weights, with offer eight favored more on salary. Offer 24 is optimal for a small slice of region—with the weights partitioned around 7:3 between salary and location. Offer 17 is considered best for only a small region by the upper-left edge of the triangular area and hence is specific to a particular weight combination range.

Figure 3 is the trade-off plot[7] that shows the relative performance of the criteria for different offers on the Pareto front. Offer eight has the best salary and promotion scores, but is worst for location. Offer two has the best location, and the worst salary and promotion. Offers 22, 24 and 17 are more balanced solutions with moderately good performance for all criteria.

Among the three primary criteria, salary and location have the most trade-off, and promotion has less trade-off with either salary or location. This matches the pattern shown in the mixture plot in which the solutions are less sensitive to changes in the weighting of promotion than the other two criteria.

Select: Recall that Susan started with 25 choices, and by specifying and applying her priorities, she has been able to reduce the number of choices to four leading candidates. She still has some work to do, however, because she will be able to accept only one job offer.

To further compare the four best options identified as optimal in the interested weight region in the mixture plot, in the select step, Susan uses the synthesized efficiency plot[8] in Figure 4 to show the relative performance of the individual solution to the global optimal performance for different weighting choices. The white-gray-black scale is used for showing high to low synthesized efficiency as measured by the percentage of the optimal performance.

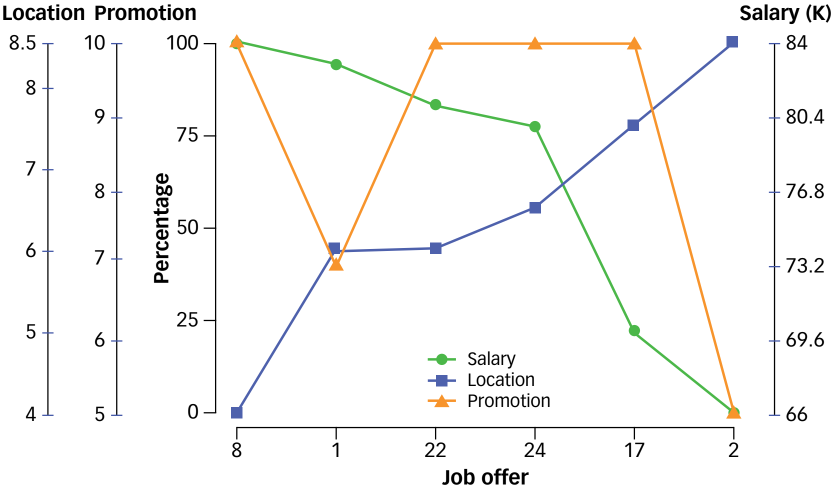
Thus, a good solution would have as large a white area as possible in the weighting region of interest. For Susan's case, offer eight has more than 95% synthesized efficiency for around 75% of the triangular area and lower efficiency (at least 80%) around the bottom-left corner in which location is given the second-largest weight.

Offer 22 has high efficiency in the bottom-left triangular area, and the lowest efficiency is above 85% when salary is weighted close to 80%. Offer 24 has a slightly larger high-efficiency area than offer 22, and the lowest efficiency is more than 90% within the focused weighting region. Offer 17 has overall darker color for a large portion of the triangular area, but is highly efficient along the left edge of the triangular area when promotion is weighted less than the other two criteria.

Overall, the four best offers can be categorized into two groups: Offers eight and 17 have the best performance when salary is the dominating criterion, but relatively poor performance when more weight is given to the other two criteria. Offers 22 and 24 have pretty good performance (at least 85% efficient) for the entire weighting region of interest.

For an easier comparison, Susan can use the fraction of weighting space (FWS) plot[9,10] (see Figure 5, p. 50) to summarize the performance over the entire focused weighting region. Each curve for an offer shows for what fraction of the weights (horizontal axis) within the focused region the solution has synthesized efficiency at least as large as a certain

Trade-off plot / FIGURE 3



Note: The plot shows the six leading offers selected using the utopia point approach with the additive desirability function.

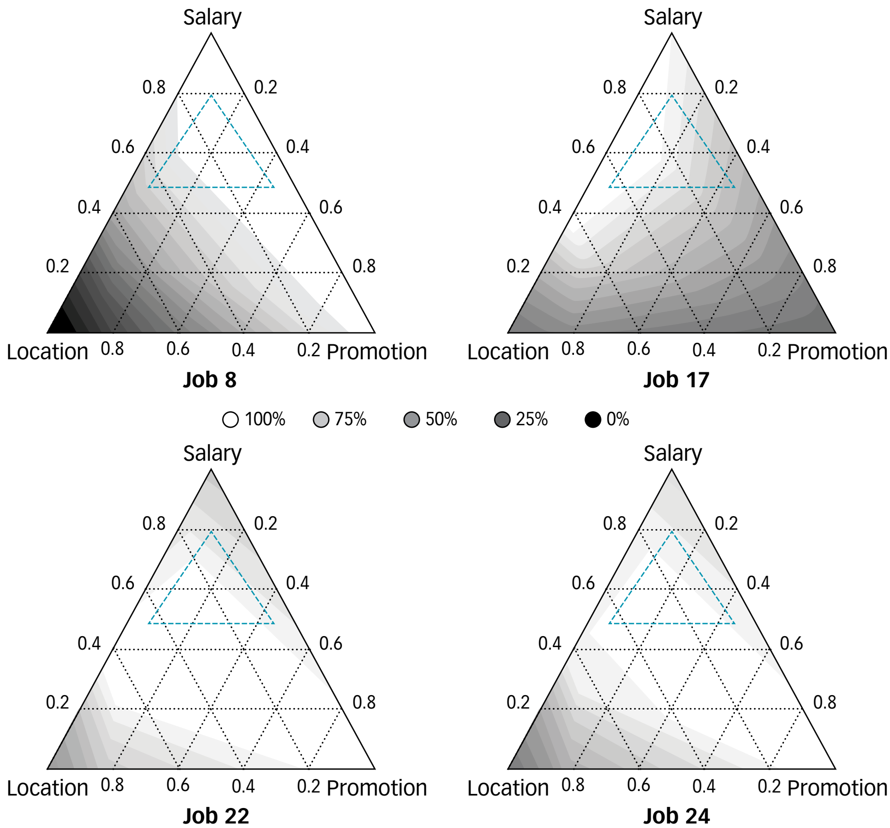
percentage of the best possible performance (vertical axis). A flat curve near the maximum of 100% is ideal.

Offer eight has about 75% of the weights with synthesized efficiency more than 93%. The performance drops quickly, however, as it moves toward the worst-case scenario. Offer 24 has a smaller area of high efficiency, but larger lowest efficiency across the focused region than offer eight.

The FWS plot for offer 22 is slightly below the curve for offer 24, which indicates a consistently smaller fraction of weights with a certain level of performance. Offer 17 has consistently lower performance than offer eight, and its lowest worst efficiency is about 75%.

Among the two categories of options, therefore, offers eight and 24 will be the top choice of each group. To choose between the two groups, if Susan wants the best performance for as large a weighting area as possible, she might want to choose offer eight; on the other hand, if she is worried more about having the best possible performance for the worst-case scenario, offer 24 would be the best choice.

Synthesized efficiency plot / FIGURE 4



Note: The plot shows the four best job offers identified as the best choices within the interested weighting region in the mixture plot.

When there is a tie between a couple—or a few—most promising choices, an effective way of choosing is to compare their performance on the supplementary criteria, which are the benefits, schedule and work environment in the job search example.

In Susan's case, the values for the three supplementary criteria for job offers eight and 24 are seven/four/six and seven/eight/seven, respectively. Offer 24 is therefore preferred when the supplementary criteria are considered.

If there is no obvious winner among the few choices based on the supplementary criteria, a similar reduce, combine and select procedure can be applied to make a final decision based on the supplementary criteria.

At the conclusion of the process, Susan has identified an overall best choice and now knows which job offer to accept. Not only has she sequentially eliminated noncontenders and less desirable solutions, but having a structured graphical approach to evaluating and considering alternatives has also led to a deeper understanding of the choices and greater comfort with the final decision.

The job she has selected has an annual salary of $81,000 (near the top end of the range of offers) and scores a perfect 10 on potential for promotion. She had to sacrifice some on the location (six of 10), but the three supplementary criteria of benefits (seven of 10), schedule (eight of 10) and work environment (seven of 10) are solidly in her comfort zone.

Justifiable final choice

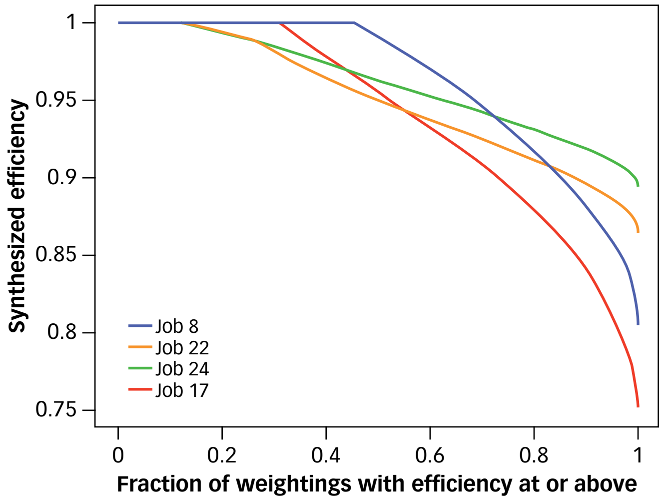
The new DMRCS process for structured decision making mirrors the approach of the DMAIC process, which has become so popular in lean Six Sigma. By dividing a complex but often unstructured process into distinct steps, the task of balancing multiple competing objectives hopefully appears less daunting. A few final reminders to emphasize:

- While the define and measure steps are easily described for the example and look straightforward, this part of the process holds the key to success for all subsequent stages. Without a properly defined goal for the decision and without high quality data on which to base all subsequent steps, the entire process could give nonsensical results. Investing in articulating the right problem to focus on and being confident in the believability of all the criteria scores for all the alternatives are essential to a quality decision.
- The use of the Pareto front in the reduce step plays a fundamental role in eliminating noncontenders without imposing any subjectivity and decision-maker preference about how to scale or compare the different criteria. Postponing the insertion of subjectivity can help give a common launching point, particularly for discussions when teams are involved.
- The process and specific tools used in the subjective steps can be separated. After talking with decision makers, we realize there are many different ways to consider the trade-offs between alternatives. The described tools have worked well for several groups, but there are certainly many other ways to evaluate a smaller number of choices based on diverse criteria. If other tools seem like a better fit, perhaps include ways to visualize the data in the process. Graphical displays provide an engaging way to study choices and help facilitate deeper discussions about the relative metrics of alternative options.

The keys to successful decision making lie in focusing on the right criteria, having solid quantitative measures on which to base choices, eliminating silly options that are inferior to other choices, and finding a way to meaningfully and fairly compare the "apples and oranges" of the different dimensions of the problem.

The DMRCS process can guide decision makers through a sequence of steps to reach an informed and justifiable final choice. QP

Fraction of weighting space plot / FIGURE 5



Note: The plot shows for the four best job offers identified in the mixture plot.

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