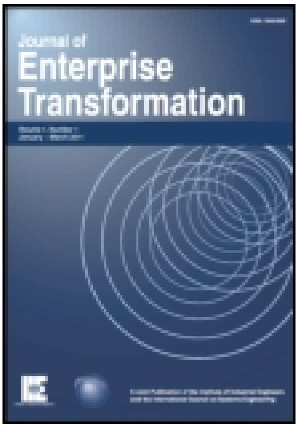

Journal of Enterprise Transformation
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/ujet20

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Version of record first published: 20 Apr 2013.

Journal of Enterprise Transformation, 3:1–15, 2013
ISSN: 1948-8289 print / 1948-8297 online
DOI: 10.1080/19488289.2013.784221

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□ *The goal of this article is to encourage the use of quantitative techniques to improve decision making and operational processes and ultimately facilitate organizational transformation. An Air Force process improvement case is used as the backdrop for the methodology introduced in this article, specifically, the quantification of the Possible, Implement, Challenge, Kill (PICK) quadrant chart for process improvement decisions. The authors use the case example of laboratory chemicals and hazardous materials procurement for Environmental Safety and Occupational Health (ESOH) at the Air Force Institute of Technology (AFIT). The challenge was to improve the procurement process for chemicals and hazardous materials for laboratories. Effective process improvement decisions can improve overall organizational effectiveness, thereby leading to sustainable organizational transformation. The Department of Defense (DoD) has recognized for several years the need for operational improvement in acquisitions, but only limited quantitative approaches have been implemented. This article illustrates how quantitative approaches in industrial engineering can facilitate improved operational decisions. It is anticipated that this article will encourage the use of analytical tools and techniques in working toward military process improvement goals.*

Keywords PICK chart; military process improvement; operational efficiency; industrial engineering; military enterprise transformation

INTRODUCTION

Organizational transformation is achieved by making changes within the organization. Such changes involve facilitating efficiency and effectiveness in organizational processes, such as procurement and acquisition decisions. Any attempt to achieve organizational transformation must be based on leveraging effective decision-making processes within the organization. Industrial Engineering (IE), by virtue of its collective legacy of efficiency, provides a strategic option for achieving the desired organizational transformation through rigorous decision-making approaches. IE is able to

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bridge the gap between quantitative and qualitative factors in the decision environment. This article advocates the use of IE quantitative techniques to improve decision and operational processes to facilitate organizational transformation through improved efficiency and effectiveness. A particular case of Air Force process improvement is used as the backdrop for the methodology introduced here. Specifically, the authors present the quantification of the Possible, Implement, Challenge, Kill (PICK) quadrant chart for process improvement decisions and use the example of laboratory chemicals and hazardous materials procurement for Environmental Safety and Occupational Health (ESOH) at the Air Force Institute of Technology (AFIT).

Any decision environment has an interplay of quantitative and qualitative information, which must be integrated for a defendable decision. For emergency and urgent decision-making needs, managers often resort to intuitive guesswork rather than quantitative analysis. Such qualitative approaches can hardly be defended analytically, even though they may have intrinsic experiential merit, and this issue becomes particularly critical in complex operating environments. The popular analytic hierarchy process (AHP) provides a good coupling of qualitative reasoning and quantitative analysis (Fong and Choi, 2000; Kuo, 2010; Saaty, 2008; Vaidya and Kumar, 2006). It is desirable to achieve similar quantitative and qualitative coupling for other tools. The PICK quadrant chart is a good candidate for applying a quantitative methodology. Incorporating some element of quantification into the PICK chart will make it more defendable as an analytical tool.

This article introduces a quantification technique in the application of the PICK chart. The quantification methodology is motivated by an actual improvement project completed by Racz and Wirthlin (2010) at AFIT. The case involves the procurement of laboratory chemicals and hazardous materials for an ESOH program. The challenge was to improve the procurement process for chemicals and hazardous materials for laboratories. Effective process improvement decisions lead to improved organizational effectiveness and, thus, to sustainable organizational transformation. Transformation, in this sense, refers to changes that move an organization toward its desired goals and objectives. The need for operational improvement in acquisitions has been widely recognized by the Department of Defense (DoD), and to meet new and emerging challenges, it is imperative that new tools and techniques be developed. It is anticipated that this proposed quantitative approach can be migrated to other military decision improvement processes. The proposed quantification technique, coupled with other IE tools and techniques, can facilitate enterprise process improvement and better organizational effectiveness, particularly in acquisition programs. Badiru (2012a) introduced the half-life modeling of learning curves for better decision making in the acquisition life cycle. A quantitative PICK chart approach used in combination with learning curve modeling can generate additional robust decision-making tools.

WHAT IS A PICK CHART?

The PICK chart was originally developed by Lockheed Martin to identify and prioritize improvement opportunities in the company's process improvement applications (George, 2006). It is a very effective Lean Six Sigma tool (Stamatis, 2004) used to categorize process improvement ideas. Its approach is to qualitatively identify the ideas that provide the most value-added options. A 2×2 grid is normally drawn on a white board or a large flip chart. Ideas that were written on sticky notes by team members are placed on the grid based on a group assessment of the payoff relative to the level of difficulty. The iterative approach is to identify the most useful ideas, especially those that can be accomplished immediately with little difficulty. These are called "Just-Do-Its." The general layout of the PICK chart grid is shown in Figure 1. The PICK chart quadrants are summarized as follows:

Possible (easy, low payoff)	$\rightarrow$	third quadrant
Implement (easy, high payoff)	$\rightarrow$	second quadrant
Challenge (hard, high payoff)	$\rightarrow$	first quadrant
Kill (hard, low payoff)	$\rightarrow$	fourth quadrant

The "PICKing" technique is normally done subjectively by a team of decision makers through a group decision process. This can lead to bias and protracted debate of where each item belongs on the chart. Just as the AHP endured in its early years (Calantone, Di Benedetto, and Schmidt, 1999; Chou, Lee, and Chung, 2004; Wong and Li, 2008), the PICK chart is often criticized for its subjective rankings and lack of quantitative analysis. The approach presented here is intended to improve the efficacy of the process

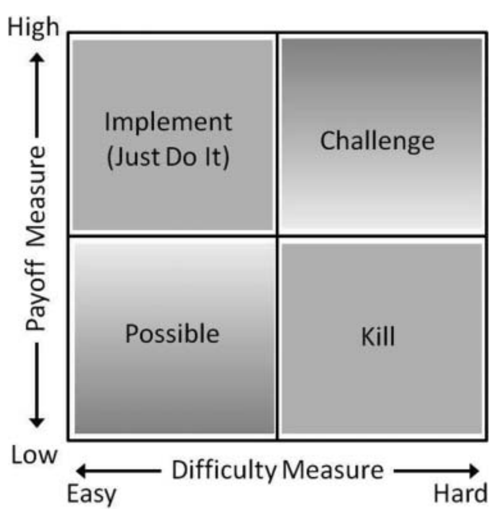

FIGURE 1 Basic layout of the PICK chart.

by introducing some quantitative analysis by normalizing and quantifying the subjective rakings.

LITERATURE BACKGROUND AND APPLICATION SCENARIO

The military enterprise substantively and directly affects the national economy either through direct employment, subcontracts, military construction, or technology transfer. Thus, it is fitting to expect that military process improvement can have direct impacts on general civilian enterprises. Kotnour (2010, 2011) presented the fundamental elements and challenges of enterprise transformation, and his key elements describe successful change as

- leadership driven,
- strategy driven,
- project managed,
- involving continuous learning, and
- involving a systematic change process.

These elements, in the context of Air Force enterprise transformation, are all within the scope of the application of IE tools and techniques. Rifkin (2011) raised questions about the time and cost elements of acquisitions in the context of enterprise transformation. Giachetti (2010) presented guidelines for designing enterprise systems for the purpose of improving decision making. These and similar references show that there is a good collection of IE and business tools and techniques that the military enterprise can adopt for internal process improvement.

Functional integration and efficiencies are a primary goal in the Air Force acquisitions enterprise as well as in other DoD programs. In a report to congressional committees, the Government Accountability Office (GAO, 2011), calls for new approaches to synchronize, harmonize, and integrate the planning and operation of programs in the Intelligence, Surveillance, and Reconnaissance (ISR) enterprise of the DOD. The need for functional integration and efficiencies is depicted in Figure 2. The various diverse elements portrayed in the figure must be aligned and functionally integrated. Figure 3 shows a representation of the life-cycle framework for Air Force acquisitions enterprise based on standard a DoD acquisitions framework. The framework provides an event-based process in which acquisition proceeds through a series of milestones and movable decision points associated with significant program phases. Many of these phases are amenable to the application of quantitative PICK charting of decisions involving project selection, cost baseline, analysis of alternatives, resources allocation options, logistics options, and technology selection.

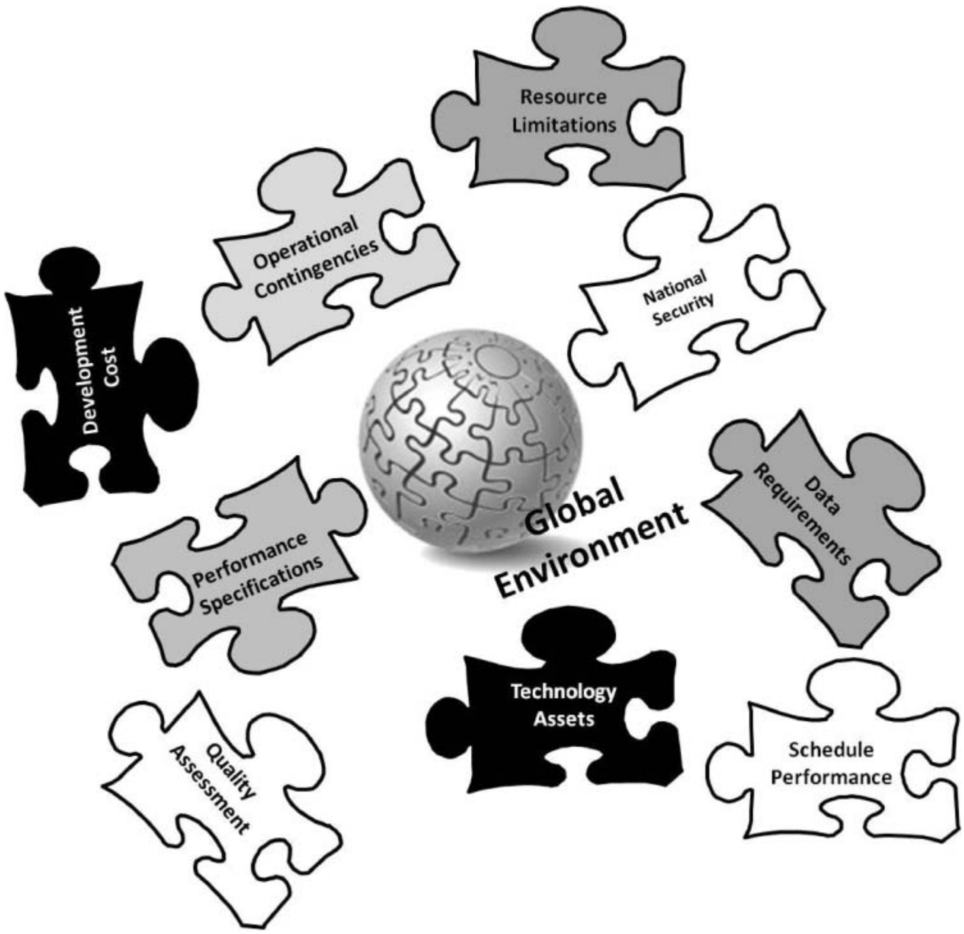

FIGURE 2 Factors of efficiencies and integration in acquisitions enterprise.

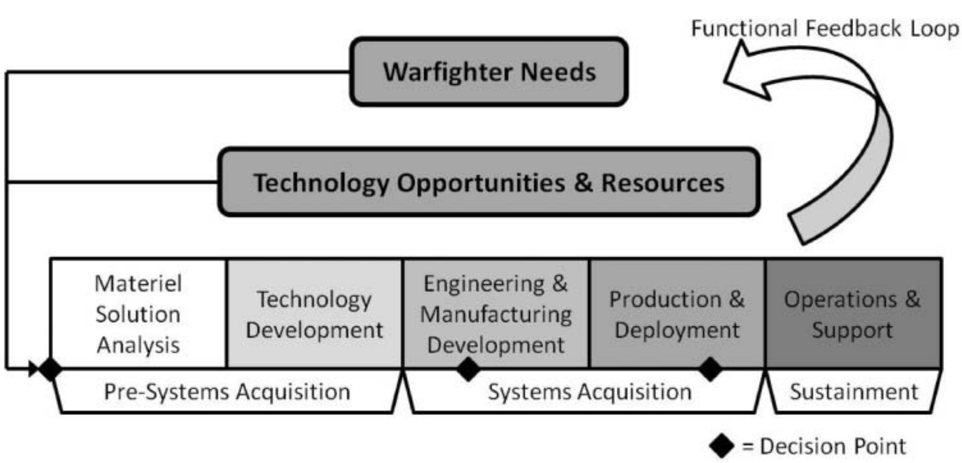

FIGURE 3 Typical Air Force acquisitions life-cycle framework.

In as much as DoD programs are evaluated on three primary and distinct dimensions of cost, schedule, and performance, efforts are being made within and outside DoD to develop quantitative accountability tools for these elements. The quantification of the PICK chart fits that goal. Ward (2012) has been at the forefront of sensitizing DoD to an integrated approach to acquisitions process improvement. With his Fast, Inexpensive, Simple, and Tiny (FIST) model, he has proposed a variety of approaches to improve cost, schedule, and performance for DoD programs. Implementing FIST for acquisitions enterprise transformation for better operational efficiencies will revolve around organizational structure, process design, tools, technologies, and system architecture, all of which have embedded options and requirements. A quantitative application of the PICK chart for decisions and selections across the elements listed above could further enhance the concept of FIST in DOD acquisition challenges.

Gibbons (2011) presented a case example of how Starbucks instituted enterprise transformation to achieve international competitiveness. The same operational improvement that is achieved in the corporate world can be pursued in the military enterprise. Table 1 illustrates how the classical scientific management of Frederick Taylor (1911) has evolved, based on current managerial needs, into contemporary scientific management tools and techniques. The positioning of the PICK chart in the table explains its more recent emergence as a decision tool. The taxonomy in the table can form the backdrop for the implementation of the ongoing Air Force process improvement program known as Air Force Smart Operations for the 21st Century (AFSO21), as described by Badiru (2007). Notice that lean principles, which are the core of AFSO21, apply to several entries in the second column of the table. An analytically rigorous approach to using the PICK chart is desirable in cases when there is only a single opportunity to pick and make the right selection in the decision process.

QUANTITATIVE MEASURES OF EFFICIENCY AND EFFECTIVENESS

The PICK chart may be used as a hybrid component of existing quantitative measures of operational efficiency. Performance can be defined in terms of several organization-specific metrics. Examples are efficiency, effectiveness, and productivity, which usually go hand in hand. The existing techniques for improving efficiency, effectiveness, and productivity are quite amenable for military adaptation. Efficiency refers to the extent to which a resource (time, money, effort, etc.) is properly utilized to achieve an expected outcome. The goal, thus, is to minimize resource expenditure, reduce waste, eliminate unnecessary effort, and maximize output. The ideal (i.e., the perfect case) is to have 100% efficiency; this is rarely possible in practice.

TABLE 1 Classical Scientific Management Compared to Contemporary Techniques

Taylor's classical principles of scientific management	Equivalent contemporary principles, tools, and techniques	Applicability for improving acquisitions efficiency
1. Time studies	Work measurement; process design; Plan-Do-Check-Act; define, measure, analyze, improve, control	Effective resource allocation, schedule optimization
2. Functional supervision	Matrix organization structure; Specific, Measurable, Aligned, Realistic, Timed task assignments; lean principles	Team structure for efficiency
3. Standardization of tools and implements	Tool bins, interchangeable parts, modularity of components, ergonomics, lean principles	Optimization of resource utilization
4. Standardization of work methods	Six sigma processes; observe, orient, decide, and act loop; lean principles	Reduction of variability
5. Separate planning function	Task assignment techniques, Pareto analysis, lean principles	Reduction of waste and redundancy
6. Management by exception	Failure mode and effect analysis (FMEA), project management, Pareto analysis	Focus on vital few, task prioritization
7. Use of slide-rules and similar time-saving devices	Blueprint templates, computer hardware and software	Use of boilerplate models
8. Instruction cards for workmen	Standards maps, process mapping, work breakdown structure, lean principles	Reinforcement of learning
9. Task allocation and large bonus for successful performance	Benefit-cost analysis, value-added systems, performance appraisal	Cost reduction, productivity improvement, consistency of morale
10. The use of differential rate	Value engineering, work rate analysis, AHP, lean principles	Input–output task coordination
11. Mnemonic systems for classifying products and implements	Relationship charts group technology, charts and color coding	Goal alignment, work simplification
12. A routing system	Lean principles, facility layout, PICK chart, DEJI (design, evaluate, justify, integrate)	Minimization of transportation and handling, reduction of procurement cost
13. A modern costing system	Value engineering, earned value analysis	Cost optimization

Usually expressed as a percentage, *efficiency* (e) is computed as output over input:

$$e = \frac{output}{input} = \frac{result}{effort}$$

As will be shown later, the above ratio is also adapted for measuring productivity. For the purpose of Air Force process improvement application, this article offers the following definition of operational efficiency:

> Operational efficiency *is achieved when all participants and stakeholders coordinate their respective activities and consider all the prevailing factors. Thus, overall*

organizational goals can be achieved with systematic input–process–output relationships with the minimum expenditure of resources, yielding maximum possible outputs.

Effectiveness is an ambiguous evaluative term that is difficult to quantify. It is primarily concerned with achieving the specific objectives that constitute the broad goals of an organization. To model effectiveness quantitatively, consider that an "objective" is essentially an "output" related to the numerator of the above efficiency equation. Thus, we can assess the extent to which the various objectives of an organization are met with respect to the available resources. Although efficiency and effectiveness often go hand in hand, they are, indeed, different and distinct. For example, one can forego efficiency for the sake of getting a particular objective accomplished. Consider this statement: "If we can get it done, money is no object." The military, because it is mission driven, often operates this way. If, for instance, our goal is to go from point A to point B to hit a target, and we do hit the target, no matter what it takes, then we are effective. We may not be efficient based on the amount of resources expended to hit the target. For the purpose of this article, a cost-based measure of *effectiveness* is defined as

$$ef = \frac{s_{\mathrm{o}}}{c_o}, \quad c_o > 0,$$

where

ef is the measure of effectiveness on interval (0, 1),
s_o is the level of satisfaction of the objective (rated on a scale of 0 to 1), and
c_o is the cost of achieving the objective (expressed in pertinent cost basis: money, time, measurable resources, etc.).

If an objective is fully achieved, its satisfaction rating will be 1. If not achieved, it will be 0. Thus, having the cost in the denominator gives a measure of achieving the objective per unit cost. If the effectiveness measures of achieving several objectives are to be compared, then the denominator (i.e., cost) will need to be normalized to a uniform scale. Overall system effectiveness can be computed as a summation as follows:

$$ef_{\mathrm{c}} = \sum_{i=1}^{n} \frac{s_o}{c_o},$$

where

ef_c is the composite effectiveness measure, and
n is the number of objectives in the effectiveness window.

Because of the potential for the effectiveness measure to be very small based on the magnitude of the cost denominator, it is essential to scale this measure to a scale of 0 to 100. Thus, the highest comparative effectiveness per unit cost will be 100, while the lowest will be 0. The above quantitative measure of effectiveness makes the most sense when comparing alternatives for achieving a specific objective. If the effectiveness of achieving an objective in absolute (non-comparative) terms is desired, it would be necessary to determine the range of costs, minimum to maximum, applicable for achieving the objective. Then, we can assess how well we satisfy the objective with the expenditure of the maximum cost versus the expenditure of the minimum cost. By analogy, "killing two birds with one stone" is efficient. By comparison, the question of effectiveness is whether we kill a bird with one stone or kill the same bird with two stones, if the primary goal is to nonetheless kill the bird. In technical terms, systems that are designed with parallel redundancy can be effective, but not necessarily efficient. In such cases, the goal is to be effective (get the job done) rather than to be efficient.

Productivity is a measure of throughput per unit time. The traditional application of productivity computation is in the production environment with countable or measurable units of output in repetitive operations. Manufacturing is a perfect scenario for productivity computations. Typical productivity formulas include the following:

$$P = \frac{Q}{q} \quad \text{or} \quad P = \frac{Q}{q}(u),$$

where P denotes productivity, Q is the output quantity, q is the input quantity, and u stands for utilization percentage. Notice that Q/q also represents efficiency (i.e., output/input) as defined earlier. Applying the utilization percentage to this ratio modifies the ratio to provide actual productivity yield. For the military environment, which is a non-manufacturing setting, productivity analysis is still of interest. The military organization is composed, primarily, of knowledge workers whose productivity must be measured in alternate terms, perhaps through work rate analysis. Rifkin (2011) presented the following productivity equation, which is suitable for implementation for the Air Force environment:

$$\begin{aligned} \textit{Product}\,(\text{i.e., output}) &= \textit{Productivity}\,(\text{objects per person} - \text{time}) \\ &\quad \times \textit{Effort}(\text{person} - \text{time}), \end{aligned}$$

where $\textit{Effort} = \textit{Duration} \times \textit{Number of People}$. He suggested using this measure of productivity to draw inference about organizational transformation. This article asserts that greater efficiency, effectiveness, and productivity are not simply a resource availability issue. An organization with ample resources can still be inefficient, ineffective, and unproductive. Thus, organizational impediments, apart from resource availability, should be identified and mitigated. Examples of such impediments are ambiguous process steps, undefined policies, unwritten procedures, lack of communication, cumbersome reporting lines, and wrong organizational structure.

AIR FORCE CASE EXAMPLE OF PICK CHART APPLICATION

As a problem scenario that paves the way for our PICK chart quantification methodology, this section presents a case example of an improvement project at the AFIT (Racz et al., 2010). As a part of the Air Force enterprise transformation effort, high-value projects are selected and targeted for the application of improvement methodologies. One selected project is an acquisitions challenge in the ESOH program in which it is desired to improve the ways the AFIT procures and manages chemicals and hazardous materials for laboratories. Figure 4 illustrates the overall project execution environment for the improvement project. We focus on two examples of the improvement tools used during the ESOH project. The first is a suppliers, inputs, process, outputs, customers (SIPOC) chart, which details the integrated flow of information from the beginning to the end. This is shown in Table 2. The difficulty in concluding the decision with only an SIPOC chart necessitated the search for an alternate method, which led the team to become interested in the PICK chart, albeit with a need for an enhanced implementation.

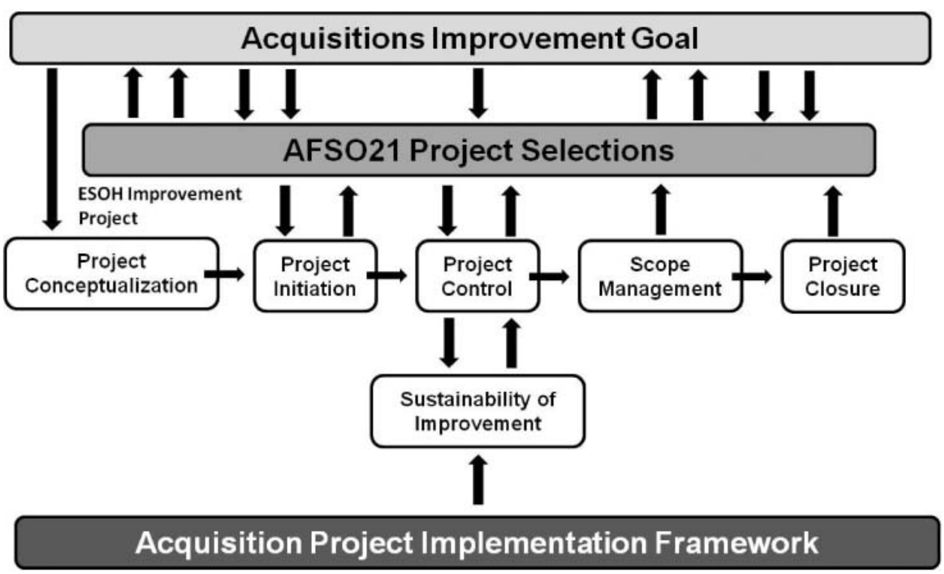

FIGURE 4 Project execution framework for ESOH AFSO21 improvement project.

TABLE 2 SIPOC Chart for ESOH Improvement Project (Racz et al., 2010)

Suppliers	Inputs	Process	Outputs	Customers
Consultants Faculty Chemical vendors Equipment vendors Base system (physical plant, chemical management system, supply/disposal) AFIT management Students/research assistant Comp support Funding agencies Local business Contractors Collaboration with other colleges Local inventor Funding source Base laser safety Inspectors	Training Purchase process Inventory Personal protective equipment (PPE) Site/lab survey Price quotes Government purchase card Federal and local law Time to complete forms Research proposal approvals Equipment Expertise Sponsor requirements DoD guidelines	Value stream maps	Safe working environment Compliance with Air Force, local, state, federal requirements Properly trained students Students perform excellent R&D Student education Useable product for sponsor (equipment, publication, information) Safety culture Degrees Contracts Reports to AF groups, contractors, etc. Excess item disposal	Local, state, and federal agencies Defense financial accounting (invoices, payments) AFIT users (students, faculty, AFRL visitors) Research sponsors Maintenance staff Compliance managers Facility Manager Air Force leadership AFIT regulations

Figure 5 illustrates the PICK chart used for the ESOH project. The horizontal axis, representing ease of implementation, would typically include some assessment of the cost to implement the category. More expensive actions can be said to be more difficult to implement. Although this acquisitions example represents a simple scenario, the same tools, techniques, and decision process used can be expanded and extended to the more complicated higher level acquisitions challenges of the Air Force.

A QUANTIFICATION METHODOLOGY FOR THE PICK CHART

Placing items into one of the four categories in a PICK chart is done through expert ratings, which are often subjective and non-quantitative. To add a quantitative basis to the PICK chart analysis, this article presents a new methodology of dual numeric scaling on the impact and difficulty axes. Suppose each project is ranked on a scale of 1 to 10 and plotted accordingly on the PICK chart. Then each project can be evaluated on a binomial pairing of the respective rating on each scale. For our ESOH example, let x represent level of impact, and let y represent a rating along the axes of difficulty; note that a high rating along x is desirable, while a high rating along y is not

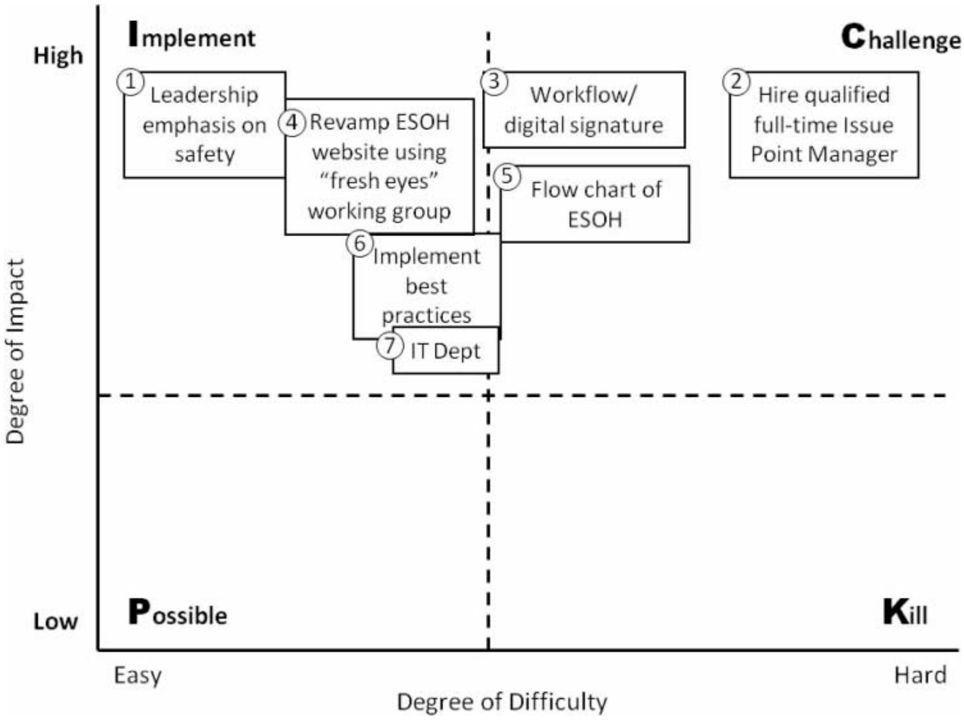

FIGURE 5 PICK chart example for ESOH improvement project.

desirable. Thus, a composite rating involving x and y must account for the adverse effect of high values of y. A simple approach is to define $y' = (11 - y)$, which is then used in the composite evaluation. If there are more factors involved in the overall project selection scenario, the other factors can take on their own lettered labeling (e.g., a, b, c, z, etc.). Then each project will have an n-tuple assessment vector. In its simplest form, this approach will generate a rating such as the following:

$$PICK_{R,i}(x, y') = x + y',$$

where

$PICK_{R,i}(x,y)$ is the PICK rating of project i ($i = 1, 2, 3, \ldots, n$),
n is the number of project under consideration,
x is the rating along the impact axis ($1 \leq x \leq 10$),
y is the rating along the difficulty axis ($1 \leq y \leq 10$), and
$y' = (11 - y)$.

If $x + y'$ is the evaluative basis, then each project's composite rating will range from 2 to 20, with 2 being the minimum and 20 being the maximum possible. If $(x)\,(y)$ is the evaluative basis, then each project's composite rating

TABLE 3 Numeric Evaluation of PICK Chart Rating for ESOH Project

Improvement project	x Rating	y Rating	$y' = 11 - y$	$x + y'$	xy'
1. Leadership emphasis	9	2	9	**18**	81
2. Full-time issue manager	9	10	1	**10**	9
3. Work flow digital signature	9	6	5	14	45
4. Work group process	8	3	8	16	64
5. Work flow chart VSM (value stream mapping)	7	6	5	12	35
6. Implement best practices	7	4	7	14	49
7. Support center, other	6	4	7	13	42

will range from 1 to 100. In general, any desired functional form may be adopted for the composite evaluation. Another possible functional form is

$$\begin{aligned} PICK_{R,i}(x, y'') &= f(x, y'') \\ &= (x + y'')^2, \end{aligned}$$

where y'' is defined as needed to account for the converse impact of the axes of difficulty. The above methodology provides a quantitative measure for translating the entries in a conventional PICK chart into an analytical technique to rank the improvement alternatives, thereby reducing the level of subjectivity in the final decision. The methodology can be extended to cover cases where a project has the potential to create negative impacts that impede organizational advancement. Referring back to the PICK chart for the ESOH example, we develop the numeric illustration shown in Table 3.

As expected, the highest $x + y'$ composite rating (i.e., 18) is in the second quadrant, which represents the "implement" region. The lowest composite rating is 10 in the first quadrant, which is the "challenge" region. This quantitative approach facilitates a more rigorous analytical technique compared to the traditional totally subjective approaches. One concern is that, although quantifying the placement of alternatives on the PICK chart may improve the granularity of relative locations on the chart, it still does not eliminate the subjectivity of how the alternatives are assigned to quadrants in the first place. This is a recognized feature of many decision tools. This can be mitigated by the use of additional techniques that aid decision makers to refine their choices. The AHP could be useful for this purpose. Similarly, application of the design, evaluate, justify, and integrate (DEJI) model (Badiru, 2012b) can be applied to further enhance the option selection process. Quantifying subjectivity is a continuing challenge in decision analysis. The PICK chart quantification introduced in this article offers an improvement over the conventional approach.

STEPS FOR IMPLEMENTING THE PICK CHART

Although the PICK chart has been used extensively in industry, there are few published examples in the open literature. The quantification approach presented here may expand interest in the tool among researchers and practitioners, thus leading to more published works. The tool is effective for managing process enhancement ideas and classifying them during the identification and prioritization phases of a Six-Sigma project. The steps for implementing a PICK chart as a decision tool are now summarized.

Step 1: On a chart, place the subject question. The question needs to be asked and answered by the team at different stages to be sure that the data that is collected is relevant.

Step 2: Put each component of the data on a different note like a post-it or small cards. These notes should be arranged on the left side of the chart.

Step 3: Each team member must read all notes individually and decide whether the element should or should not remain a fraction of the significant sample. The notes are then removed and moved to the other side of the chart. The data is now condensed enough to be processed for a particular purpose by means of tools, such as KJ Analysis, which is a group-focusing approach developed by Japanese Jiro Kawakita to quickly allow groups to reach a consensus on priorities of subjective and qualitative data.

Step 4: Apply the quantification methodology presented above to normalize the qualitative inputs of the team.

CONCLUSIONS

The Air Force has embarked upon several long-term efficiency initiatives, many of which center on organizational transformation programs. For these initiatives to be fully successful, the Air Force must leverage IE tools and techniques. This article has addressed the specific topic of using the PICK chart to improve acquisition process improvement at the AFIT and presented a methodology for quantifying the PICK chart decision process. It is anticipated that the methodology and other quantitative approaches can be extended to other acquisition challenges to make the decision process more rigorous, analytical, and defendable. The technique of quantifying project ratings in a PICK chart is new and useful for justifying improvement projects, and the approach can be extended to more robust application scenarios. Human uncertainty and personal preferences often creep into corporate decision processes, and incorporating some quantifiable measure is a good way to mitigate the adverse effects of qualitative reasoning. It is anticipated that this study will motivate additional examples of how and where IE tools and techniques can be applied in the military and other government institutions. For example, the Air Force has a large number of degreed industrial engineers whose skills and expertise, through appropriate assignments, can directly be applied to Air Force enterprise transformation and process improvement.

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