Decide and

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In 50 Words Or Less

- A Pugh matrix is a decision-making tool that can help teams compare and evaluate design options.
- The qualitative, design concept tool uses ratings of positive, negative and same to assess ideas.
- The matrix also allows users to create new hybrid solutions that combine the best attributes of options under consideration.

CONQUER

A Pugh matrix can help teams appraise situations, evaluate choices

MOST OF US spend at least part of our time working in groups or teams. These may be functional or cross functional groups such as project, design or process improvement teams.

The work of these groups or teams can be enhanced by using many available tools. Working teams often prefer to reach important decisions through consensus. Fortunately, there are decision-making tools that can help to facilitate that consensus.

For simple decisions, multivoting or list reduction techniques might be useful. For more complex situations, some sort of selection matrix might be a better tool. This matrix could be called a prioritization matrix or a decision matrix.[1]

In either case, the group selects rating criteria and relative weights for each criterion and rates the alternatives. The rating is multiplied by the weight, resulting in a score. The scores across the criteria for each alternative are added together, and the different alternatives are compared.

This approach has advantages, but it is also prone to misuse. Misuse arises when we do not have data to apply to the criteria, and we use a rating system based on the group's perceptions. There is nothing wrong with using these informed opinions, per se. But if we use them in this type of matrix and insert a rating number, multiply it by a weight and sum scores for the various alternatives, it's easy to fool ourselves into thinking we just went through a quantitative exercise—even though the underlying analysis is qualitative.

Each stage of the process requires group discussion. If we understand this is a qualitative exercise, this approach can be useful in building consensus. The value of this approach is in the conversations generated—not just the numbers.

The first discussion takes place when we decide which alternatives to consider. The second, often lengthy one, occurs when we select our criteria. Discussion will happen again when we determine the weights to apply to each criterion. Finally, we will rate each alternative, and in the process of agreeing on these ratings, we will have another set of conversations.

These conversations and discussions will lead to a deeper understanding of each alternative's potential. The real value is in the understanding that happens, not in the numbers generated. Ultimately, the team, informed by these discussions, should make the decision. Numbers should not dictate the decision.

When we rely on the group's judgment instead of data, however, there is an alternative, clearly qualitative tool to consider: the Pugh matrix.

Pugh matrix background

Stuart Pugh, author of *Total Design: Integrated Methods for Successful Product Engineering*,[2] was a leader in the area of product engineering, development and design methods. He developed the Pugh matrix as a tool to compare alternative design concepts to an established reference to determine the best possible design concept from the comparison group.

Design-concept performance criteria, which indicate exceptional performance, provide an opportunity to combine criteria from different design concepts to create a new hybrid solution that combines each concept's best attributes.

A Pugh matrix is a qualitative comparison technique that uses pluses, minuses and "S" (same) instead of assigning weighted numerical values to eval-

Design concept comparison / TABLE 1

Concept selection legend Better + Same S Worse –	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5
Performance criteria 1		+	S	S	+
Performance criteria 2		S	+	S	+
Performance criteria 3		S	+	–	S
Performance criteria 4		+	S	–	S
Performance criteria 5		–	+	+	+
Cost 1		S	–	S	+
Cost 2		S	S	+	+
Sum of positives		2	3	2	5
Sum of negatives		1	1	2	
Sum of sames		4	3	3	2

Design concept comparison with hybrid / TABLE 2

Concept selection legend Better + Same S Worse –	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5	Concept 6—hybrid
Performance criteria 1		+	S	S	+	+
Performance criteria 2		S	+	S	+	+
Performance criteria 3		S	+	–	S	+
Performance criteria 4		+	S	–	S	+
Performance criteria 5		–	+	+	+	+
Cost 1		S	–	S	+	+
Cost 2		S	S	+	+	+
Sum of positives		2	3	2	5	**7**
Sum of negatives		1	1	2		
Sum of sames		4	3	3	2	

Red indicates where the table is updated.

uate concept attributes. Table 1 illustrates a basic Pugh matrix used to evaluate potential design concepts.[3] Concept one is the reference concept against which we can compare and evaluate four other design concepts.

The results of the Pugh matrix shown in Table 1 indicate concept No. 5 scores the highest—with a five for the sum of positives and a two for the sum of S's. The Pugh matrix also indicates a potential to improve concept five by creating a hybrid concept from the highest-performing attributes. The Pugh matrix in Table 1 updated with the new hybrid concept is shown in Table 2.

Alternative uses

Although Pugh developed his matrix for design-concept evaluation, there are other potential uses for this tool. Alternatively, the Pugh matrix can be used as a tool for decision-making or situation appraisal. Specific examples include:

- Evaluating plans for computer network defense (CND).
- Allocating resources based on a level-of-care utilization system (LOCUS) for psychiatric and addiction services.
- Evaluating criticality of nonconformance (NC) investigations for medical device manufacturing organizations.

CND plan

The National Institute of Standards and Technology *Recommended Security Controls for Federal Information Systems Special Publication* says, "Security controls are the management, operational, and technical safeguards or countermeasures prescribed for an information system to protect the confidentiality, integrity and availability of the system and its information."[4]

Areas for planning CND are numerous and varied. Whether the defense plans are meant to protect U.S. Department of Defense networks or a privately owned business and its customer information database, most CND plans come down to the basics of maintaining confidentiality, availability and integrity of networks, data, and back-office services such as email, word and data-processing programs. The costs to implement and create minimal burdens to users also are important factors to consider.

Comparison of computer network defense (CND) plans / TABLE 3

	Reference CND plan	CND plan 1	CND plan 2	CND plan 3	CND plan 4	CND plan 5
Confidentiality—information protection						
• Network		+	S	S	–	+
• Data		S	+	+	S	+
• Back-office services		S	S	+	–	S
Availability—information is available on demand						
• Network		S	S	–	+	+
• Data		–	S	S	S	S
• Back-office services		+	+	+	+	+
Integrity—assurance of accuracy and consistency						
• Network		S	+	S	S	+
• Data		–	–	+	S	–
• Back-office services		+	S	–	S	+
Minimal burden to user (ease of use)		–	S	S	S	+
Cost of implementation		S	S	–	+	–
Sum of positives		3	3	4	3	7
Sum of same		5	7	4	6	2
Sum of negatives		3	1	3	2	2

An example of a Pugh matrix for comparing and evaluating potential CND plans is shown in Table 3. This matrix compares CND plan attributes for confidentiality, availability and integrity for the areas of networks, data and back-office services, along with cost and ease of use. Not surprisingly, the matrix indicates CND plans No. 3 and 5 performed best in areas of confidentiality (security) and best overall performance but show a less-desirable cost performance (that is, cost more to implement).

Table 3 indicates a potential for a hybrid CND plan using the attributes for confidentiality of back-office services and data integrity for CND plans Nos. 3 and 5. The resulting hybrid CND plan would have an overall performance that is better than the CND plans in the matrix.

An important consideration for evaluating these CND plans is the security level needed to adequately protect the network and information. The organization evaluating the different CND plans might decide the computer system does not require a higher level of security, in which case, a more economical plan such as CND plan No. 4 may provide adequate security for the organization's computer system needs.

LOCUS

With the increase of managed healthcare programs in the United States, there has been an increased need for a tool written in a common language that clinicians can use to determine the needs of psychiatric patients. The LOCUS guide[5] provides an accepted standard for measuring patient assessments to determine level of care and continued treatment.

The LOCUS system[6] has three main objectives: assessment of adult service needs, service arrays based on level-of-care categories and methodology for quantifying the needs assessment. The level-of-care determination grid[7] shown in Table 4 is used to assess individual needs. The five-point rating scale used by the LOCUS grid ranges from one as the least-severe condition to five as the most severe. The evaluator rates the patient on each parameter (listed as dimensions in the grid shown in Table 4).

A composite rating, located in the grid's bottom row, determines the recommended level of care. The highest score for the dimensions also factors into this determination. For example, the LOCUS grid indicates circled ratings in the level five and six columns that require admission regardless of the composite score (unless shown with an asterisk to indicate a low-stress and supportive recovery environment).

The list of evaluation parameters used by the level-of-care determination grid[8] includes:

1. Risk of harm.
2. Functional status.
3. Medical, addictive and psychiatric co-morbidity.
4. Recovery environment.
5. Treatment and recovery history.
6. Engagement.

While the level-of-care determination grid[9] is used as an aid to determine the individual patient's level of care, the Pugh matrix can assess the system's effectiveness rather than patient needs.

Level-of-care determination grid / TABLE 4

Level of care / Dimensions	Recovery maintenance health management Level 1	Low-intensity, community-based services Level 2	High-intensity, community-based services Level 3	Medically monitored nonresidential services Level 4	Medically monitored residential services Level 5	Medically managed residential services Level 6
Level 1. Risk of harm	2 or less	2 or less	3 or less	3 or less	④ 3	⑤ 4
Level 2. Functional status	2 or less	2 or less	3 or less	3 or less	④* 3	⑤ 4
Level 3. Co-morbidity	2 or less	2 or less	3 or less	3 or less	④* 3	⑤ 4
Level 4A. Recovery environment stress	Sum of 4A + 4B is 4 or less	Sum of 4A + 4B is 5 or less	Sum of 4A + 4B is 5 or less	3 or 4	4 or more	4 or more
Level 4B. Recovery environment support				3 or less	4 or more	4 or more
Level 5. Treatment and recovery history	2 or less	2 or less	3 or less	3 or 4	3 or more	4 or more
Level 6. Engagement	2 or less	2 or less	3 or less	3 or 4	3 or more	4 or more
Composite reading	10 to 13	14 to 16	17 to 19	20 to 22	23 to 27	28 or more

◯ Indicates independent criteria—requires admission to this level regardless of composite score.
* Unless sum of 4A and 4B equals 2

Source: American Association of Community Psychiatrists, "Level of Care Utilization System for Psychiatric and Addiction Services, Adult Version 2000," May 30, 2000.

A Pugh matrix can be used to sum up the overall severities for each admitted patient (column sums). It also can be used to aggregate this patient information and sum the severity frequency of each evaluation parameter for every patient (row sums). This information is analyzed to determine the current use for the psychiatric facility's level-of-care system and predict future demand.

The LOCUS (Table 4) and summary of severities (Table 5) use the same evaluation parameters. While the LOCUS uses a five-point rating scale, the Pugh matrix would use qualitative comparisons. Parameters with ratings of one or two would be categorized as positive to indicate a better condition. Parameters with a rating of three would be categorized as S to indicate moderate severity. Parameters with the most severe ratings of four or five would be categorized as negative to indicate a worse condition.

Table 5 shows an example of how a psychiatric facility might use the Pugh matrix to aggregate LOCUS level-of-care determination grid[10] data for the purpose of determining how its services are used.

Summary of severities / TABLE 5

Reference - moderate	Patient A	Patient B	Patient C	Patient D	Patient E	Sum of negatives	Sum of sames	Sum of positives
LOCUS								
Risk of harm	–	–	S	–	S	**3**	**2**	**0**
Functional status (degree of impairment)	S	–	–	S	S	**2**	**3**	**0**
Medical, addictive and psychiatric co-morbidity	–	–	S	–	–	**4**	**1**	**0**
Recovery environment (level of stress)	S	S	+	S	–	**1**	**3**	**1**
Recovery environment (level of support)	–	–	S	S	S	**2**	**3**	**0**
Treatment and recovery history (responsiveness to treatment and recovery management)	–	–	+	+	S	**2**	**1**	**2**
Engagement	S	–	S	+	–	**2**	**2**	**1**
Sum of negatives (serious or severe)	**4**	**6**	**1**	**2**	**0**			
Sum of same (moderate)	**3**	**1**	**4**	**3**	**4**			
Sum of positives (none or minor)	**0**	**0**	**2**	**2**	**3**			

LOCUS = level-of-care utilization system

By using a Pugh matrix (Table 5) to collect patient data for an extended period and using the patient summaries (bottom rows in Table 5), the psychiatric facility can track monthly patient severity trends (Figure 1, p. 36). This chart also indicates the number of patients admitted is higher at the beginning and end of the year. Also, the severity and level of care required by patients appears to indicate a possible cyclic pattern of peaks during the year's coldest and hottest months.

Another use of the information collected in the Pugh matrix shown in Table 5 is for periodic reports summarizing severities for the LOCUS parameters (the right side of Table 5). This information can be used to determine periodic frequencies of severe evaluation parameters (Figure 2, p. 36). This bar chart indicates the demand on the LOCUS for the psychiatric facility is greatest for medical, addictive and psychiatric co-morbidity, and demand has increased.

Using the same data for the chart in Figure 2, a Pareto chart (Figure 3, p. 37) is created and confirms medical, addictive and psychiatric co-morbidity accounts for the largest demand on the level of care. Given the results indicated by the Pareto chart, the recommendation to this psychiatric facility would be further analysis of data to determine what is causing the increase in the medical, addictive and psychiatric co-morbidity severity to better evaluate the allocation of resources for level-of-care services.

NC investigations

The U.S. Food and Drug Administration's (FDA) Code of Federal Regulations 21CFR820.90 says: "The evaluation of nonconformances shall include a determination of the need for an investigation and notification of the persons or organizations responsible for the nonconformance. The evaluation and any investigation shall be documented."[11]

Conducting evaluations and making decisions to determine the level of NC investigation in FDA-regulated industries, such as medical devices, requires traceability to critical-to-quality (CTQ) requirements such as potential product impact, detection through existing quality checks, frequency of recurrence, interim corrective actions and potential root causes.

Evaluating recent NCs compared to a previous NC that was an escalated investigation based on previously listed criteria would provide documented justification for management decisions to escalate or not escalate an investigation while maintaining CTQ traceability.

Pugh writes, "Choose criteria against which the concepts are to be evaluated."[12] For the Pugh matrix in Table 6, a recurrent NC that was previously escalated to an elevated investigation was chosen as the reference data.

Although this choice was not ideal, the decision to choose this elevated investigation was based on the frequency of recurrence, unknown root causes, NC detected through process controls and interim corrective actions to contain nonconforming product.

In the case of a NC investigation, CTQ attributes that would affect the severity of the NC were chosen as criteria. The initial list included:

1. Potential for NC to affect a product or user.
2. NC detected through process controls.
3. NC that is recurrent or likely to recur.
4. Interim corrective actions available.
5. Known root causes.
6. NC associated with a complaint.

This list was expanded to include strength (potency), identity, safety, purity and quality (SISPQ) to incorporate safety with the 21 U.S.C. requirement[13] for "validation of effects of changes" for drug manufacturers.

Although the Pugh matrix comparison technique typically uses pluses, minuses and S's to show how the concept of interest compares to the established reference, the matrix can be enhanced with colors and shapes to improve understanding.

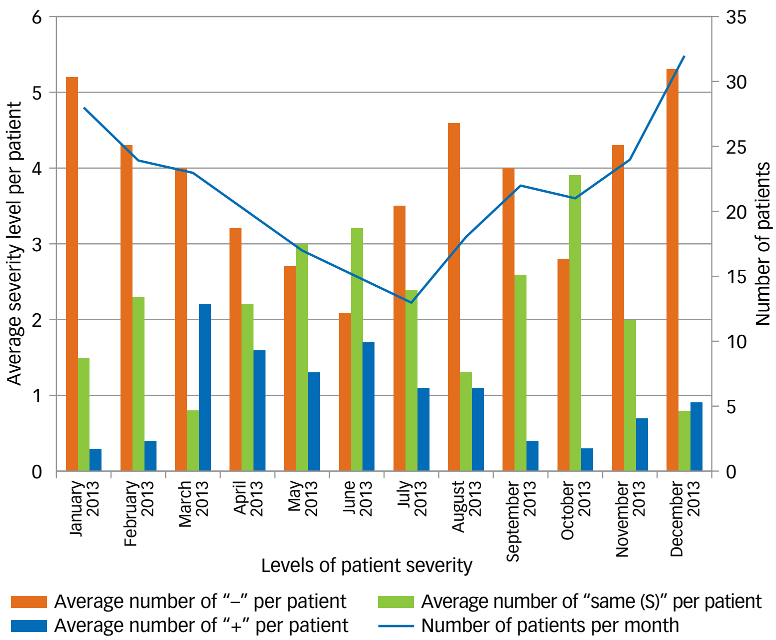
In the instance of the CTQ attribute of NC recurrence, for example, a plus sign that is meant to indicate a condition that is better than the reference (fewer recurrences) might be misinterpreted to mean a greater number of recurrences—a condition that is worse than the reference.

Color indicators were used to show red for a CTQ attribute that is worse than the data, yellow to indicate the same as the data, and green to indicate a better state than the data. Shapes were used with the colors to allow further differentiation (Table 6).

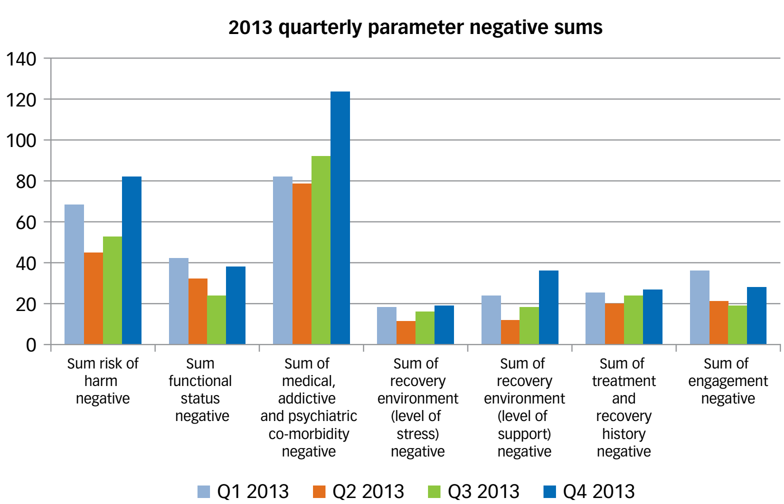
Based on the sum of the color indicators, NC No. 2 shows the overall worst potential impact and is the most likely candidate to be escalated, having four red warning indicators and four yellow caution indicators. That does not mean NC No. 5 with three red warning indicators and three yellow caution indicators should not be escalated.

Although NC No. 5 is not indicating a severity

Trend analysis / FIGURE 1



Bar chart of negatives / FIGURE 2



level as high as NC No. 2, it might still warrant escalation. NC No. 1 (with only one red warning, four yellow cautions and seven green "go" indicators) would not likely be escalated.

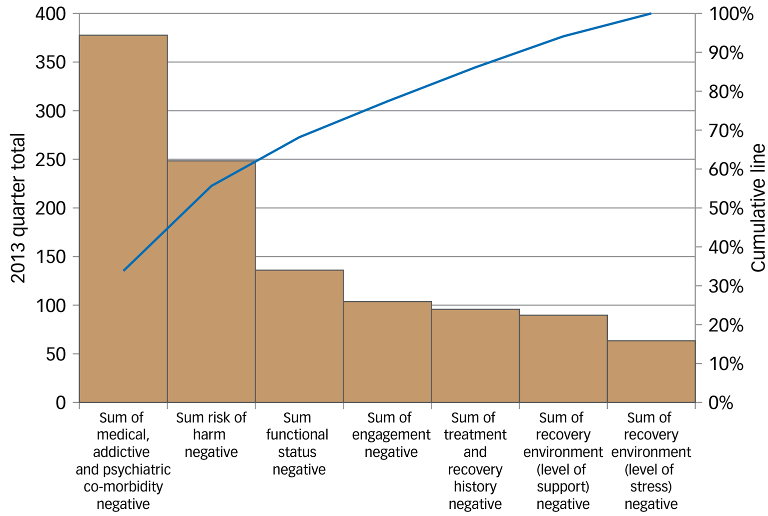
This Pugh matrix for evaluating the criticality of NC investigations has the potential to provide a medical device manufacturer a way to document the CTQ decision-making process used to justify why a recurrent NC requires escalation or does not.

Qualitative vs. quantitative

The Pugh matrix is a qualitative design concept tool that can be used for various situation-appraisal or decision-making opportunities. Anytime an important decision must be made using ratings rather than data, a Pugh matrix should be considered.

Using a purely qualitative comparison tool such as a Pugh matrix for quantitative comparisons gives teams clarity to build consensus for decision making, while providing management with a concise, high-level visual tool to support a team's decisions. QP

Pareto chart of negatives / FIGURE 3



Enhanced matrix / TABLE 6

Nonconformances (NC) evaluated for elevated investigations						
	Reference	NC 1	NC 2	NC 3	NC 4	NC 5
Potential for NC to affect product or user	R	△	⬢	○	△	⬢
NC detected through process controls	E	⬢	⬢	△	⬢	○
NC recurrent or likely to recur	F	○	○	△	△	△
Interim corrective actions available	E	△	△	⬢	△	○
Known root cause(s)	R	○	△	⬢	○	△
NC associated with a complaint	E	○	○	○	○	○
NC product or process specification departure	N	△	⬢	△	△	△
Potential impact to product safety	C	○	○	○	○	○
Potential impact to product identity	E	○	○	○	○	○
Potential impact or product purity		○	△	○	○	○
Potential impact to product strength or potency		○	△	△	○	⬢
Potential impact to product quality		△	⬢	△	⬢	⬢
Sum of red warnings	⬢	1	4	2	2	3
Sum of yellow cautions	△	4	4	5	4	3
Sum of green go	○	7	4	5	6	6

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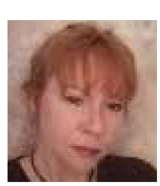

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