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R&D Customer Satisfaction Feedback (CSF) Methodology

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Executive Summary

The University of Southern California's (USC) Center for Risk and Economic Analysis of Terrorism Events (CREATE), on behalf of the Technology Scouting and Transition Division (TST) of the Department of Homeland Security (DHS), Science and Technology Directorate (S&T), Office of Science and Engineering (OSE), has developed a working draft of an Research and Development (R&D) Customer Satisfaction Feedback (CSF) methodology responding to a recommendation from the United States Government Accountability Office (GAO)*. The recommended draft CSF methodology, the **S**trategic **M**ultiattribute **R**ating **T**echnique of **C**ustomer **S**atisfaction (SMART-CS) shown in Figure ES-1, features an academically rigorous multi-attribute utility rating technique with a robust analytical basis and widespread use in numerous practical applications. The recommended process integration of the methodology with S&T's Business Process Flow (BPF) 2.0 and Program/Project Management (PM) templates has been identified, as shown in Figure ES-2. The draft methodology has incorporated input and comments from key DHS Stakeholders in the process and was tested in a tabletop exercise (TTX) with the U.S. Coast Guard (USCG). The proposed draft SMART-CS methodology reflects the many rounds of feedback and refinement resulting from stakeholder input. The implementation of this customer feedback mechanism will enable more focused S&T self-assessment, and lead to improvements in R&D outcomes.

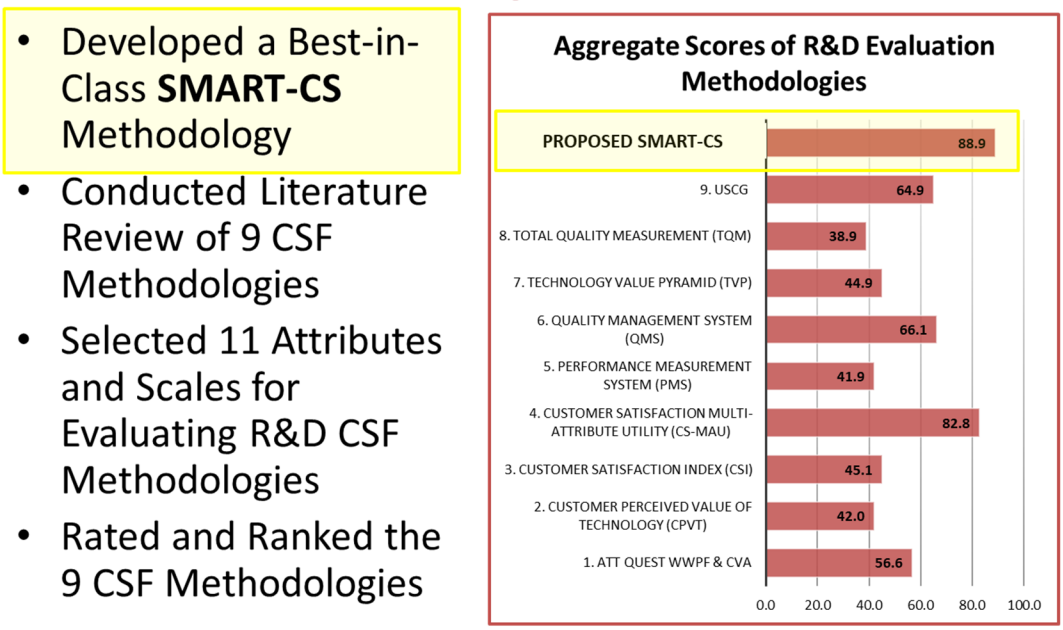


Figure ES-1. The Strategic Multi-Attribute Rating Technique of Customer Satisfaction (SMART-CS) – the S&T R&D Customer Satisfaction Feedback Analysis Model & Tool

*Homeland Security Research & Development Coordination Has Improved, but Additional Actions Needed to Track and Evaluate Projects, United States Government Accountability Office Report, GAO-19-210, March 2019, p. 40. "The Deputy Secretary of the Department of Homeland Security should develop standard processes and procedures for collecting and analyzing customer feedback, applicable to components conducting R&D, for improving the usefulness of existing customer feedback mechanisms to assess R&D efforts and for implementing such mechanisms where absent. (Recommendation 4)"

The draft recommended SMART-CS methodology is a combination of a scientifically grounded multi-attribute utility analysis and an adaptation of methodologies used by the USCG to evaluate R&D projects and to conduct a post-completing review. The multi-attribute utility part consists of customer ratings of R&D projects and products on several outcome criteria, which can be weighted and aggregated into an overall customer satisfaction outcome rating. The criteria were adapted from input received from several operational components, especially drawing from the USCG Post Completion Review methodology, and includes criteria addressing cost savings, improved operational performance, and improved decision making. Also adapting a previous USCG R&D methodology for evaluation R&D projects in transition, the SMART-CS methodology distinguishes the likelihood of use from the potential impact (beneficial outcomes), once actually in use. A total outcome rating is the product of the likelihood of eventual use (from 0-1) and the rating assuming successful implementation and use.

Research products are also rated on two process criteria, adequacy of funding and technical support, leading to a second overall rating reflecting the satisfaction with the process of developing and implementing the R&D product. Different stakeholders can provide independent responses to the questions, leading to possibly different ratings for comparison and use in analyzing the feedback provided. For demonstration purposes, the draft SMART-CS methodology is implemented in Qualtrics with an easy-to-use interface.

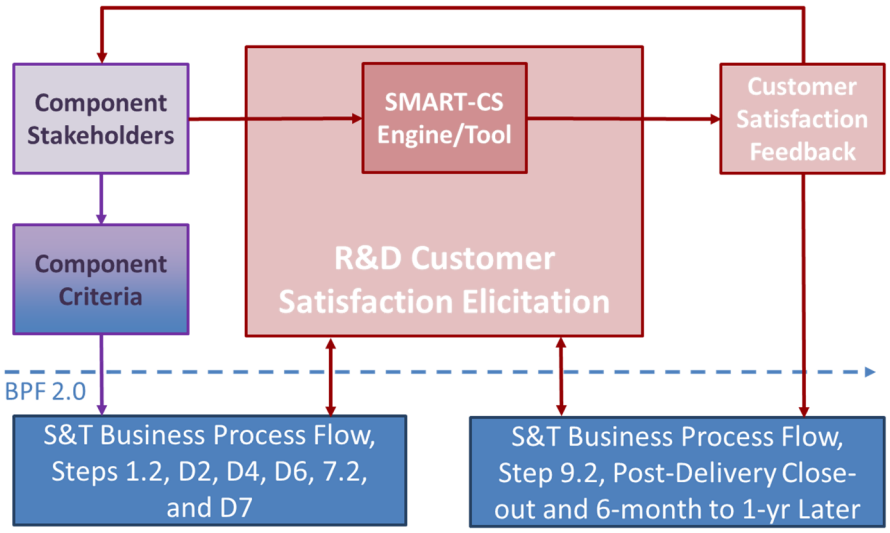


Figure ES-2. Proposed integration of SMART-CS with S&T's Business Processes Flow 2.0

The proposed integration of the draft SMART-CS with the S&T's BPF 2.0 was developed in close consultation with S&T's stakeholders, including the S&T Transition Measures Working Group and the DHS NDAA Transition Measures Working Group, S&T Portfolio Managers (PfMs), the Office of Science and Engineering (OSE)/Tech Centers, and the Office of Mission Capability Support (MCS) Program Managers (PMs). Criteria for quantifying R&D Customer Satisfaction were presented for comment to the operational components (CBP, CIS, CISA, FEMA, ICE, TSA, USCG and USSS). The TTX with USCG Stakeholders was conducted with personnel from its headquarters Research, Development, Testing and Evaluation (RDT&E) division and its Research and Development Center (RDC) in New London, CT. The TTX provided valuable and practical insights and comments on using the SMART-CS methodology.

Table of Contents

Customer Satisfaction Feedback (CSF) Methodology

Isaac Maya, Richard John, Katie Byrd and Detlof von Winterfeldt

1. Introduction

1.1. Background

The effort described in this report is a result of a United States Government Accountability Office (GAO) recommendation for the DHS Science and Technology Directorate (S&T) to "develop standard processes and procedures for collecting and analyzing customer feedback, applicable to components conducting R&D, for improving the usefulness of existing customer feedback mechanisms to assess R&D efforts and for implementing such mechanisms where absent. (Recommendation 4)"[1]

The Customer Satisfaction Feedback (CSF) Methodology described herein aims to achieve the recommended mechanism to assess customers' satisfaction with S&T's R&D projects and products delivered. The activity was conducted as part of a Basic Ordering Agreement (BOA) HSHQDC-17-A-B0004/70RSAT20FR0000097 awarded to the Center for Risk and Economic Analysis of Terrorism Events (CREATE) at the University of Southern California (USC). The activity was conducted in close cooperation with and in support of the Technology Scouting and Transition (TST) Division's Transition Management Branch.

The referenced GAO report further stipulates that the recommended approach should,

- include the ability to scale the feedback mechanism and appropriately collect information to inform both the success of deliverables and project outcomes and business process improvements on new R&D efforts
- be designed to use scientific rigor and knowledge of approaches to accurately capture customer feedback without leading or manipulating responses
- be flexible, but include traceability, to permit for written or in-person collection.

The referenced GAO report further adds that establishing time frames and milestones for collecting and evaluating feedback from its customers will help S&T better determine the usefulness and impact of its R&D projects and deliverables and make better-informed decisions regarding future work. Thus, the proposed methodology should include guidance on the most favorable time frames and milestones for collecting feedback.

Finally, the GAO report highlighted that research on leading practices in the area of customer satisfaction suggests that multiple approaches are needed to effectively listen to customers about their perceptions of quality service and needs. The research also points to a need for centrally integrating all customer feedback so that managers can achieve a better understanding of

[1] Homeland Security Research & Development Coordination Has Improved, but Additional Actions Needed to Track and Evaluate Projects, United States Government Accountability Office Report, GAO-19-210, March 2019, p. 40.

customers' perceptions and needs. It concluded by indicating that it has been previously reported that leading organizations combine quantitative and qualitative listening tools to obtain customer feedback and then centrally integrate the data in one location.

1.2. Technical Approach

CREATE's research team tasked with the development of a Consumer Satisfaction Feedback (CSF) methodology included two psychologists and two systems engineers. All were familiar with previous applications of survey methodologies and their applications to various fields of judgment and decision-making. In addition, three team members were trained in judgment and decision-making methodologies, including decision analysis, risk analysis, multiattribute utility analysis, and risk communication. One team member has previously worked closely with S&T and DHS components on multiple projects, especially related to business flow, transition, and data management.

The task was performed in several steps:

- Literature review, evaluation of alternative methodologies, recommending a hybrid methodology using a combination of best-of features responsive to GAO's stipulations
- Developing the recommended **S**trategic **M**ulti-**A**ttribute **R**ating **T**echnique of **C**ustomer **S**atisfaction (SMART-CS) methodology in detail, including criteria, scoring instructions, and instruments, in detail
- Testing the SMART-CS methodology in a tabletop exercise (TTX) with a DHS operational component customer, the USC Coast Guard (USCG), and revising the methodology based on feedback and the experience
- Documenting the SMART-CS methodology and instruments for its use by S&T

These steps are described in more detail below.

2. Literature Review, Evaluation of Alternative Methodologies, and Recommended Model

2.1. Overview of Literature Review of R&D Customer Satisfaction Feedback (CSF) Methodologies

We conducted a literature search and selected a total of nine methodologies, seven of which (See Table 1, #1-#3 and #5-#8) were published over the past twenty-five years (1995-2020) and were most applicable to R&D customer satisfaction, and that represented a broad range of application domains and general approaches. In addition, we included the USCG methodology (Table 1, #9) that is currently used within DHS S&T, and a version of Multi-Attribute Utility (MAU), adapted for assessing Customer Satisfaction (CS-MAU). Frameworks and key components for each of the nine methodologies are excerpted from the published papers and included in Appendix A.

Table 1. Survey of R&D Customer Satisfaction Feedback (CSF) Literature

Literature Review
1. ATT Quest (WWPF & CVA)
2. Customer Perceived Value of Technology (CPVT)
3. Customer Satisfaction Index (CSI)
4. Customer Satisfaction Multi-Attribute Utility (CS-MAU)

5. Performance Measurement System (PMS)
6. Quality Management System (QMS)
7. Technology Value Pyramid (TVP)
8. Total Quality Measurement (TQM)
9. USCG R&D Customer Satisfaction (USCG)

2.2. Rating Criteria and Ranking of R&D Customer Satisfaction Feedback (CSF) Methodologies

We applied Multi-Attribute Utility Analysis to evaluate the nine identified methodologies listed in Table 1. Following discussions within S&T, and further considering the stipulations in the GAO recommendation, we developed a list of eleven desirable attributes for R&D customer satisfaction feedback methodologies, and converted them to measurable attributes which are listed in Table 2. For each of the attributes listed in Table 2, we constructed a scale that provided a measure of performance of each of the methodologies listed in Table 1. Detailed descriptions of these constructed scales are provided in Appendix B. Note that each value of four or value point scales includes a verbal anchor to facilitate mapping the R&D customer satisfaction evaluation methodologies to a specific level of performance on each attribute. Three of the eleven scales (C, D, and L) utilized natural metrics (counts, time, % s) that did not require verbal anchors.

Table 2. Attributes for Evaluating R&D Customer Satisfaction Feedback (CSF) Methodologies

Attributes for Evaluating R&D Customer Satisfaction Feedback (CSF) Methodologies
A. Ability to Accommodate Value Tradeoffs
B. Ability to Update
C. Application Track Record
D. Ease/Complexity of Required Responses
E. Generalizability and Adaptability
F. Impact Uncertainty
G. Logical Soundness
H. Software Support
I. Time Requirements of Customers
J. Transparency and Communication
K. Uncertainty of Eventual Use Success

The complete score matrix for the eleven attributes (columns) and nine R&D customer satisfaction methodologies (rows) identified in Table 1 is presented in Table 3. In addition, a tenth hybrid R&D customer satisfaction methodology (#10) that includes best-of components of both CS-MAU (#4) and the USGC methodology (#9) was considered. All scores are based on a consensus judgement of team members using information from the available literature. The best and worst possible levels for each of the eleven attribute scales (as described in Appendix B) are provided in the bottom two rows of Table 3.

Table 3. Literature Review Methodology Evaluation, Raw Scale Scores and Scale Ranges

Raw Scores	A. Ability to Accommodate Value Tradeoffs	B. Ability to Update	C. Application Track Record	*D. Ease/ Complexity of Required Responses	E. Generalizability and Adaptability	F. Impact Uncertainty	G. Logical Soundness	H. Software Support	*I. Time Requirements of Customers (hours)	J. Transparency and Communication	K. Transition Success Uncertainty
1. ATT Quest WWPF & CVA	4	2	10	5%	2	1	3	2	0.5	4	1
Fetz (1996)											
2. Customer Perceived Value of Technology (CPVT)	2	2	1	10%	3	1	3	3	1	2	1
Yoon, Jeong, Lee, Lee (2020)											
3. Customer Satisfaction Index (CSI)	2	2	1	10%	3	1	3	3	1	3	1
Sarkar, Batabyal (2011)											
4. Customer Satisfaction Multi-Attribute Utility (CS-MAU)	5	2	10	10%	4	3	4	5	1	3	3
5. Performance Measurement System (PMS)	2	2	0	10%	2	2	2	2	1	3	2
Chiesa, Masella (1996)											
6. Quality Management System (QMS)	2	2	10	10%	2	4	3	2	1	3	4
Auer, Karjalainen, Sappanen (1996)											
7. Technology Value Pyramid (TVP)	2	2	10	10%	2	1	2	2	1	3	1
Schwartz, Miller, Plummer, Fusfeld (2011)											
8.Total Quality Measurement (TQM)	2	2	0	10%	3	1	2	2	1	3	1
Schumann, Ransley, Prestwood (1995)											
9. USCG	1	2	10	5%	2	3	3	2	0.5	4	4
10. Proposed Hybrid Multi-Attribute Utility (H-MAU)	5	2	0	10%	4	3	4	5	1	4	4
Ranges											
Worst Level	1	1	0	100%	1	1	1	1	8	1	1
Best Level	5	4	10	0%	4	4	4	5	0	4	4

*Note: Customer response times (H) and incomplete or unusable response rates (I) are estimates and will depend on the number and complexity of projects evaluated.

The raw scale scores in Table 3 were transformed to create normalized scale scores that range from 0 (worst possible) to 100 (best possible) using the following equation:

Normalized Scale Score = 100*(Raw Scale Score – Worst Level)/(Best Level – Worst Level)

Normalized scale scores are provided in Table 4 for the complete matrix of eleven attributes and ten R&D customer satisfaction methodologies. For each of the eleven attributes, a normalized scale scores of 0 or 100 indicate that the R&D customer satisfaction methodology is at the worst or best level, respectively, as defined by the attribute scales.

Careful inspection of Table 4 indicates that the proposed Hybrid Multi-Attribute Utility methodology (H-MAU) is the better (or equal to) the other nine methodologies on all but three attributes (D, F, and L). Even on these three attributes, H-MAU scores very high, suggesting that H-MAU will outperform the other nine R&D customer satisfaction methodologies for any reasonable set of weights that does not place all weight on one of these three attributes. We aggregated the scores in Table 4 to create an overall index of merit for each of the ten R&D customer satisfaction methodologies based on equally weighting all eleven attribute scores. Equal weighting implies that the range from the worst level (0) to the best level (100) of each scale represents a fixed increment in value that does not vary across attributes. Overall scores for each of the ten R&D customer satisfaction methodologies are presented graphically in Figure 1.

Table 4. Literature Review Methodology Evaluation, Normalized Scores: Best Level = 100; Worst Level = 0

Normalized Scores	A. Ability to Accommodate Value Tradeoffs	B. Ability to Update	C. Application Track Record	*D. Ease/ Complexity of Required Responses	E. Generalizability and Adaptability	F. Impact Uncertainty	G. Logical Soundness	H. Software Support	*I. Time Requirements of Customers (hours)	J. Transparency and Communication	K. Transition Success Uncertainty
1. ATT Quest WWPF & CVA Fetz (1996)	75.0	33.3	100.0	95.0	33.3	0.0	66.7	25.0	93.8	100.0	0.0
2. Customer Perceived Value of Technology (CPVT) Yoon, Jeong, Lee, Lee (2020)	25.0	33.3	10.0	90.0	66.7	0.0	66.7	50.0	87.5	33.3	0.0
3. Customer Satisfaction Index (CSI) Sarkar, Batabyal (2011)	25.0	33.3	10.0	90.0	66.7	0.0	66.7	50.0	87.5	66.7	0.0
4. Customer Satisfaction Multi-Attribute Utility (CS-MAU)	100.0	33.3	100.0	90.0	100.0	66.7	100.0	100.0	87.5	66.7	66.7
5. Performance Measurement System (PMS) Chiesa, Masella (1996)	25.0	33.3	0.0	90.0	33.3	33.3	33.3	25.0	87.5	66.7	33.3
6. Quality Management System (QMS) Auer, Karjalainen, Sappanen (1996)	25.0	33.3	100.0	90.0	33.3	100.0	66.7	25.0	87.5	66.7	100.0
7. Technology Value Pyramid (TVP) Schwartz, Miller, Plummer, Fusfeld (2011)	25.0	33.3	100.0	90.0	33.3	0.0	33.3	25.0	87.5	66.7	0.0
8.Total Quality Measurement (TQM) Schumann, Ransley, Prestwood (1995)	25.0	33.3	0.0	90.0	66.7	0.0	33.3	25.0	87.5	66.7	0.0
9. USCG	0.0	33.3	100.0	95.0	33.3	66.7	66.7	25.0	93.8	100.0	100.0
10. Proposed Hybrid	100.0	33.3	100.0	90.0	100.0	66.7	100.0	100.0	87.5	100.0	100.0

* Note: Customer response times (H) and incomplete or unusable response rates (I) are estimates and will depend on the number and complexity of projects evaluated

The top two methodologies are both based on versions of multiattribute utility analysis (H-MAU and CS-MAU). As indicated in Table 4, H-MAU (#10) dominates CS-MAU (#4), since H-MAU is equal to or better than CS-MAU on all eleven attributes. It is clear that the proposed hybrid, combining elements of both CS-MAU and the USCG methodology, is the best-in-class for evaluating R&D customer satisfaction. The proposed hybrid, H-MAU, was selected as the recommended R&D customer satisfaction methodology.

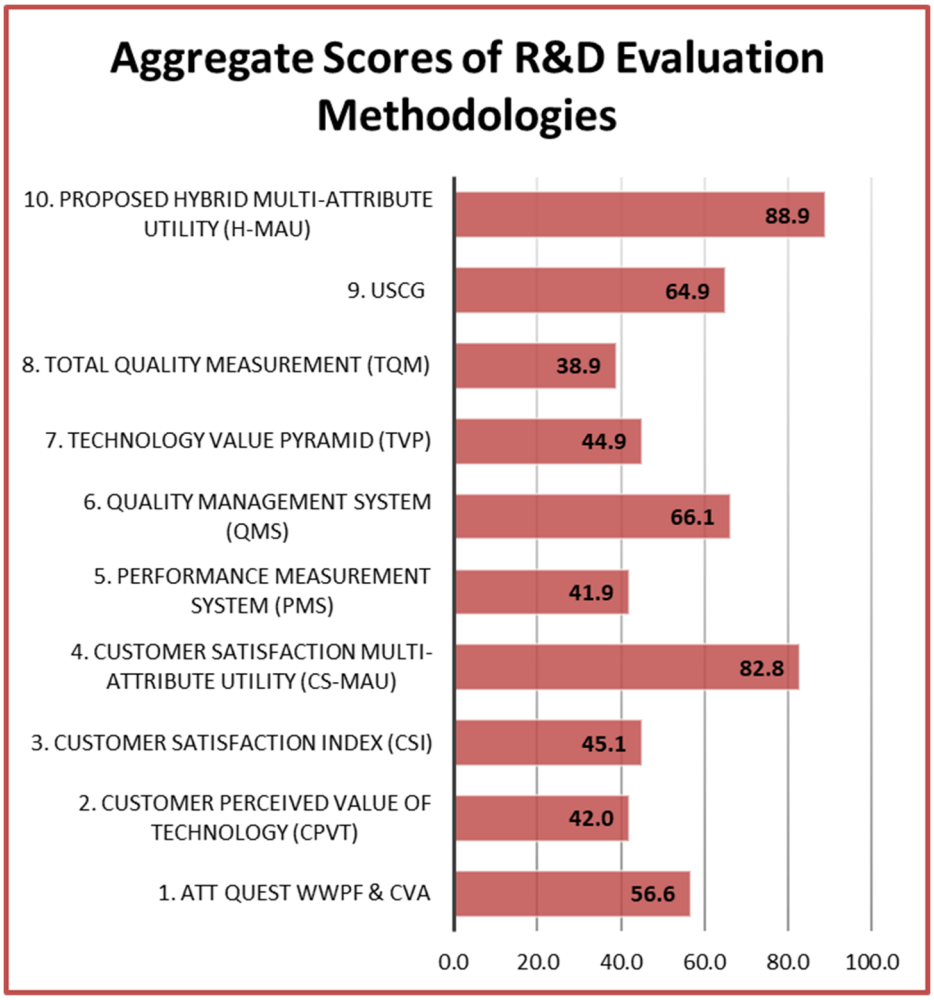


Figure 1. Aggregate Scores of R&D Customer Satisfaction Feedback (CSF) Evaluation Methodologies. Evaluation results assume equal weights across all 11 criteria.

2.3. Recommended Strategic Multi-Attribute Ranking Technique for R&D Customer Satisfaction

As shown in Figure 1 and discussed above, three existing methodologies scored highest in the evaluation: The multiattribute utility methodology (82.8 out of a possible score of 100), the Quality Management System (66.1) and the USCG Post Completion Review and related methodologies for R&D project evaluation. (64.9). The Quality Management System is conceptually and practically very similar to the multiattribute methodology. The USCG methodology included several interesting aspects that were different, though, including the use of transition likelihood and the distinctions between outcome and process criteria in customer satisfaction. The CREATE team therefore created the hybrid in the form of a combination of the best-of features from the USCG and the multi-attribute methodology, and hereinafter referred to as the **S**trategic **M**ulti-**A**ttribute **R**ating **T**echnique of **C**ustomer **S**atisfaction (SMART-CS), described in the following section.

3. The SMART-CS Methodology

3.1. S&T R&D Stakeholders

The stakeholders in the CSF methodology process include both the feedback providers (the recipients of the R&D products) and those that are providing the R&D service (the R&D performers). In addition, it is important to acknowledge that there is a third group of stakeholders that includes the ultimate budget providers/authorizers, i.e., Congressional representatives, accountability for the reporting of R&D transitions per the National Defense Authorization Act of 2017 (NDAA)[2], and the general public, the ultimate beneficiaries of the true impact of R&D products leading to improved homeland security. The constituents in each of these groups are listed and discussed below.

In practice, conducting the SMART-CS methodology will require that the appropriate stakeholders in each of these groups are clearly identified and engaged early in the process. This will ensure that all parties impacting the satisfaction rating are aware of the SMART-CS methodology, the satisfaction scoring criteria, and the overall evaluation process. Though all of the positional individuals in the list are affected by and are interested in the R&D products, the likely key stakeholders and participants in the SMART-CS evaluation are identified with an * below.

- **Component-Side Customers (R&D Satisfaction *Feedback Providers*)**
  - Component Leadership
  - **Component's Requirements and Capabilities Analysis Unit (variously named), and its S&T POC*** -- it is critical that both a representative from this group, which is intimately familiar with the Component's need for the R&D, and the designated S&T representative/POC be engaged early in the process as described in S&T's Business Process Flow (BPF) integration section below.
  - Component's Acquisition Organization
  - Component's Policy and Standard Operating Procedures (SOP) Integration Organizations
  - System/Hardware/Software Implementation and Integration (Operational and IT)
  - **End-user's Supervisor*** -- as the person likely responsible for the performance of the ultimate End-User of the R&D product, this position has a vested interest in the outcome of the R&D.
  - **Field-level End-user*** -- the ultimate recipient/user of the R&D product, and the likely most affected and familiar personnel with the impact of the R&D results

  *** 4 Primary SMART-CS Respondent Stakeholders**

[2] NDAA reference

- **S&T-Side (R&D Satisfaction Providers)**
  - DHS and S&T Leadership
  - **S&T Portfolio Supervisors and Managers (PfMs), Component POCs*** -- The PfMs report to the PfM Supervisors and lead S&T's Component customer engagements, and are thus the ultimate responsible parties in the R&D outcomes.
  - **S&T Program and Project Managers (PMs)*** -- The PM is assigned by the PM Coordinator (PMC) and/or Supervisor PM (Supv PM) for each R&D effort, and organizationally reports directly to a Supv PM, but is accountable to the Operations and Requirements Analysis Division (ORA) PfM for project alignment to IPT requirements and project success. A PM may simultaneously manage multiple projects spanning various portfolios.
  - S&T's Operational Requirements Analysis Division (ORA)
  - R&D Performers' Company Leadership
  - R&D Performers' Program and Project Managers
  - R&D Performers' Personnel

  *** 2-4 Primary SMART-CS *Feedback Receiver* Stakeholders**
- **Other Stakeholders (R&D accountability and beneficiaries)**
  - Congress and Congressional Staffers
  - General Public

3.2. Customer Satisfaction Criteria

The CREATE team reviewed criteria used in other CSF methodologies (see section 2), and interviewed multiple component stakeholders at DHS to determine the criteria used in the past or wished to be used in the future to gauge R&D customer satisfaction. Some of the results are shown in Table 5.

The criteria colored in **red** were related to outcomes of the research, which generally are considered the most important criteria. For example, Cost Impact, Operational Impact/Effectiveness, and Value. Other criteria are related to the process and communication with R&D staff and PMs experienced by the customer, for example, Responsiveness by R&D Staff, Timeliness, Operator Assessment Surveys. Yet others refer to the stages of the R&D process and the maturity of the R&D project or product, for example, % towards final operational capability, Meeting KPPs. In addition to these criteria, a methodology developed by the USCG R&D Center to evaluate projects not yet transitioned separated the evaluation into an assessment of the likelihood of a successful transition and a (holistic) assessment of the impact

on USCG decision making and operations, if successfully transitioned (see von Winterfeldt et al. for a description of this distinction)[3].

It should be noted that the satisfaction criteria could offer several pre-determined scales developed for different expected R&D products/outputs, e.g., a knowledge product vs a software tool, vs a physical technology, or perhaps based on the expected impact, e.g., reduced costs, improved efficiencies, faster response, etc.

[3] von Winterfeldt, D., Farrow, S., John, R., Eyer, J., Rose, A., & Rosoff, H. (2020). Assessing the Benefits and Costs of Homeland Security Research: A Risk-Informed Methodology with Applications to the U.S. Coast Guard. *Risk Analysis,* 40, 3, 450-475.

Table 5. Customer Satisfaction Criteria Collected from Reviews and Interviews

USCG (1-5 scale)	CBP	General R&D Satisfaction Criteria Options
Overall Evaluation	**Technology Progress/Advancement**	**R&D/Technology Results**
Ease of Use - The effort required to request and use R&D Program Support was reasonable.	Did the R&D product reach Initial Operational Capability (IOC)?	**Operational Impact - Effectiveness:** How well do the R&D results meet operational impact goals (reduced cost, reduced risk, improved efficiency, etc.)
Customer Satisfaction - Overall, the project execution & product(s) met my expectations.	What percent of the Key Performance Parameters (KPPs) were 100% met/partially met?	**Cost Impact** – Operational Process, Acquisition, Implementation, Maintenance: How much will the new technology cost to implement for start-up/acquisition and for maintenance (lifetime cost)
Repeat Business - I would choose the R&D Program to do work for me in the future.	What % towards Final Operational Capability (FOC) was achieved?	**Operational Process Changes Needed to Implement:** How much change to current processes will be required to functionally implement/integrate the R&D results
	Were Operator Assessment Surveys conducted?	**Training Needs:** How much start-up and on-going training will be required to implement the R&D results
Project Execution/Deliverable Evaluation		**S&T's R&D Management Process**
Timeliness - I received the R&D product or services when promised.		**Administrative Overhead:** How much time/effort was required to properly support the R&D effort
Utility - The product or services met my needs.		**Effectiveness:** How effective was S&T's Business Process Flow in focusing the R&D project on stated gaps, needs and requirements
Value - The product or service was worth the investment.		**R&D Selection Process:** Did S&T select the appropriate solution approach to address the component's requirement/need/gap?
R&D Staff Evaluation		**R&D Performance**
Technical Knowledge - The R&D staff had the expertise to do the job.		**Performer/Company:** How qualified were the Subject Matter Experts (SMEs) and performers to conduct the R&D effort?
Responsiveness - The R&D staff listened to and addressed my suggestions, concerns, and requirements.		**PM:** How well did the S&T PM understand the component's process for implementing the R&D results? How well did the PM communicate progress/status/risks?
Communications - R&D staff kept me informed throughout project execution.		**Resourced:** Was the budget for the R&D appropriate for its intended purpose/goals?
What could we do to make you a more satisfied customer?		

The SMART-CS methodology focuses on expected/anticipated outcome criteria. However, we also recognize the importance of calibrating and incorporating the maturity of the R&D project, if its R&D output product is not yet in use. Therefore, we added criteria related to the probability of an eventual successful use and the timeline for its use, similar to the USCG R&D Center's distinctions. These criteria are combined into an outcome rating, weighted by the probability of successful use. Though what ultimately count most for satisfaction are outcomes, we also account to a lesser degree with the process by which they were achieved. Therefore, we added two criteria related to effectiveness, one criterion on the degree to which the R&D project was adequately funded, and a criterion related to the appropriateness of the degree of skills of the technical staff involved in the R&D project. These two latter criteria are combined into a process rating.

The questions related to the criteria and the measures used in the SMART CS are:

1. Is the R&D product currently in use? (yes/no)
2. If not yet in use, Why not? There is much useful feedback that can be gained from understanding the Why Not reasons, as they can be categorized into R&D-related and Non-R&D Related.
3. Also if not yet in use, what is the probability of its eventual successful use? (sliding scale from 0-100%)
4. Also if not yet in use, what is the expected timeline for the anticipated R&D product to be used (sliding scale from weeks to months to years).

The following outcome question then addressed the likely benefits, once it is in use.

5. What are the primary benefits of the R&D product? (Multiple choice listing of 5 benefit categories plus one "other" category to be specified by the respondent; multiple benefits can be chosen). Benefit categories are:

    a. Cost savings
    b. Reduction of effort (e.g., less staff hours)
    c. Improved performance of operations
    d. Improved decision making (value of information)
    e. Improved staff performance through training

6. The magnitude of the benefits is determined with three questions (example: Cost Savings):

5.1 What is the annual baseline cost (If baseline is not known, assume that it is 100%)

5.2 Savings Relative to the Baseline Cost (Sliding scale from 0% to 100%)

5.3 Degree of confidence in the response (low, moderate, high)

The scales for gauging the benefits for decision-making or improving staff performance through training were somewhat simpler in terms of 4-point scales of the relative degree of performance in both criteria.

These criteria and associated scales are shown in more detail in the actual Qualtrics implementation of the SMART-CS, which follows in the next section.

3.3. Qualtrics Implementation of the SMART-CS Methodology

Figure 2 shows the question flow of the questions in the Qualtrics implementation of the SMART-CS methodology, followed by a series of screenshots of each question (Figures 3-15). As indicated in Figure 2, there are three branching questions that control the presentation of question screens. The first is a question about the R&D product being in use. If the product is or has been in use, the respondent is directed to a screen listing five possible benefits of the R&D product; if the product has not yet been used (or the project's outcome is unclear), the respondent estimates the likelihood of eventual use and the approximate timing of the possible use. Following these use uncertainty and timing questions, the respondent is directed to the expected/anticipated benefits identification page. For each of the benefits identified (checked), respondents branch to a series of either one or three questions; three benefits require baseline estimates, % change attributable to the R&D product, and a confidence rating, while two benefits each consist of a single multiple-choice question. Following completion of questions for each of the checked benefits, two questions related to process are presented, followed by the third branching question that allows respondents to either return to the first question to review and possibly modify their responses, or to submit the responses. Once submitted, responses are stored in a Qualtrics file, and may be exported and downloaded in a variety of formats, including delimited text, Excel, and SPSS.

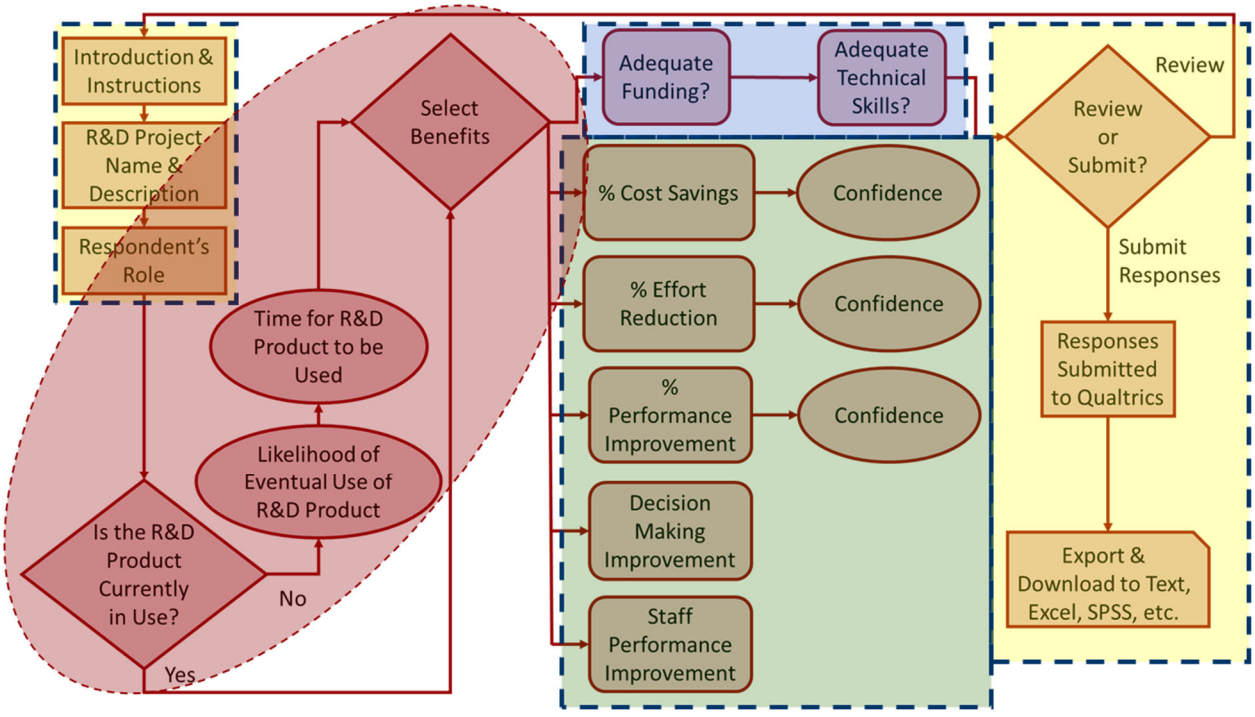


Figure 2. Flowchart of Question Sequencing and Branching in the Qualtrics Implementation of SMART-CS

There are six questions about the R&D project and the respondent's role relative to the R&D project, none of which ask for personal data. Four questions address the use of the R&D product, one question about benefit categories, one or three questions per selected benefit category, and two questions about process (funding level and technical skills of R&D staff). The minimum number of questions is 12 (4 for the role of respondent; one to determine if the R&D product is in use, and if yes; 1 for benefit categories; 1 or 3 for degree of benefit if only one benefit category is chosen, and 2 for process satisfaction). The maximum number of questions is 20, if all five benefit categories are chosen, a rare occurrence. Thus, the total time for completing the questionnaire will usually be around 5-10 minutes and rarely above 10 minutes.

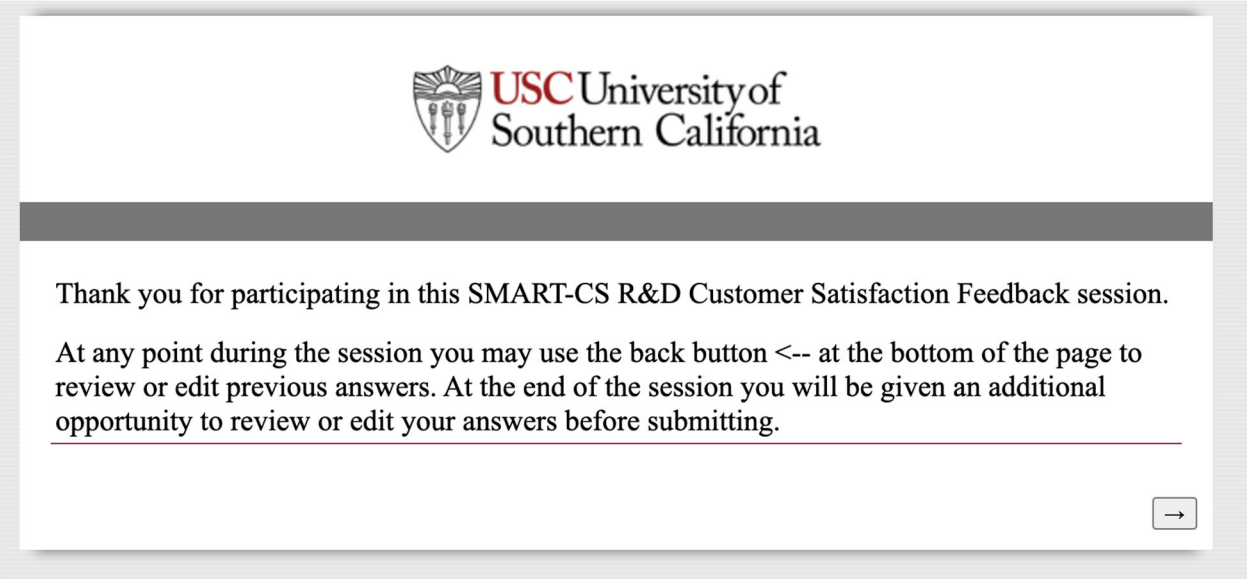


Figure 3. Qualtrics introduction and instructions.

Please help us categorize your role in the R&D implementation process.

Name of R&D Project

R&D Product Description

Responder's Operational Component
(e.g., CBP, FEMA, USCG)

Responder's Organizational Group within Component
(e.g., CBP/USBP/Sector/Station, USCG/DCMS/RDT&E, etc.)

Responder's Role in the R&D Process
(e.g., PM, Field/Group Supervisor)

Intended End-User's Organizational Role
(e.g., Analyst, First Responder, Border Patrol Agent, etc.)

← →

Figure 4. Qualtrics questions regarding the R&D project, and the respondent's role in the R&D project.

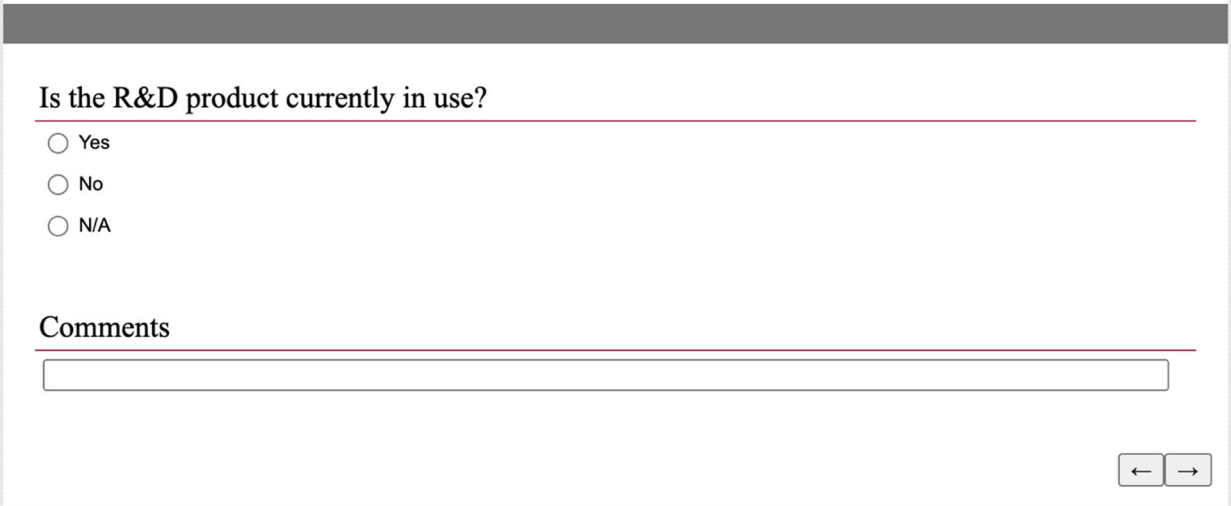


Figure 5. Qualtrics question about whether R&D product is currently in use.

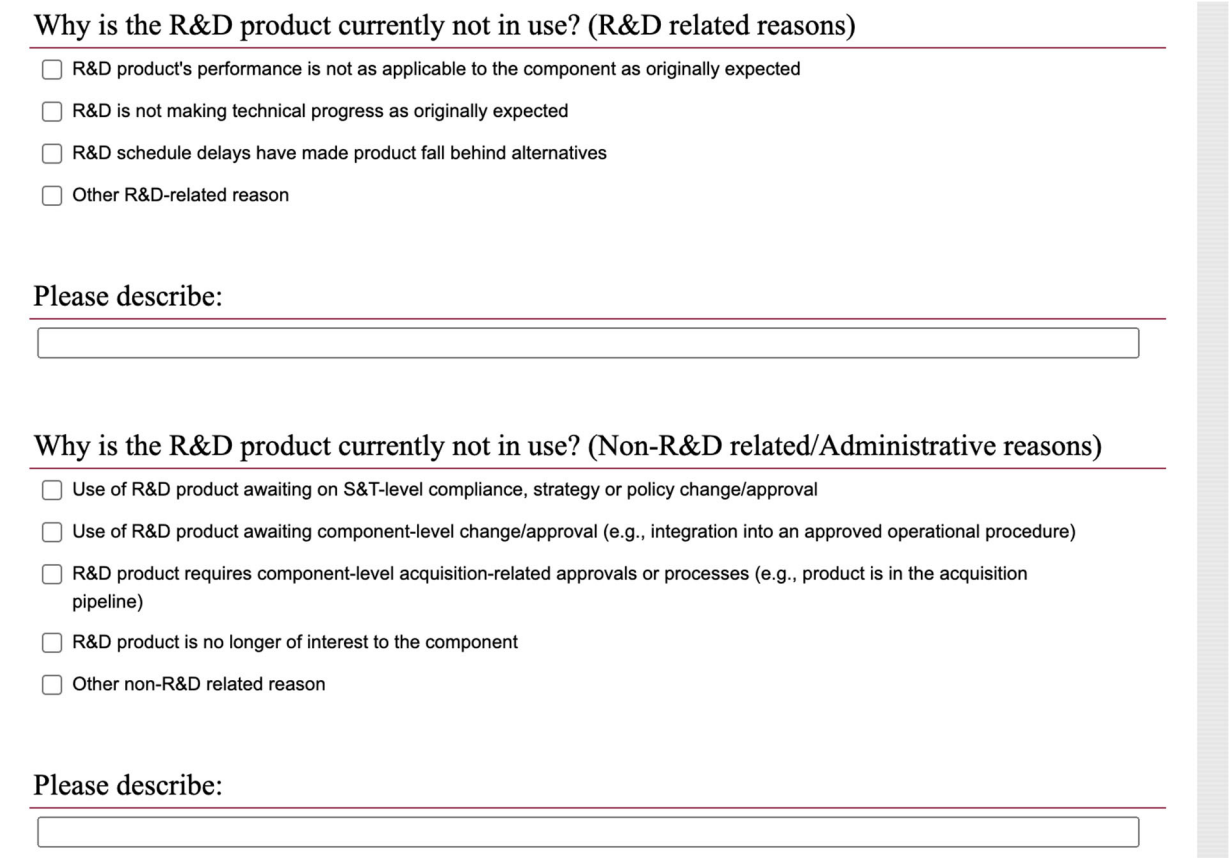


Figure 6. Qualtrics questions about reasons for R&D Product Not Being in Use.

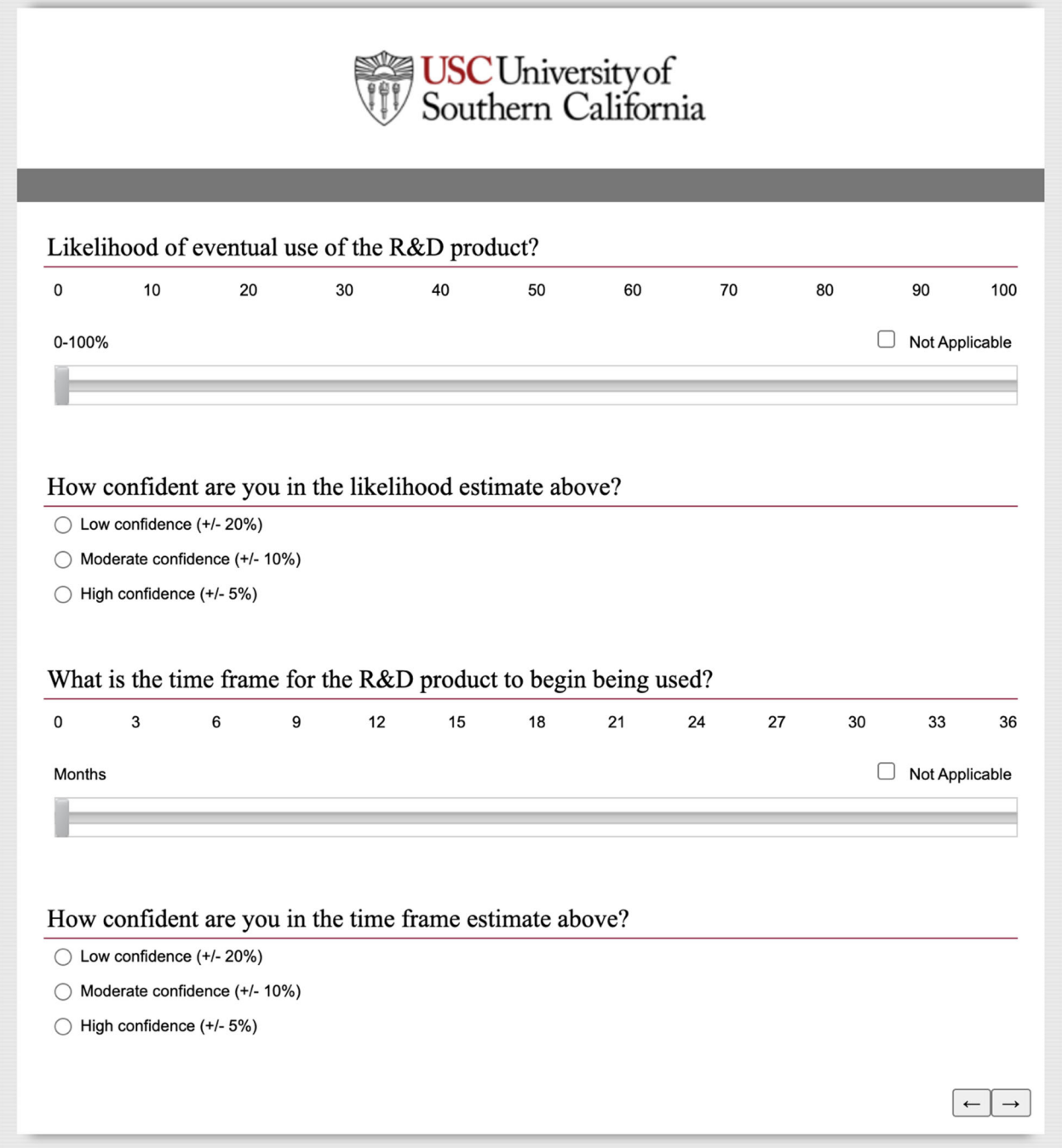


Figure 7. Qualtrics question about likelihood and timing of the R&D product being used.

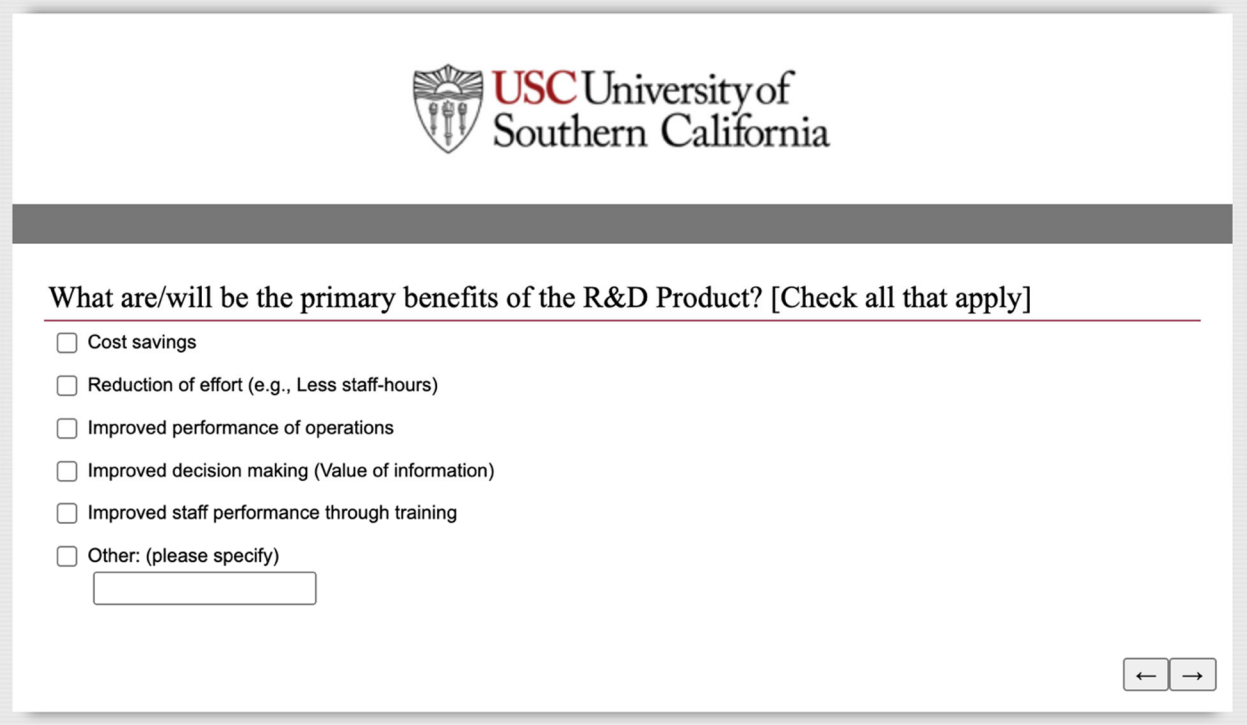


Figure 8. Qualtrics question to identify primary benefits of the R&D product.

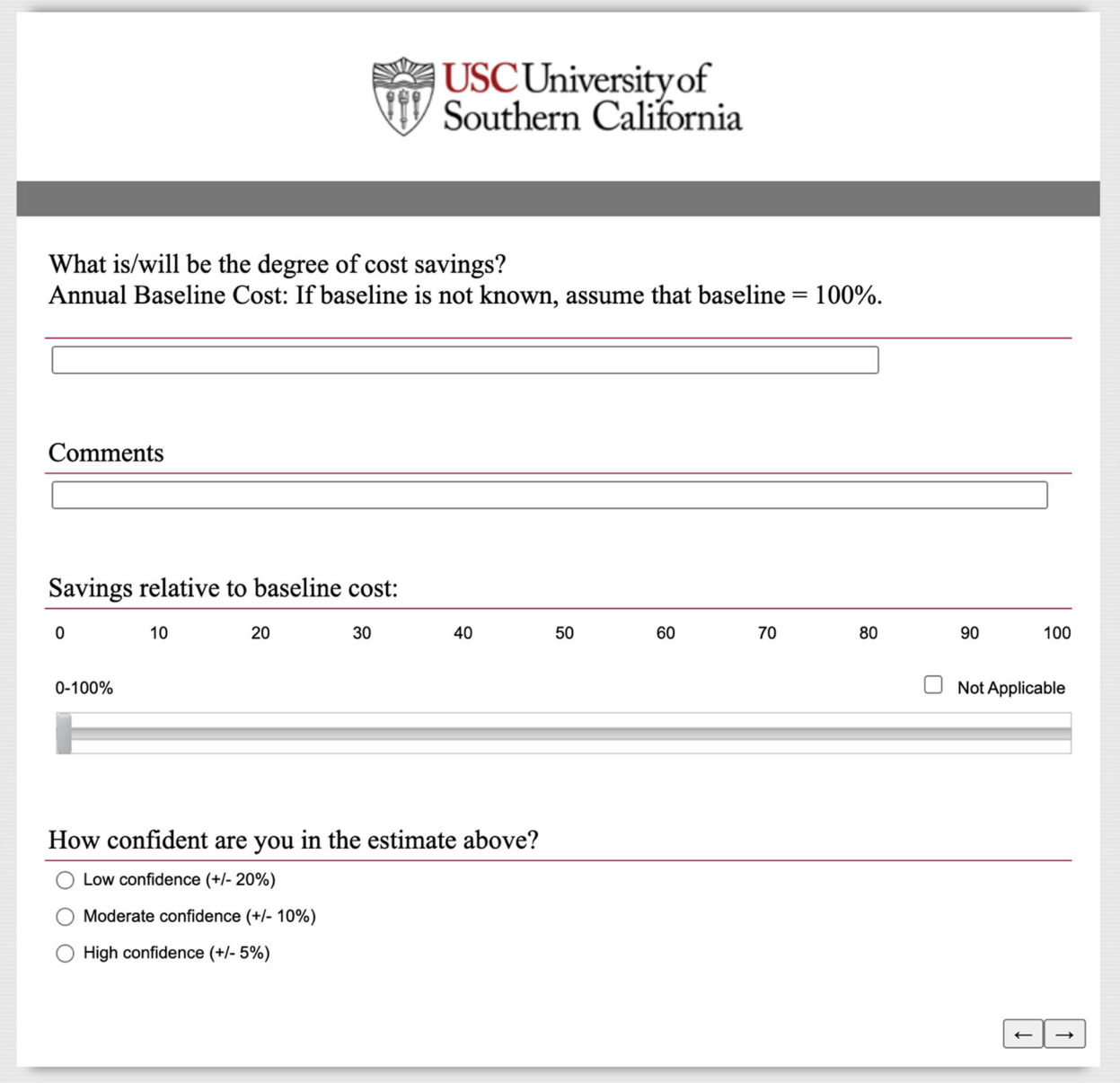


Figure 9. Qualtrics questions to estimate baseline cost ($), % savings relative to baseline, and confidence level of estimated savings %

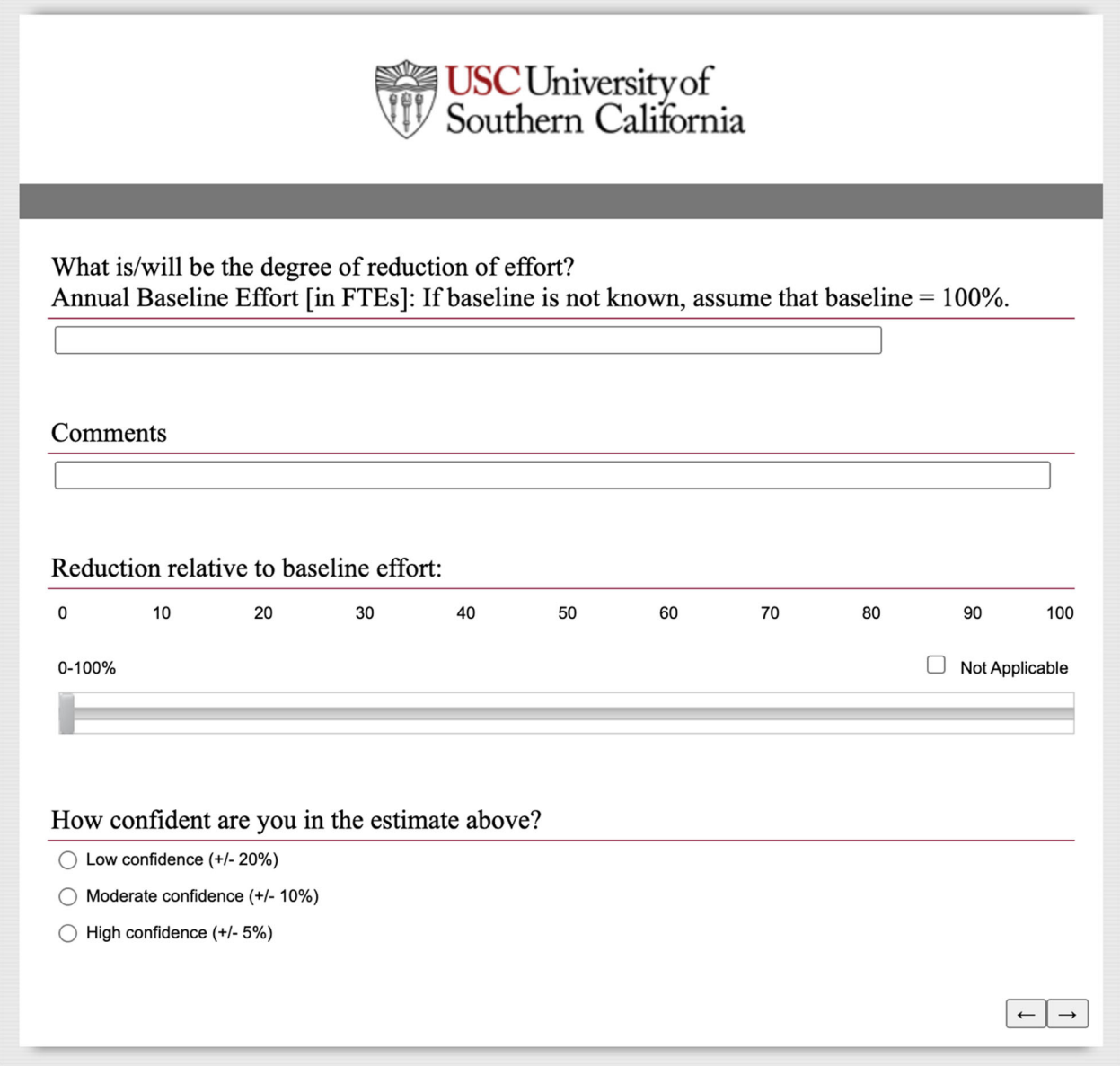


Figure 10. Qualtrics questions to estimate baseline effort (in personnel Full-Time Equivalents, FTEs), % reduction relative to baseline, and confidence level of estimated reduction %

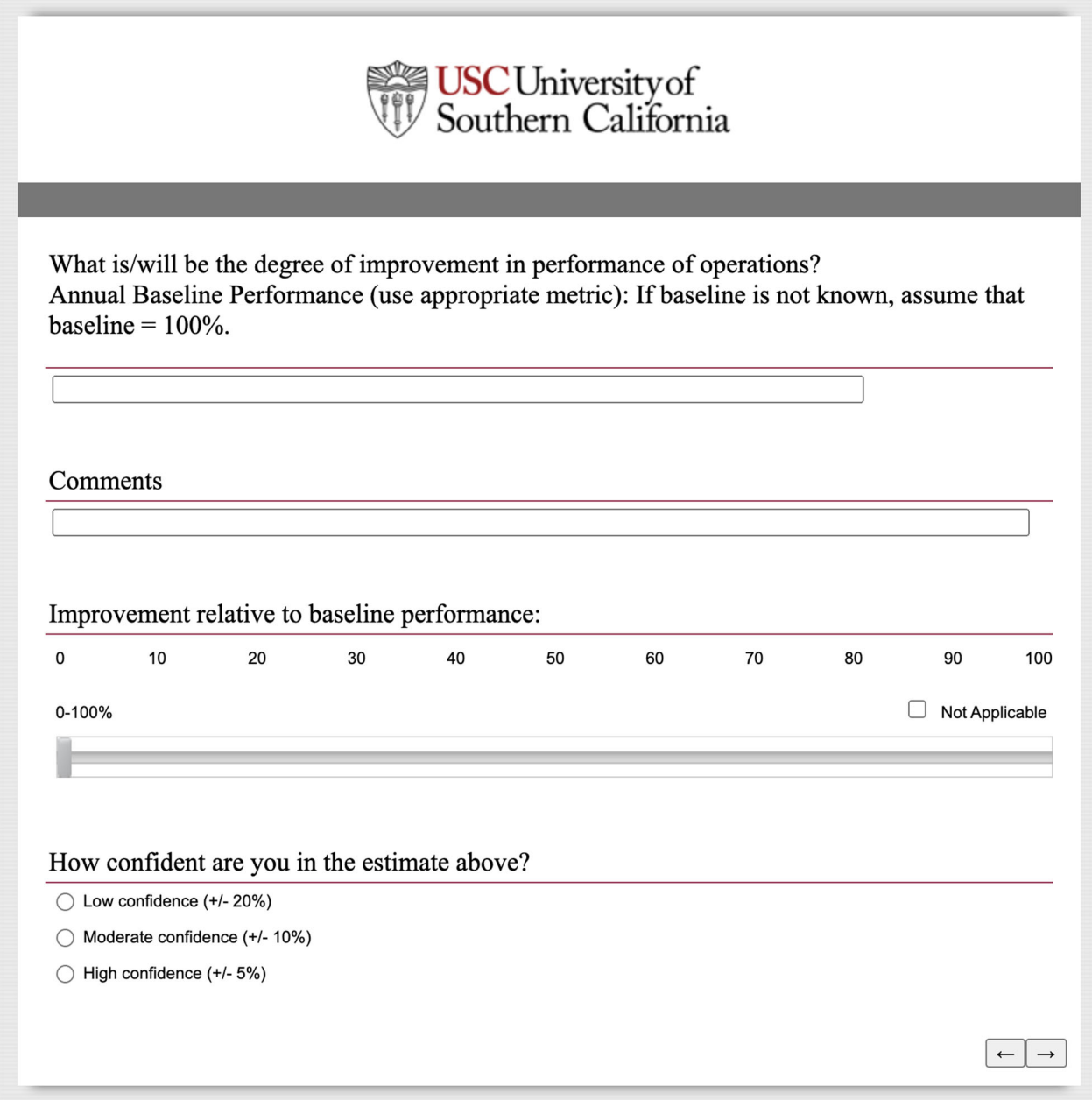


Figure 11. Qualtrics questions to estimate baseline performance, % improvement relative to baseline, and confidence level of estimated reduction %

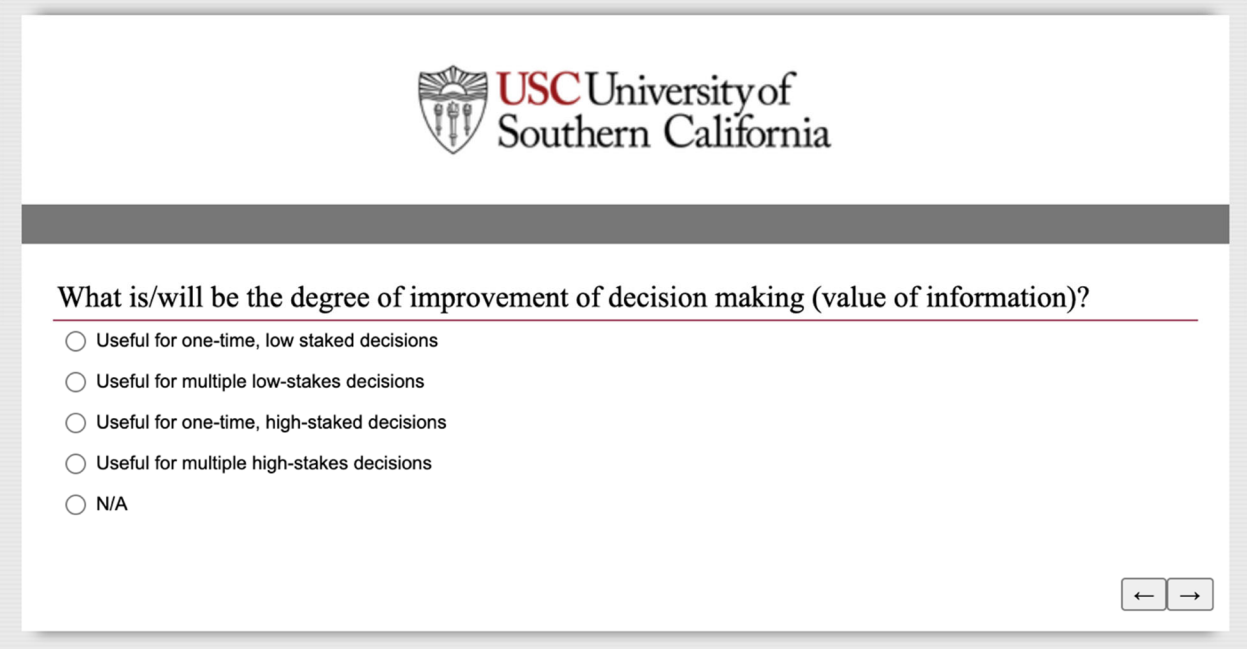


Figure 12. Qualtrics question about improvement in decision making (VOI)

Figure 13. Qualtrics question about impact of training on staff performance

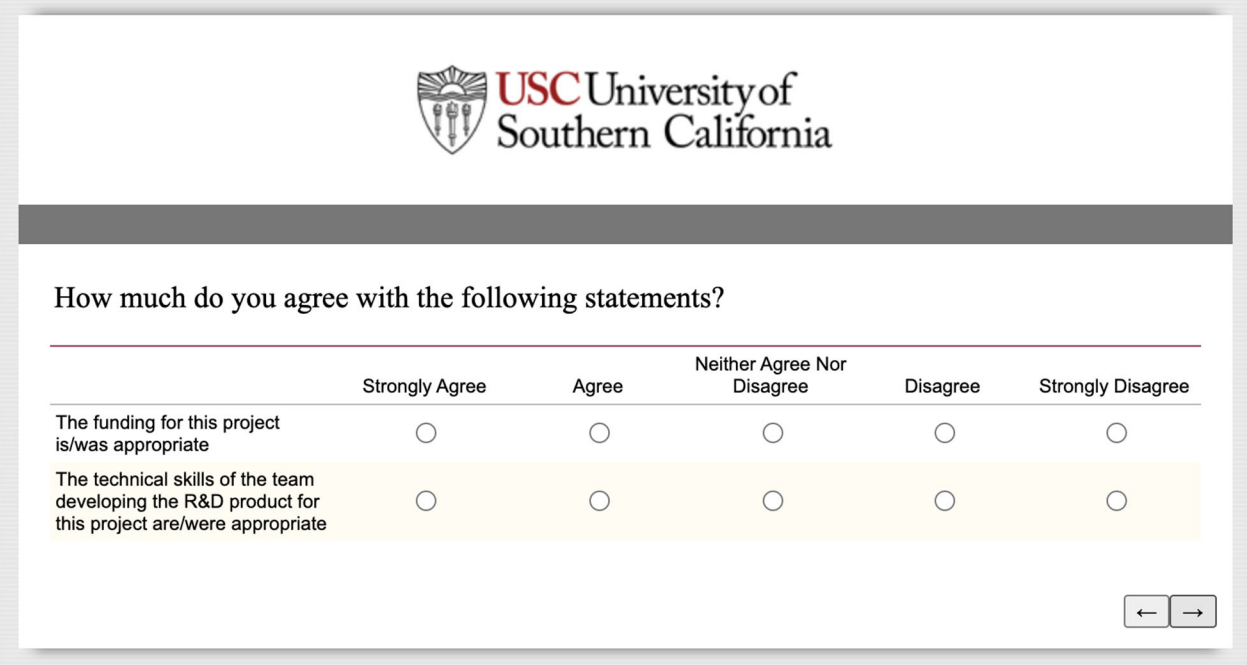


Figure 14. Qualtrics process questions regarding R&D funding level and technical skill resources for the project.

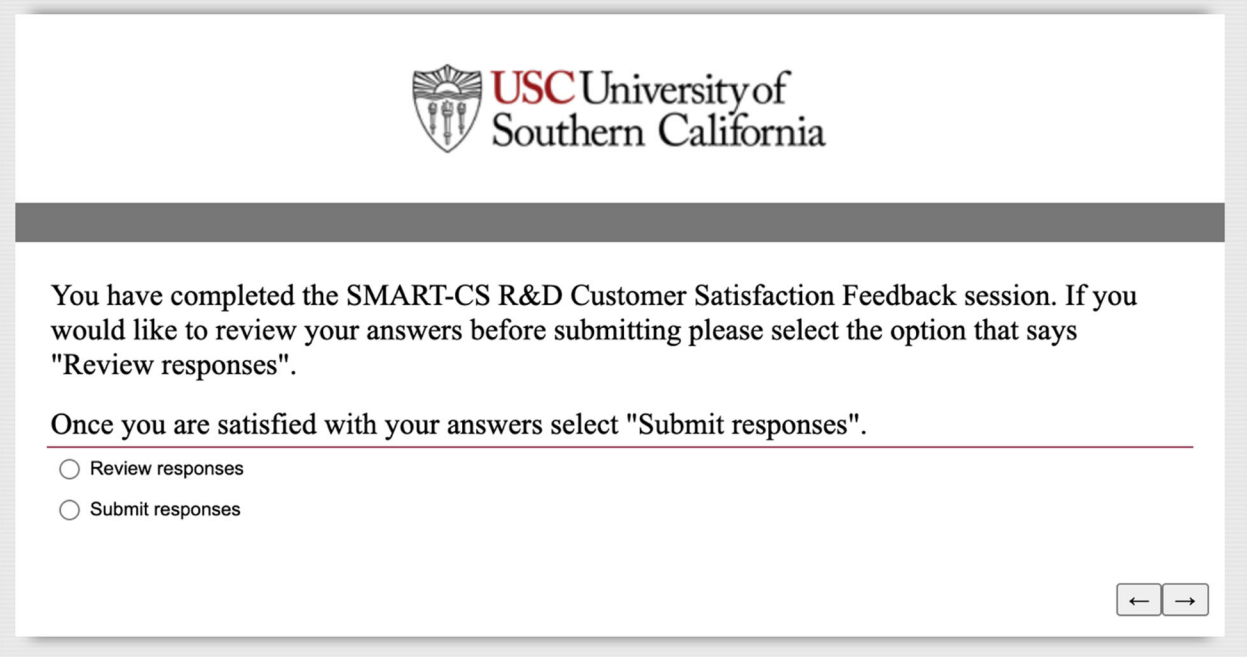


Figure 15. Qualtrics screen allowing for review of responses or submission of responses and end.

3.4. Post-Processing and Aggregate Customer Satisfaction Scores

The responses to the Qualtrics questionnaire can be downloaded in a relatively compact form, but Qualtrics does not provide any aggregation or analysis of the ratings. To obtain the two aggregate ratings (one for outcomes, one for process), only a modest amount of post-processing is necessary.

Table 6 shows the results of an example elicitation with USCG R&D staff in the first stakeholder column (see a more detailed description in section 4). Blank cells indicate that no responses were necessary. The question marks were entered because the respondents did not know the appropriate metric off hand. (This was one of the reasons for allowing respondents to set the baseline to 100%). The second stakeholder column shows the responses of the previous director of the funding agency of this project (CREATE), who also knew the baseline and agreed with the 50% improvement based on performer data. The other stakeholder columns are left empty and are for reference only.

Table 6. Responses from Qualtrics in Excel for Two Stakeholders Evaluating the R&D Project PROTECT Software for Randomizing USCG Boston Harbor Security Patrols

	Stakeholder 1	Stakeholder 2	Stakeholder 3	Stakeholder 4
STAKEHOLDER INFORMATION				
Type of Stakeholder	R&D Rep	R&D funder		
Affiliation	USCG	OUP/CREATE		
OUTCOME CRITERIA				
In Use?	Yes	Yes		
Probability of Eventual Use	1	1		
Timing of Eventual Use				
Cost Savings				
Operational Baseline				
Operational Improvement				
Reduction of Effort				
Operational Baseline				
Operational Improvement				
Improvement of Operations	yes	yes		
Operational Baseline	?	100		
Operational Improvement	50%	50%		
Improved Decision-Making				
Improvement through Training				
PROCESS CRITERIA				
Appropriateness of Funding Level	Yes	Yes		
Appropriateness of Technical Skills	Yes	Yes		

Table 7 shows a more compact result, omitting all irrelevant questions, and showing the two CSF aggregate satisfaction ratings, one for outcome criteria and one for process criteria.

Table 7. Compact Version of Qualtrics Results with Post-Processing Overall Outcome and Process Satisfaction Ratings

	Stakeholder 1	Stakeholder 2
STAKEHOLDER INFORMATION		
Type of Stakeholder	R&D Rep	R&D funder
Affiliation	USCG	OUP/CREATE
OUTCOME CRITERIA		
Utilized Before Project Close-Out?	Yes	Yes
Probability of Utilization	1	1
Improvement of Operations	yes	yes
Operational Baseline	100	100
Operational Improvement	50%	50%
OVERALL OUTCOME RATING	50	50
PROCESS CRITERIA		
Appropriateness of Funding Level	Yes	Yes
Appropriateness of Technical Skills	Yes	Yes
OVERALL PROCESS RATING	100	100

The outcome rating is calculated as follows:

Outcome Rating = Probability of Eventual Use*Improvement Rating

Since the baseline metric and estimate is always calibrated to 100, the effective outcome rating is only dependent on the eventual use probability and the improvement rating. In most cases, the outcome rating will range between 0 and 100. This can be achieved for a research product already in use that doubles the baseline performance (100% improvement or 100& reduction in costs or effort).

In rare cases the improvement rating will be above 100%, in which case, it is acceptable to let the outcome rating float above 100. It can also happen that there are two or maybe even three benefit categories with total improvement or reduction in costs or effort ratings totaling above 100). In those rare cases, the outcome ratings will be added across benefit categories and may add to more than 100.

The rating of decision-making and training benefits is treated a bit differently. For improved decision-making the outcome ratings are

No improvement	0
One-time low-stakes decisions	25
Multiple low-stakes decisions	50
One-time high-stakes decisions	75
Multiple high-stakes decisions	100

Similarly, the rating of improved staff performance through training is

No improvement	0
A few staff members in moderately important areas	25
Many staff members in moderately important areas	50
A few staff members in highly important areas	75
Many staff members in highly important areas	100

The process rating is assigned depending on the response to the first question (adequate funding?) and the second question (appropriate skills):

No/No	0
Yes/No	50
No/Yes	50
Yes/Yes	100

3.5. Interpretation of Results

The results of the Qualtrics responses as shown in Table 7, together with the aggregate ratings, provide the basis of interpreting the degree of customer satisfaction with a research project or product. Aggregate ratings of 100 or higher on both outcome and process criteria indicate excellent satisfaction with an R&D product. Ratings at the lower end of 25 or below suggest a low degree of satisfaction.

More importantly, the summary table also provides insights, why an R&D product is seen as having high or low degree of satisfaction and how different stakeholders can have different perceptions and the reasons for these differences.

If two stakeholders disagree, for example, on the probability of eventual use, it is also useful; to take a second look at the confidence of their judgments. It may be the case that one stakeholder expressed a low degree of confidence, while another expressed a high degree. This provides some guidance on how important the stakeholder's judgments are. While we do not propose to formally aggregate ratings across stakeholders based on confidence or any other judgments, there

may be circumstances when the assessments of the stakeholders with a. high degree of confidence should be given more consideration in decision-making.

The ultimate use of the SMART-CS, as with other consumer satisfaction feedback methodologies, is to improve R&D decision-making. This includes decisions on terminating vs. continuing funding of projects that have not yet been implemented into use, changing funding levels, and tracking and monitoring successful R&D products.

The SMART-CS methodology can also be thought of as a pre-cursor to a benefit-cost analysis. Most questions about outcomes are the same questions that a benefit-cost analyst would ask to quantify costs and benefits of an R&D product actually transitioned into use (see von Winterfeldt et al., 2019, referenced above).

4. Pilot Implementation of the SMART-CS Methodology

4.1. Overview of USCG Case Study with the PROTECT R&D Project

To obtain first-hand feedback and comments with a DHS Operational Component conducting the SMART-CS methodology, CREATE engaged the USCG in a tabletop exercise (TTX) of the process. We used the Port Resilience Operational/Tactical Enforcement of Terrorism (PROTECT) R&D project which had been conducted a few years earlier specifically for the USCG. The project is described as,

> PROTECT. The Port Resilience Operational/Tactical Enforcement of Terrorism (PROTECT) tool is a software program that creates a "smart" randomization schedule of U.S. Coast Guard harbor patrols, accounting for the value of possible targets of terrorist attacks and the limited resources for patrolling. High-value targets are protected more often than low-value targets, and, subject to resource constraints, PROTECT maximizes the uncertainty about which target is protected at any given time. This keeps the attackers guessing about which target will be protected, even if they can observe the patrol schedule of the defender (Shieh et al., 2015).[4]

CREATE first presented an overview of the SMART-CS methodology, reviewed the objectives of the TTX and the PROTECT project, and then asked two stakeholders to respond to the Qualtrics elicitation. The results are described in the sections below.

4.2. Qualtrics Pilot Results

The SMART-CS methodology was pilot tested for the PROTECT R&D project, described above in Section 4.1. Two different stakeholders were recruited for the pilot test: (1) R&D staff member, and (2) former director of the COE that funded the PROTECT project. They independently accessed the Qualtrics survey tool and successfully provided answers for all questions. As indicated in Table 6, their responses were in close agreement. PROTECT was judged to have been successfully used and both indicated that the primary benefit was improved operations. Both stakeholders agreed that PROTECT improved operations by 50% and that funding and technical skills resources were adequate for the project. This small pilot suggests

[4] PROTECT reference

that the Qualtrics elicitation instrument is capable of obtaining customer satisfaction information required by the SMART-CS methodology.

4.3. Post-processing Results

The pilot study stakeholder inputs presented in Table 6 were analyzed using the SMART-CS aggregation logic to produce two indices of customer satisfaction with respect to the benefits afforded by the R&D product and the experience related to the process of the R&D project. As presented in Table 7, the PROTECT project a rating of 50 in terms of benefits, based on a 50% improvement on one of the five benefit categories (Improvement of Operations). Since there was no indication of benefit from the other four categories, there is no additional benefit component calculated in the SMART-CS benefit rating. The process rating for the PROTECT project was a perfect 100, since both funding and technical skills for the R&D development were adequate for the task.

5. Embedding the SMART-CS Methodology into the S&T Business Process Flow (BPF 2.0)

S&T's Business Process Flow (BPF)[5] is critical to achieving better engagement with Component customers to provide R&D solutions that enable effective, efficient, and secure operations across the spectrum of operational DHS missions. The draft CSF methodology proposed herein is closely integrated with this BPF to leverage the inherently built-in interactions and discussions among S&T participants and Component participants. The draft proposed CSF methodology thus minimizes the additional administrative overhead for obtaining feedback on the Components' satisfaction with the delivered R&D products.

Figure 16 shows the flow diagram for conducting the CSF methodology, and its close integration with BPF 2.0. Purple designates Component Input, Blue is the S&T BPF 2.0, and Cardinal is the proposed draft CSF Methodology. The identified Steps 1-5 in the CSF methodology are matched to the BPF 2.0 processes as shown in Figure 17.

[5] Understanding S&T's Business Process Flow: Overview of S&T's Matrixed Research and Development Process, Revision 2, March 11, 2021.

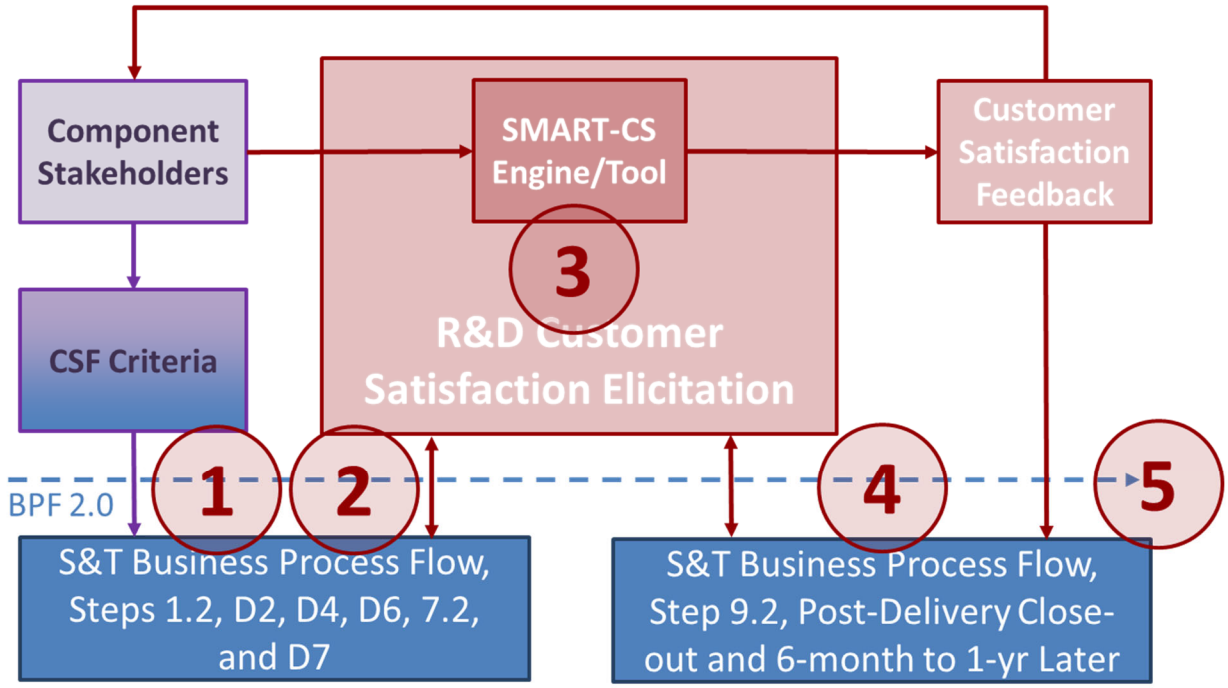


Figure 16. Flow Diagram of Draft R&D Customer Satisfaction Feedback Methodology Using SMART-CS.

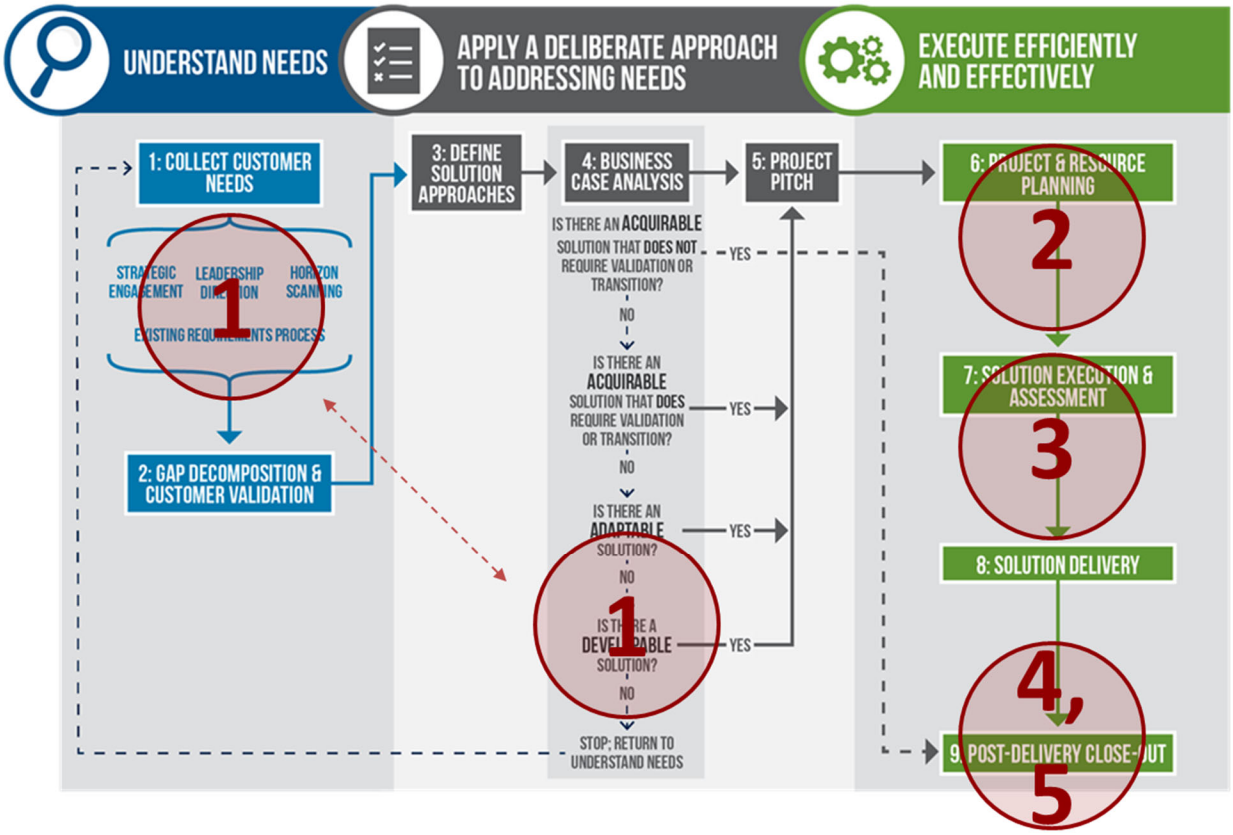


Figure 17. Integration of the Draft R&D Customer Satisfaction Feedback Methodology with the S&T BPF 2.0.

Step 1. At BPF Process Step 1.2, Data Intake, the CSF Criteria are either provided by the Component as input to the CSF process, or they can choose from a standard set presented to them, and are confirmed by the Component at Decisions D2 and/or D4.

Step 2. At BPF Decision Point 6, Customer Agrees to Move Forward with Project Plan. The CSF Criteria are revised as necessary in Process 6, Activity 6.3, and the Component stakeholders that will participate in the CSF SMART-CS scoring and rating process are identified at Decision Point 6.

Step 3. (Optional) BPF Process 7, Solution Execution & Assessment. The PM and Component could regularly use SMART-CS to assess R&D Satisfaction and the Criteria as part of the Activity 7.2 Periodic Reviews. As part of Activity 7.3, Validate & Verify Solution, leading to Decision Point 7, the Component can do one final in-process assessment of Satisfaction prior to close-out. Since the elicitation methodology only involves a few questions, as detailed in the earlier sections, this could prove to be a valuable feedback mechanism and tool for PMs.

Step 4. BPF Activity 9.1, Close out Project, and BPF Activity 9.2, Assess Solution (Internal Review). Finally, the SMART-CS assessment is conducted as part of Process 9, Post-

Delivery Close-out, in Activities 9.2 and 9.3, with the explicit goal of obtaining the final R&D CSF rating, which can then be used for process improvement, both to S&T on its R&D effort, and to the Component on their Criteria.

Step 5. (Optional) The SMART-CS elicitation could have two versions, one immediately at Project Closeout (Step 4), and one perhaps 6 months to a year later, after acquisition and/or R&D product implementation. Though this assessment is not NDAA-related, it could perhaps be combined at some future date.

Specific guidance keyed to BPF 2.0 includes,

- In BPF Process Activity 1.2, Data input
  - Component provides current Baseline performance measure targeted by R&D effort.
  - Component identifies benefit type and estimates target improvement to baseline from R&D product.
  - S&T PM identifies and notifies the full range of Stakeholders that should participate in CSF process.
- In BPF Decision Point 6
  - Component confirms Criteria for establishing Customer Satisfaction, and identifies Component stakeholders that will participate in SMART-CS process.
  - Component agrees that Project has been planned and resourced to achieve stated benefit performance improvement target.
- In BPF Activity 9.1, Close out Project and BPF Activity 9.2, Assess Solution (Internal Review)
  - Component Stakeholders participate in SMART-CS elicitation process.
  - SMART-CS results analyzed by S&T, and feedback provided and acted on as appropriate.

For complete integration of the SMART-CS steps listed above with S&T's standard operating processes and procedures, the specific instructions and explanations should be added/be part of/integrated with the Program/Project Management (PM) Planning Manual Templates, specifically in Section 1.5, Measures of Success, and Section 6, Close-Out.

Appendix A: Summary of Literature Review Citations

A.1. ATT Quest (WWPF & CVA): "Measuring customer satisfaction for an R&D organization," B.H. Fetz, Nineteenth IEEE/CPMT International Electronics Manufacturing Technology Symposium, 14-16 Oct. 1996.

Quality may be defined as the extent to which a product or service meets (or exceeds) the customers' expectations. Thus, the measurement and use of customer satisfaction data is at the heart of any quality program. But how does the concept of customer satisfaction apply to internal organizations (such as R&D) within a corporation? This paper presents the experiences and the lessons learned from managing a customer satisfaction program for a large R&D organization within AT&T.

Quality may be defined as the extent to which a product or service meets (or exceeds) the customers' expecations. Thus, the measurement and use of customer satisfaction data is at the heart of any quality program. But how does the concept

Attributes of Service

They were asked what attributes of a service would determine whether or not they were satisfied and would repurchase the services. Then they were asked to distribute 100 points across those attributes so that their relative importance would be known. The attributes did vary by service, but certain ones would tend to occur regularly. An example of a list of attributes and weights would be the following:

Technical Expertise	40
Responsiveness	20
Meeting Commitments	15
Documentation	10
Interpersonal Skills	5
Partnering	5
Initiative	5

These elements could be viewed as the components of quality in the eyes of the customers. However,

Worth What Paid For (WWPF)

overall question was added to measure how satisfied the customers were overall considering both quality and price together. The wording of this question was as follows:

> "Overall, considering both quality and price, how would you rate this service on a scale of 1 to 10 with 1 being poor and 10 being excellent, as being Worth What You Paid For It."

This became known as the Worth What Paid For question, or WWPF for short.

Customer Value Added (CVA)

results.[1] At about the same time Brad Gale was introducing his idea on Customer Value Added (CVA). Gale defined CVA as the perceived value of a product or services relative to that of the competition.[2] Value includes both quality and price and is clearly related to Worth What Paid For. Kordupleski defined CVA for AT&T applications by the following equation.

$$CVA = \frac{\text{WWPF (for AT\&T)}}{\text{WWPF (for avg. competitor)}} \times 100$$

A.2. Customer Perceived Value of Technology (CPVT): "A systematic approach to prioritizing R&D projects based on customer-perceived value using opinion mining," Yoon, Byungun & Jeong, Yujin & Lee, Keeeun & Lee, Sungjoo, 2020. Technovation, Elsevier, vol. 98(C).

As product development has recently emphasized user innovation, it should necessarily reflect customer-perceived value, as well as technological value itself. However, while previous studies for technology planning have focused on analyzing the potential of technology, they have not considered the customer-perceived value that technology can create in a new product. Therefore, this research suggests a new approach to assessing the level of technology and evaluating R&D projects, by investigating customer-perceived value on technology through the use of the structural equation model and opinion mining. For this, the assessment framework is developed in terms of technology, product quality, and customer satisfaction, respectively, by investigating a variety of databases on each factor. The relationship between technology level and customer satisfaction is analyzed, using structural equation model and opinion mining. Based on the results, a strategy for technology development is established through gap analysis and simulation, after selecting and evaluating technologies that need to be developed. The proposed approach is applied to the real case of a moving system, in particular an automobile door, and we obtained that an R&D project for hinge-related technology would be promising, enhancing the customer satisfaction. It can suggest a future direction for new technology development. This paper contributes to enhancing the efficiency of technology planning based on the customer-perceived value, enabling the launch of new R&D projects.

framework is developed in terms of technology, product quality, and customer satisfaction, respectively, by investigating a variety of databases on each factor. The relationship between technology level and customer satisfaction is analyzed, using structural equation model and opinion mining. Based on the results, a strategy for technology development is established through gap analysis and simulation, after selecting and evaluating technologies that need to be developed.

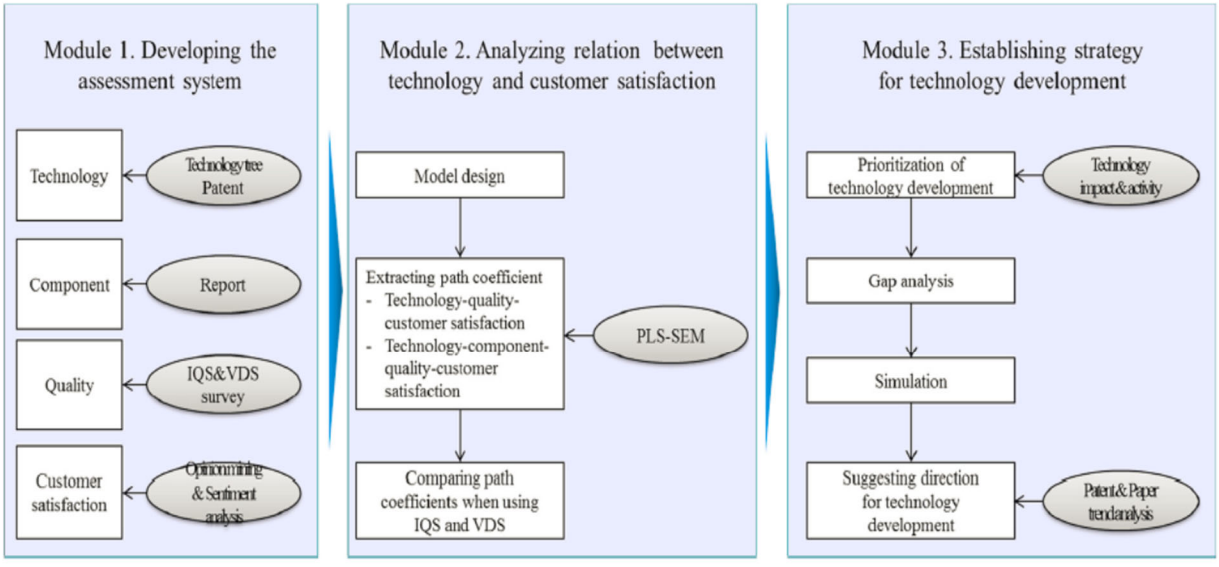


Fig. 1. Research framework.

A.3. Customer Satisfaction Index (CSI): "Evaluation of customer satisfaction in R&D organization: a conceptual framework," Tapas Sarkar, Asit Kr. Batabyal. Asian Journal on Quality, 21 June 2011.

Purpose. The paper aims to develop an evaluation model of the customer satisfaction index (CSI) in an R&D organization. A conceptual framework on customer satisfaction with a probabilistic approach has been attempted based on customer requirements and expectations in compliance with the clauses of ISO 9001:2008.

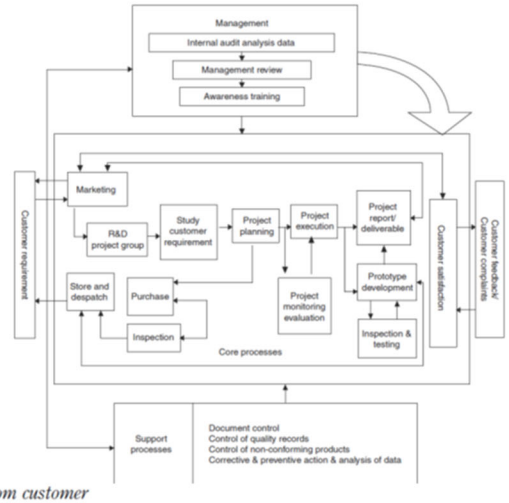
Design/methodology/approach. A survey through a well-designed customer feedback data sheet has been used as an effective tool for the measurement of CSI. The questionnaire was framed on the basis of the requirements of a quality management system with advice to the customer for allotting grade points on a given scale to the quality parameters. The research model has been analyzed based on a fault-tree approach and the probability of failure of each quality parameter has been assigned on the basis of grade point average. Data analysis for the estimation of the probability of failure at a customer satisfaction level (CSL) was carried out based on the probability of failure of each quality element graded by the customers. The data were also tested through statistical inference of whether customer-to-customer satisfaction level differs or not.

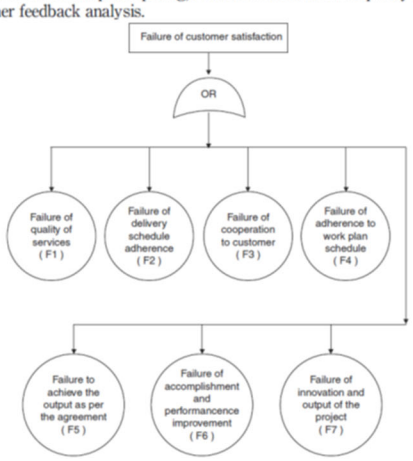
Findings. As a result of case study analysis, 88 percent of customers are fully satisfied. This gives significant information to the management process as well as providing a guiding tool for future improvements. The analysis was carried out based on a framed questionnaire graded by the customer and the result reveals that there is no significant difference between customer satisfaction levels.

Research limitations/implications. This model can be used by any organization, irrespective of the number of customers participating, as well as the number of quality parameters being assigned in the customer feedback analysis.

Originality/value. A literature review found that there are various approaches for evaluating a CSI. The paper describes how a newly-applied conceptual model based on the failure of CSL in the form of a fault-tree approach was designed and how the probability of failure of each element/parameters was assigned on the basis of a grade point average to evaluate the CSI, as well as the variation in satisfaction levels between customers being analyzed.

Purpose – The paper aims to develop an evaluation model of the customer satisfaction index (CSI) in an R&D organization. A conceptual framework on customer satisfaction with a probabilistic approach has been attempted based on customer requirements and expectations in compliance with the clauses of ISO 9001:2008.
Design/methodology/approach – A survey through a well-designed customer feedback data sheet has been used as an effective tool for the measurement of CSI. The questionnaire was framed on the basis of the requirements of a quality management system with advice to the customer for allotting grade points on a given scale to the quality parameters. The research model has been analyzed based on a fault-tree approach and the probability of failure of each quality parameter has been assigned on the basis of grade point average. Data analysis for the estimation of the probability of failure at a customer satisfaction level (CSL) was carried out based on the probability of failure of each quality element graded by the customers. The data were also tested through statistical inference of whether customer-to-customer satisfaction level differs or not.
Findings – As a result of case study analysis, 88 percent of customers are fully satisfied. This gives significant information to the management process as well as providing a guiding tool for future improvements. The analysis was carried out based on a framed questionnaire graded by the customer and the result reveals that there is no significant difference between customer satisfaction levels.
Research limitations/implications – This model can be used by any organization, irrespective of the number of customers participating, as well as the number of quality parameters being assigned in the customer feedback analysis.





2.2 Response from customer
Customers were advised to allot grade points to the seven quality parameters based on the merit of jobs/projects/services completed and delivered to them.
The seven quality parameters and grades are as follows:

(1) quality of services rendered by the institute (F1);
(2) adherence to delivery schedule (F2);
(3) cooperation extended to the customer (F3);
(4) achieving objective as per agreement (F4);
(5) adherence to work plan (F5);
(6) output accomplishment and performance improvement (F6); and
(7) usability of innovation and output of the project (F7).

Grades are designated in a one- to four-point scale as excellent: 4, very good: 3, good: 2 and satisfactory: 1.
Feedback reports from customers are on a yearly basis.

A.4. Customer Satisfaction Multi-Attribute Utility (CS-MAU)

- Based on judgments of implementation success (qualitative probability scale)
- And judgments of benefits, if successful
- For the former, use R&D maturity from implemented use data
- For the latter, elicit criteria and weights from selected customers

A.5. Performance Measurement System (PMS): "Searching for an effective measure of R&D performance," Vittorio Chiesa, Christina Masella. Management Decision, 1 September 1996.

Notes that measurement of R&D performance has always posed great problems due to the nature of R&D activity and the difficulties in identifying a tangible output. Also that performance measurement systems have often been built on input variables or on qualitative evaluation of the output. Attempts to identify quantitative measures of R&D performance and to single out those related to activities under complete and partial control of R&D managers. Takes as a starting-point the concept of economic value creation as a firm's normative objective and the analysis of the contribution of R&D to it. Builds on this a performance measurement system that leads to identify proxy measures of both R&D effectiveness and efficiency.

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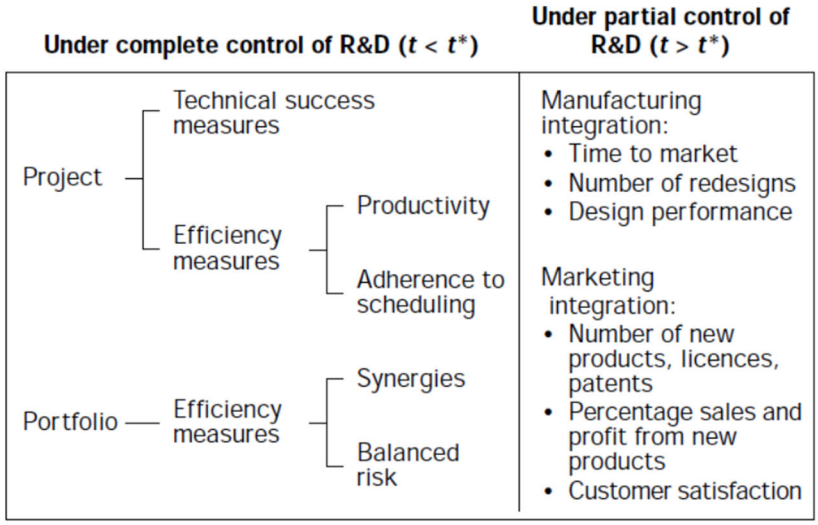
Figure 2
The performance measures



A.6. Quality Management System (QMS): "Improving R&D processes by an ISO 9001-based quality management system," Antti Auer, Jukka Karjalainen, Veikko Seppänen. Journal of Systems Architecture, Volume 42, Issue 8, pp. 643-651, 31 December 1996.

This paper presents practical experience in planning, implementing, and adopting a Quality Management System (QMS) for embedded systems development at VTT Electronics. The main objective for the development of the QMS was to make it practical for real-life embedded systems research and development (R&D) projects. We have applied the ISO 9001 standard and ISO 9000–3 guidelines in building the quality system. From our personnel's point of view, the most important parts of the system have been document skeletons and plan templates that were made accessible to everyone. One of the major quality improvement resulting from the use of the QMS has been the enhanced predictability of R&D projects. This makes it possible for the organization to concentrate on essential matters. From our clients' point of view, we have clearly improved the quality of our R&D services in terms of the customer satisfaction index. Based on QMS auditing activities, we have been able to evaluate and tune our R&D procedures in a systematic manner. We have decided to use Total Quality Management and Quality Award frameworks in the further development of the QMS. Customer service and human resources management are examples of important areas for further quality improvement.

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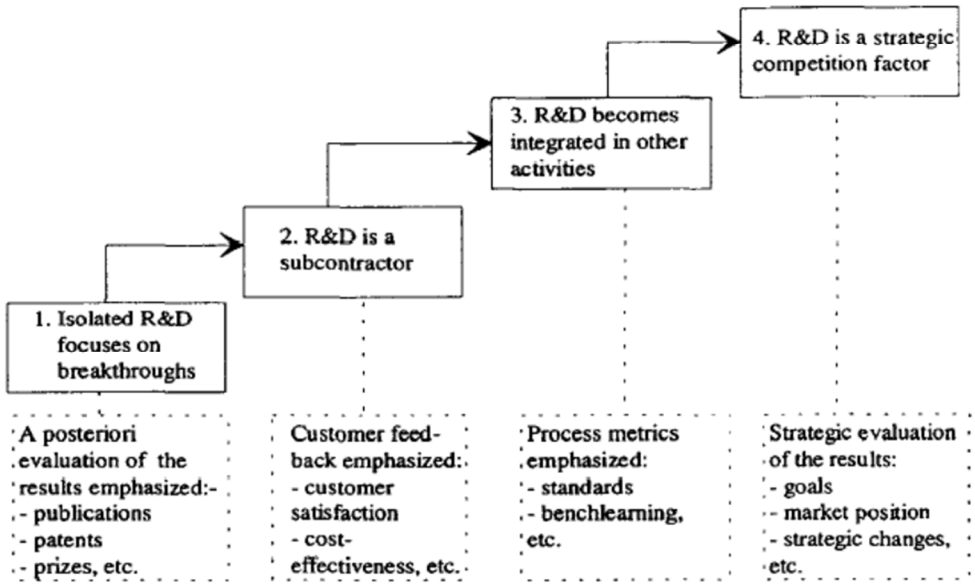

Fig. 1. Quality ladder for research and development [3].

A.7. Technology Value Pyramid (TVP): "Measuring the Effectiveness of R&D," Lawrence Schwartz, Roger Miller, Daniel Plummer, and Alan R. Fusfeld. Research Technology Management · September 2011.

Measuring the effectiveness of R&D has been a perennial challenge. IRI's Research-on-Research working group Measuring the Effectiveness of R&D sought to investigate how managers define R&D effectiveness and what metrics they use to measure it. Via surveys and questionnaires, attendees at IRI meetings revealed that while the three top metrics are unchanged over the past 15 years, there were significant differences in metrics used depending on the industry type. The study also revealed issues with metrics in general and the need for new metrics to meet the changing R&D environment.

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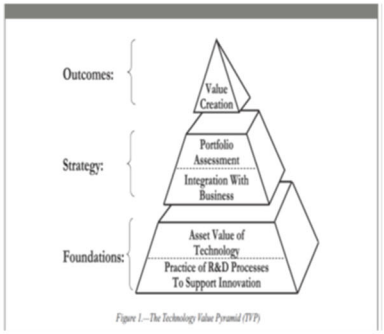

Figure 1.—The Technology Value Pyramid (TVP)

Table 2.—Survey B results: Top five metrics by TVP level

Metric	Ranking
Outcome	
Financial Return	1
Gross Profit	2
Market Share	3
Projected Value of Pipeline	4
IP Management	5
Strategy	
Financial Return	1
Projected Value of Pipeline	2
Gross Profit	3
R&D Investment/Sales	4
Strategic Alignment	5
Foundations	
IP Management	1
Number and Quality of Patents	2
People Development	3
Creativity	4
Cost versus Budget	5

Table 3.—Survey B results: Top metrics by innovation game

Innovation Game	TVP Level: Value Creation	Strategy	Foundation
New & Improved (Standalone)	Financial Return Projected Value of R&D Pipeline Gross Profit Gross Margin	Financial Return Projected Value of R&D Pipeline Gross Profit Gross Margin	None identified at statistically significant level.
Pushing the Envelope (Integrated Systems)	Financial Return Projected Value of R&D Pipeline Gross Profit Gross Margin	Financial Return Projected Value of R&D Pipeline Gross Profit Gross Margin R&D Investment as % of Sales	People Development Intellectual Property Management Number and Quality of Patents
Consumer Products	Financial Return Product Quality & Reliability Gross Margin Gross Profit Market Share	Financial Return Gross Margin Gross Profit R&D Investment as % of Sales Probability of Success	People Development Intellectual Property Management Number and Quality of Patents
Services	Intellectual Property Management Financial Return	Financial Return	Idea Generation and Creativity R&D Process People Development Quality of Personnel Number and Quality of Patents

A.8. **Total Quality Measurement (TQM): "Measuring R&D Performance,"** Paul A. Schumann Jr., Derek L. Ransley and Donna C. L. Prestwood. Research Technology Management, Vol. 38, No. 3 (MAY–JUNE 1995), pp. 45-54.

The growing acceptance of a need to measure R&D performance is in contrast to a lack of a systematic process for determining appropriate measurements. The search for appropriate R&D performance measurements has been akin to the search for the Holy Grail. In contrast, the authors contend that R&D is too complex a subject for a few measurements to satisfy all needs. However, if R&D is viewed as a process, performance measurements can be effectively determined. The framework proposed in this paper provides a quality-based approach that considers the R&D process elements for measurement to be people–process–output–internal customers–external customers–society. After a market-driven objective is determined, it can be decided whether to track internal performance, performance improvement, competitor assessment, benchmarking, or some other aspect of R&D activities. Then, the need is to determine which measurements to focus on in each of the elements of the R&D process. The few key measurements can then be sought from among many to satisfy the market-driven objective.

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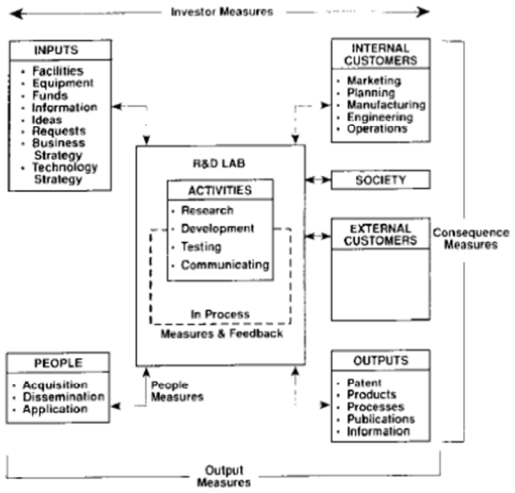

Figure 3.—R&D is sufficiently complex that several different measures are needed depending on which element of the process is being studied.

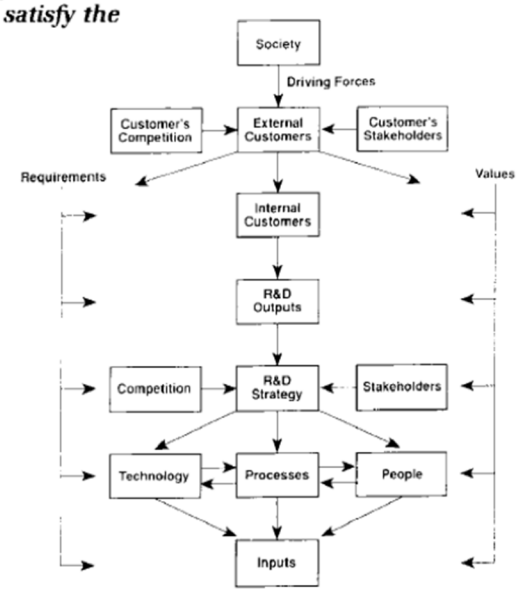

Figure 4.—The driving forces from society, competition and stakeholders on the external customer drive the market-driven requirements and values process.

A.9. USCG R&D Customer Satisfaction (USCG): "Product Transition Readiness Assessment," Kathleen Shea Kettel. Performing Report No. UDI # 1387, April 2014.

Coast Guard (CG) field units and external Department of Homeland Security (DHS) Science and Technology (S&T) Office of University Programs (OUP) innovators develop concepts and/or prototype products of interest to the Coast Guard. The Coast Guard has guidance for transitioning these products CG-wide.

This white paper provides a method to assess the readiness of these products for CG transition. It takes key elements from the CG Software Development Life Cycle's Business Case Template. These are the System Justification, Stakeholders, Benefits and Costs elements. Under each key element there is a break out of one or more categories. These categories are CG Requirements, Enterprise Architecture, Mission Sponsor, End Users, Product Support, Alignment with Mission and Strategic Goals and Funding Support. Each of these Business Case categories has a table with 4 specific transition-related conditions for that category. Each condition has a value from 1

to 10. These conditions are assessed for a product of interest. The scores are calculated and plotted on a quadrant chart of Mission Criticality against Transition Strength.

This paper will be used with products that are part of the CG Research and Development Center's Portfolio and the scores will be provided in the product transmittal letter.

- The USCG developed and applied a methodology for evaluating R&D projects and products (USCG R&D Center)
- Based on judgments of likelihood of success (0-10 scale)
- And Impact, if successful (0-10 scale)
- An adaptation of this approach was used to select promising R&D projects funded by OUP for in-depth benefit-cost analyses

Appendix B: Attributes and Scales for Evaluating R&D Customer Satisfaction Methodologies

B.1. Ability to Accommodate Value Tradeoffs

Ease of explicitly assessing and modeling value trade-offs among conflicting R&D evaluation criteria

1. Methodology cannot capture trade-offs
2. Methodology could be adapted to capture an ordinal measure of trade-offs
3. Methodology could be adapted to capture trade-offs in the form of weight ratios
4. Methodology includes assessment of trade-offs for an additive model
5. Methodology includes assessment of trade-offs that allow for non-additive (interactive) value models capturing attribute synergies

B.2. Ability to Update

Adaptability of the R&D evaluation methodology for periodic updating

1. No facility for updating specified; would be equivalent to "starting over"
2. No facility for updating specified, but methodology could be adapted to allow for new customer feedback over time
3. Methodology anticipates the need to add new customer feedback over time but does not include ability to map changes over time
4. Methodology explicitly captures and models customer feedback over time and analyzes changes

B.3. Application Track Record

Quality and size of documented applications of the R&D evaluation methodology

- Natural Scale: Count of actual applications (not "toy" demonstrations) of methodology
- Worst Level: 0 applications
- Best Level: 10 (or more) applications

B.4. Ease/Complexity of Required Responses

Expected difficulty of customers in providing inputs required by the R&D evaluation methodology

- Proxy attribute: Expected % of respondents who provide incomplete or unusable responses
- Worst Level: 100%
- Best Level: 0%

B.5. Generalizability and Adaptability

Applicability of the methodology to a diverse range of different domains, projects, and customers

1. Designed for a particular narrow R&D domain and not easily generalized
2. Designed for a particular narrow R&D domain and could be generalized to other domains
3. Designed for a range of R&D domains and could be generalized to other domains

4. Completely general methodology applicable to virtually any R&D domain

B.6. Impact Uncertainty

Adaptability of the methodology to account for uncertainty about impact of R&D, conditional on successful use

1. Not readily adaptable
2. Adaptable to obtain qualitative measures of use success uncertainty
3. Adaptable to obtain probabilistic measures of use success uncertainty
4. Incorporated into the methodology

B.7. Logical Soundness

Extent to which R&D evaluation methodology is based on theoretically defensible rationale

1. Methodology completely ad hoc, no rationale
2. Methodology not based on a given rationale, but does follow prior R&D evaluation tradition
3. Methodology based on a rationale that is internally consistent
4. Methodology based on a carefully constructed axiomatic foundation

B.8. Software Support

Level of software support available

1. None available
2. Methodology amenable to use of generic software for survey delivery and statistical analysis
3. Specialized software developed for collecting customer feedback
4. Specialized software developed for collecting and analyzing customer feedback responses
5. Specialized software developed for collecting, analyzing, and communicating results, including sensitivity analysis of customer feedback responses

B.9. Time Requirements of Customers

Total time required of customer respondents, including time training if required and time answering questions

- Natural Scale, average hours required
- Worst Level = 8.0 hours (1 day)
- Best Level = 0.0 hours (uses existing data)

B.10. Transparency and Communication

Extent to which the procedures, models, and results of the R&D evaluation methodology can be communicated and understood

1. Methodology is a black box; procedures and results are extremely difficult to communicate
2. Methodology is complicated and requires extensive effort and training to communicate

3. Methodology can be communicated and understood with moderate effort and training
4. Methodology is highly intuitive and can be easily communicated with little effort and no training

B.11. Eventual Use Success Uncertainty

Adaptability of the methodology to account for uncertainty about eventual use success

1. Not readily adaptable
2. Adaptable to obtain qualitative measures of use success uncertainty
3. Adaptable to obtain probabilistic measures of use success uncertainty
4. Incorporated into the methodology

Appendix C: References to Successful MAU Applications, with Abstracts

C.1. Zerva, A., Tsantopoulos, G., Grigoroudis, E., & Arabatzis, G. (2018). Perceived citizens' satisfaction with climate change stakeholders using a multicriteria decision analysis approach. *Environmental Science & Policy*, *82*, 60-70.

The objective of this study is to examine citizen satisfaction with the actions of the stakeholders involved in climate change. The study was conducted in Greece using a structured questionnaire; 1536 questionnaires were collected from January 2014 to June 2015 and the relevant data were processed using the MUSA method (MUlticriteria Satisfaction Analysis).

C.2. Angelis, A., Kanavos, P., & Montibeller, G. (2017). Resource allocation and priority setting in health care: a multi-criteria decision analysis problem of value?. *Global Policy*, *8*, 76-83.

This paper suggests that multi-criteria decision analysis could provide a more comprehensive and transparent approach in health care to systematically capture decision-makers' concerns, compare value trade-offs and elicit their value preferences. The authors conclude that such methods could inform the development of a decision support system in health care, contributing towards more efficient, rational and legitimate resource allocation decisions.

C.3. Celik, E., Aydin, N., & Gumus, A. T. (2014). A multiattribute customer satisfaction evaluation approach for rail transit network: A real case study for Istanbul, Turkey. *Transport Policy*, *36*, 283-293.

A multi-attribute customer satisfaction evaluation approach is proposed. A real case study for rail transit network of Istanbul based on a survey is conducted. The attributes need to be improved for each line of rail transit network is determined and improvement suggestions are provided. The proposed approach is generic so that can be applied to other systems.

C.4. Dickinson, J. B. (2014). Customer loyalty: A multi-attribute approach. *Research in Business and Economics Journal*, *9*, 1.

The proposed model is theoretically grounded in the multi-attribute attitude literature. It is proposed that the antecedents of customer loyalty are be partitioned into three categories.

C.5. Manolitzas, P., Grigoroudis, E., & Matsatsinis, N. (2014). Using multicriteria decision analysis to evaluate patient satisfaction in a hospital emergency department. *Journal of Health Management*, *16*(2), 245-258.

The scope of this study is to evaluate the level of patient satisfaction and to propose the solutions on how to increase the levels of satisfaction by using multicriteria analysis. A multicriteria user satisfaction analysis was used to measure the satisfaction and to elucidate the weak and strong points of satisfaction.

C.6. Institute of Medicine. (2013). *Ranking vaccines: A prioritization software tool: Phase II: Prototype of a decision-support system.* Washington, DC: The National Academies Press.

This report discusses the methods underlying the development, validation, and evaluation of SMART Vaccines 1.0. The creation of SMART Vaccines is unique to the Institute of Medicine (IOM), and it may also be ushering in a new era for the National Academies. There are multiple users and stakeholders who could benefit from SMART Vaccines 1.0 and they include decision makers in all realms of vaccine development and delivery in the public, private, and nongovernmental enterprises.

C.7. Salo, A., Keisler, J., & Morton, A. (Eds.). (2011). *Portfolio decision analysis: improved methods for resource allocation* (Vol. 162). Springer Science & Business Media.

Includes several chapters of applications of MAU to resource allocation decisions.

C.8. Zhao, M., & Dholakia, R. R. (2009). A multi-attribute model of web site interactivity and customer satisfaction. *Managing Service Quality: An International Journal*.

The purpose of this paper is to address the following questions in the context of a transactional web site. How do web site attributes influence customer satisfaction? Will an increase in the performance of a specific attribute lead to increased satisfaction? Since interactivity is considered a distinguishing characteristic of the new media and a web site is composed of multiple attributes, the paper empirically examines the interactivity-satisfaction relationship at the individual attribute level.

C.9. Kleinmuntz, D.M. (2007). Resource allocation decisions. In Edwards, W., Miles, R.M., & von Winterfeldt, D. (eds.) *Advances in decision analysis*. New York: Cambridge University Press, pp. 400-410.

The use of resource allocation models in hospital capital budgeting is described. This chapter reviews methods for prioritizing projects using mathematical optimization or benefit-cost ratios in concert with standard decision analysis and risk analysis tools. These tools include multiattribute utility and value models.

C.10. Phillips, L. D., & e Costa, C. A. B. (2007). Transparent prioritisation, budgeting and resource allocation with multi-criteria decision analysis and decision conferencing. *Annals of Operations Research*, *154*(1), 51-68.

This publication first explains three current approaches to resource allocation taken from corporate finance, operational research and decision analysis, and we identify a common mistake organisations make in allocating resources. The paper then presents a technical process, multi-criteria portfolio analysis, for balancing the conflicting elements of the problem, and a social process, decision conferencing, which engages all the key players during the modelling process, ensuring their ownership of the model and the subsequent implementation. This socio-technical process improves communication within the organisation, develops shared understanding of the portfolio and generates a sense of common purpose about those projects that will best realise the organisation's objectives. The paper concludes with lessons learned from actual practice.

C.11. Mittal, V., Katrichis, J. M., Forkin, F., & Konkel, M. (1994). Does satisfaction with multi-attribute products vary over time? A performance based approach. *ACR North American Advances*.

A multi-attribute approach to study satisfaction is suggested. Linkages between an attribute's performance, goal-fulfillment (Swan 1988), and satisfaction are drawn. Preliminary exploration of automotive industry data suggests the viability of the approach.

C.12. Edwards, W., von Winterfeldt, D., & Moody, D. (1988). Simplicity in decision analysis: An example and a discussion. In D.E. Bell, H. Raiffa, and A. Tversky (Eds.) *Decision analysis: Descriptive, normative, and prescriptive aspects*. New York: Cambridge University Press, pp. 443-464.

This chapter describes the use of a multiattribute utility analysis method to prioritize R&D projects conducted by the Construction Engineering Research Laboratory of the Army Corps of Engineers.

Appendix D: SMART-CS Tool Spreadsheet Template and Example

D.1. SMART-CS Spreadsheet Template

The following table lists the SMART-CS variables used in the rating calculations performed by the Excel template. It includes 3 groups of variables: Recorded by Qualtrics (metadata), Elicited from Stakeholders, and Calculated Ratings.

Variable Name:	Variable Description:	Stakeholder 1	Stakeholder 2	Stakeholder ...	Stakeholder X
General Metadata:					
Duration (in seconds)	Duration (in seconds)				
Finished	Finished				
RecordedDate	Recorded Date				
LocationLatitude	Location Latitude				
LocationLongitude	Location Longitude				
Stakeholder Input:					
R&Dproject	Name of R&D Project				
Product	R&D Product Description				
OperationalComponent	Responder's Operational Component (e.g., CBP, FEMA, USCG)				
OrganizationalGroup	Responder's Organizational Group within Component (e.g., CBP/USBP/Sector/Station, USCG/DCMS/RDT&E, etc.)				
Role	Responder's Role in the R&D Process (e.g., PM, Field/Group Supervisor)				
OrganizationalRole	Intended End-User's Organizational Role (e.g., Analyst, First Responder, Border Patrol Agent, etc.)				
Succes	Has this R&D product been successfully transitioned?				
SuccessComments	Comments				
Likelihood_1	What is the likelihood that this R&D product will be successfully transitioned? - 0-100%				
LikelihoodConfidence	How confident are you in the likelihood estimate above?				
Time_1	What is the time frame of a possible successful transition? - Months				
TimeConfidence	How confident are you in the time frame estimate above?				
Benefits	What are the primary benefits of the R&D Product? [Check all that apply] - Selected Choice				
Benefits_6_TEXT	What are the primary benefits of the R&D Product? [Check all that apply] - Other: (please specify) - Text				
BaselineCost	What is the degree of cost savings? Annual Baseline Cost:				
CostComment	Comments				
Cost_1	Savings relative to baseline cost: - 0-100%				
CostConfidence	How confident are you in the estimate above?				
BaselineEffort	What is the degree of reduction of effort? Annual Baseline Effort [in FTEs]:				
EffortComment	Comments				
Effort_1	Reduction relative to baseline effort: - 0-100%				
EffortConfidence	How confident are you in the estimate above?				
BaselinePerformance	What is the degree of improvement in performance of operations? Annual Baseline Performance:				
PerformanceComment	Comments				
Operations_1	Improvement relative to baseline performance: - 0-100%				
OperationsConfidence	How confident are you in the estimate above?				
ImprovementDM	What is the degree of improvement of decision making (value of information)?				
ImprovementT	What is the improvement of staff performance through training?				
Funding_1	The funding for this project was appropriate				
Funding_2	The technical skills of the team developing the R&D product for this project were appropriate				
CALCULATED:					
OVERALL OUTCOME SATISFACTION RATING	Described in Report, Section 3.4				
OVERALL PROCESS SATISFACTION RATING	Described in Report, Section 3,4				

D.2. Example Reduced Spreadsheet for the USCG TTX with PROTECT

	Stakeholder 1	Stakeholder 2
STAKEHOLDER INFORMATION		
Type of Stakeholder	R&D Rep	R&D funder
Affiliation	USCG	OUP/CREATE
OUTCOME CRITERIA		
Transitioned?	Yes	Yes
Probability of Transition	1	1
Improvement of operations	yes	yes
Baseline	100	100
Improvement	50%	50%
PROCESS CRITERIA		
Appropriateness of Funding Level	Yes	Yes
Appropriateness of Technical Skills	Yes	Yes
OVERALL OUTCOME SCORE	50	50
OVERALL PROCESS SCORE	100	100

Appendix E: R&D Customer Satisfaction Feedback Methodology Stakeholder Outreach

E.1. Summary Presentations of Customer Satisfaction Feedback (CSF) Methodology

- **a. SMART-CS Overview and Walk-Through CSF Process**
- **b. Integration with BPF 2.0**

E.2. Outreach Conducted via email and Teams/Telephone

- **a. S&T Working Groups**
  - i. S&T Transition Matrix Team Coordination Meetings – March 26, April 23, May 28 June 25
  - ii. DHS R&D Transition Measures Quarterly Meetings – March 30, June 29
- **b. DHS Components and Offices for Satisfaction Criteria, Weights and Methodology Feedback**
  - **i. CBP**
    1. Michael Wetzl – Email exchange and Teams meeting input
    2. Sharon Sharp-Harrison – Email exchange and Teams meeting input
  - **ii. CIS**
    1. Pending
  - **iii. CISA**
    1. Email to Chris Boyle, Russ Freshwater, Brian Gattoni, Garfield Jones, Martin Stanley, Celeste Tarricone Lemrow
    2. Christopher Boyle – Extensive Teams meeting discussion
  - **iv. CWMD**
    1. Email to Gregory Slovik
    2. No response
  - **v. FEMA**
    1. Email to Luke Dodd, Stephanie Teller-Parikh
    2. Denis Gusty (S&T PM/FEMA POC) – Discussion via email and phone
    3. Eli Pushkarewicz (FEMA) – Replaced Luke Dodd, added to emails along with Stephanie
    4. Stephanie Teller-Parikh (FEMA) – Follow-up on 4/19
  - **vi. ICE**
    1. Email to Jim Cole
    2. Extensive discussion via email and phone, referral to Patricia Wolfhope, who has done extensive transition work in Digital Forensics
  - **vii. TSA**
    1. Email to Frank Cartwright, James Gilkeson, Erick Rekstad
    2. Extensive discussion via Teams
  - **viii. USCG**
    1. Wendy Chaves – Immediate response to outreach; Provided input via email
    2. Alexandra Swan – First contact and immediate response; Provided input via email
    3. CSF TTX
       a. Outreach to USCG Acquisitions/RDT&E/RDC
       b. TTX Conducted – May 24, Alexandra Swan, Tim Dickerson

ix. USSS

1. Email to Kyo Dolan, Shelley Penman – 4/8 my email, 4/15 reply)
2. Reply with information about R&D from OUP 4/28

c. S&T Directorate Outreach for Customer Satisfaction Methodology Feedback

i. Office of Science and Engineering/HSARPA (OSE) Leadership

1. Jamie Johnson, Principal Director (Acting), OSE
2. Jon McEntee, Director, Operations and Requirements Analysis (ORA)
3. Technology Centers
   a. Melanie Cummings, John Merrill – email 5/21/2021;
   b. Patricia Wolfhope – Teams meeting and email/document exchanges 5/5-11

ii. PfM – Presentation to PfMs May 3

1. Jim Small – Numerous interactions, calls and email exchanges, feedback/comments
2. Doug Lane – Comments provided 5/3
3. Marilyn Rudzinsky – Responded 5/3, assigned Jim Small as POC

iii. MCS, Supervisor PMs – May 12

d. Budget and Performance Branch, Joyce Jogie, Branch Chief & Budget Director – Extensive and useful discussion and email/document exchange regarding previous work related to the CSF effort

E.3. Customer Satisfaction Feedback TTX with USCG

a. Outreach to USCG Acquisitions/RDT&E/RDC – email, telephone and Teams meetings to arrange and plan

b. TTX Conducted – May 24, Alexandra Swan, Tim Dickerson – hosted by CREATE research team, walk-through process, Qualtrics elicitation, ratings analysis