Quality insight: quality integration using engineering systems methodology

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Abstract: The final analysis in the pursuit of quality for any product boils down to quality integration. This edition of quality insight revisits the importance of building quality into a product right from the outset through the hierarchical process of systems design, evaluation, justification, and integration, using the DEJI systems model. Quality is best assured when it is integrated into all aspects of the production process. We can look no further than the tools and techniques of the field of industrial engineering, which thrives on a foundation of systems thinking. This is exactly what product quality integration needs in incorporating the multi-faceted nuances of a complex product. This paper uses the DEJI Systems Model and the Engineering Problem Solving methodology to present a case for pursuing quality integration in business, industry, academia, and other organisational types.

Keywords: DEJI systems model; quality integration; process improvement; quality standards; quality feasibility; product justification.

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1 Introduction

Quality is not only in the eye of the beholder, but also on the mind of the customer. As an integration pursuit, product quality has to be assessed from the perspective of both the producer and the consumer. Manufacturers must always be vigilant to ensure that quality exists where quality is expected. Quality at the appropriate level is essential for ensuring satisfaction and safety of end users. If the manufacturer is consumed by the belief that quality exists, it may be impossible to notice or accept when quality is missing. The case of the snafu with the automated software control of Boeing 737 Max airplane is a cruel reminder of this fact. On March 10, 2019, an Ethiopian Airlines Boeing 737 Max 8 end-route to Nairobi crashed shortly after take-off from Addis Ababa airport, killing all 149 passengers and eight crew on-board. The fact that it was the second fatal accident involving Boeing 737-Max jet in five months led to worldwide concerns about the quality and safety of the airplane. The earlier crash on October 29, 2018 involved Lion Airlines and killed 189 people, shortly after taking off from Jakarta, Indonesia. Changes in the planes' flight control system that were made because of a shift in engine placement are suspected to have played a direct role in both of the crashes. The opinion of this quality-insight column is that a systems methodology, leading to systems integration, could have pointed to potential problems with the software upgrade. The hope is that manufacturers will pay more attention to the role of systems integration in product design, development, and enhancement. Complacency and lackadaisical approaches, even in high-performing organisations can lead to disastrous outcomes. Even for land vehicles, precautions must be exercised whenever and wherever control is conceded to software action. One example is provided by Badiru et al. (2019), in which case the sudden loss of power steering assist in General Motors premium vehicles is viewed as a potential hazard in certain vehicle operational scenarios. Consequently, research-informed pre-emptive controls are embedded into the design of the steering assist. Quality integration in the present digital age can be testy. This calls for a more rigorous engineered systems methodology, which is the premise of this article. A pre-emptive systems recovery strategy that is good for a land vehicle is also good for air craft, and, in fact, good for all complex products.

2 Leveraging quality integration

Quality is best assured when it is integrated into all aspects of the production process. Badiru (2019) presents guidelines for systems design, evaluation, justification, and integration. We can look no further than the tools and techniques of the field of industrial engineering, which thrives on a foundation of systems thinking. This is affirmed by the definition of an industrial engineer as one who is concerned with the design, installation, and improvement of integrated systems of people, materials, information, equipment, and energy by drawing upon specialised knowledge and skills in the mathematical, physical, and social sciences, together with the principles and methods of engineering analysis and design to specify, predict, and evaluate the results to be obtained from such systems. This is exactly what product quality integration needs in incorporating the multi-faceted nuances of a complex product.

3 Establishing quality systems

In developing, operating, and sustaining quality systems, this paper recommends a research-informed leveraging of engineering problem-solving methodology. The typical 8-step process for engineering problem solving approach consists of the following:

Step 1 Gather data and information pertinent to the problem.

Step 2 Develop an explicit Problem Statement.

Step 3 Identify what is known and unknown.

Step 4 Specify assumptions and circumstances.

Step 5 Develop schematic representations and drawings of inputs and outputs.

Step 6 Perform engineering analysis using equations and models as applicable.

Step 7 Compose a cogent articulation of the results.

Step 8 Perform verification, presentation, and 'selling' of the result.

The steps may be tweaked, condensed, or expanded depending on the specific problem being tackled. Regardless, the steps in the framework facilitate the application of a systems-integration model. The good thing about the engineering process is that technical, social, political, economic, and managerial considerations can be factored into the solution process. The end justifies the details at hand. Based on our recommended approach of approaching problems from a systems perspective, we add the following capstone requirement to the engineering problem-solving steps: Integrate the solution into the normal operating landscape of the organisation. It is through systems integration that a sustainable actualisation of the result can be achieved as a contribution to product integrity. An adaptation of the DEJI Systems Model® (Badiru, 2019) is recommended for this purpose.

4 Application of DEJI systems model®

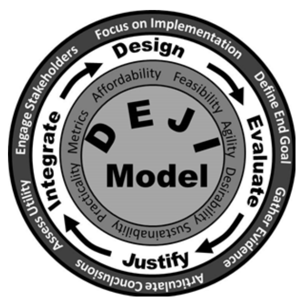
Badiru (2012) introduced the DEJI Systems Model® as a trademarked tool for structural implementation of system design, evaluation, justification, and integration. Although it was originally developed for product development applications, the model has been used for diverse applications in business, industry, government, military, and academia (Badiru, 2019). The essence of the model is captured in its iconic emblem presented in Figure 1.

The model offers flexibility across all pertinent factors that a user may be interested in. As shown in the Figure, such factors of interest may include system utility, affordability, feasibility, agility, desirability, practicality, end-goal formulation, metrics development, and stakeholder engagement. In each case, the efficacy of the model rests in its end-point focus on system integration. Without integration, even the best-crafted system will be misaligned and misguided. The DEJI model helps to harmonise the elements of the system with the operating environment of the organisation. This is of particular importance for product quality integration. In practical terms, DEJI Systems

Model facilitates linking all the factors that lead to the achievement and sustainment of the desired level of quality through efforts that accomplish the following:

- integrate
- harmonise
- synchronise
- standardise
- regularise
- blend.

Figure 1 Schematic representation of the DEJI systems model®



Source: Adapted from Badiru (2019) with permission

5 Incorporating process improvement tools

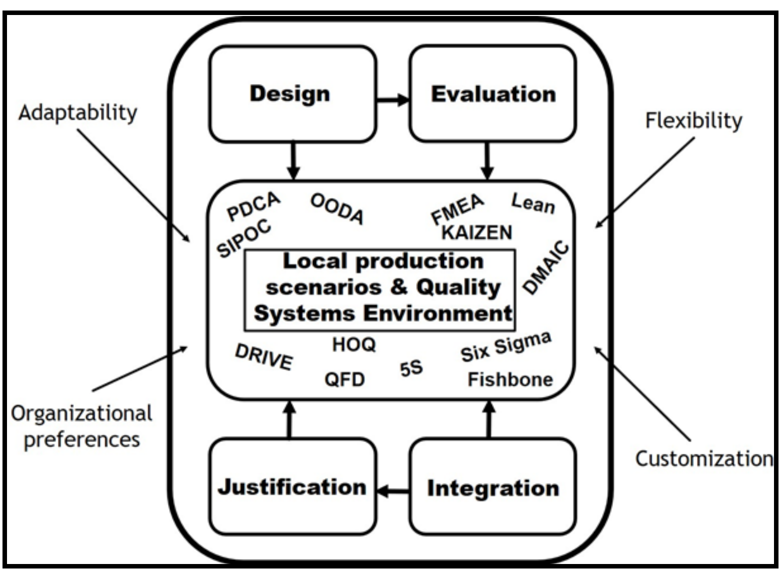
The open and flexible structure of the DEJI System Model permits the enmeshing of existing popular or familiar process improvement tools, with a common focus on achieving and sustaining product quality. Some of those tools are provided below (Agustiady and Badiru, 2013):

- plan, do, check, act (PDCA)
- observe-orient-decide-act (OODA) loop
- lean production
- Six Sigma
- define, review, identify, verify, execute (DRIVE)
- 5S (shine, straighten, shine, standardise, sustain)
- define, measure, analyse, improve, control (DMAIC)
- suppliers, inputs, processes, outputs, customers (SIPOC)
- failure mode and effects analysis (FMEA)
- fishbone diagram

- Kaizen (Japanese word for change (kai) for the better (zen))
- quality function deployment (QFD)
- house of quality (HOQ)

The house of quality tool is a product planning matrix showing how customer requirements relate directly to the processes used by a manufacturer to meet the customer's requirements. The directly ties in with the systems integration flavour of the DEJI Systems Model. Schematically, the house of quality diagram uses a design that resembles the outline of a house in constructed with components parts and benchmarked data. HOQ is the primary tool used in implementing QFD to enable group decision making, similar to crowd sourcing of product inputs. For this reason, some users mistakenly define QFD and HOQ. How all of these can fit into a practical implementation of the DEJI Systems Model is illustrated in the comprehensive rendition of Figure 2. The beauty of the representation in the figure is that any other process-improvement tool can have a complementary role in the implementation of the DEJI System Model. For example, the 'Check' in PDCA aligns well with the evaluation stage of DEJI. The 'Act' in OODA loop aligns with the actualisation of the integration stage of DEJI. The 'Standardise' in 5S could be a part of justifying a quality element in the justification stage of DEJI. The 'Measure' in DMAIC aligns with the evaluation requirement of DEJI. The 'customer' focus in SIPOC fits the requirement of the DEJI Systems Model to integrate product characteristics with what the customer really wants. All other favourite tools of quality management and improvement can fit it and complement the systems structure advocated by the DEJI Systems Model. Thus, it is a win-win approach to using the engineering systems methodology for quality integration, which is the premise of this article.

Figure 2 DEJI systems model and process improvement tools



6 Characteristics of good quality

The quality of a product is a characteristic that is recognised universally, particularly in today's globally-oriented market place, where products can flow through diverse market platforms. For example, if a product is used as intended in one market culture and judged to be of high quality, the same may not be true in a different market culture if the product usage diverges from the originally-designed purpose. A funny analogical example that I used to give my students in the 1980s and 1990s is how people often used the traditional plastic cover of a ballpoint pen as an ear pin, as the most readily-available tool when an urge to clear an itchy inner ear developed. This unacceptable social tabu is not seen much nowadays that many ballpoint pens do not have plastic covers. Rather, most pens now are 'clicker' pens. Plastic pen covers of old served the dual purpose of not only covering the ball point, but also to provide a hook for anchoring the pen to breast pockets of shirts. However, the pen plastic covers were often seen as handy and ready for picking the ear, they were seen as quite effective (i.e., of high quality) for the alternate, but unsanctioned usage. As products evolve, the quality basis can change too. This, again, points to the functional linkages that exist in quality systems, thereby necessitating an engineered approach to product design, evaluation, justification, and integration.

Quality depends on what the customer wants. That is the function of the 'integration' component of the DEJI systems model. This means that the quality of a product is a function of how the user uses the product. At this point, I can pause to challenge the reader to consider products around him or her and determine what products are being used effectively, but not for the originally-intended purpose. We will be surprised how often this happens to us at home and at work. In fact, in the time span of writing the preceding sentences, I identified four such products around my desk. If you are handy person, have you ever used the heavy lithium-battery-loaded end of your cordless drill as a quick temporary hammer to corral a wayward nail into shape? Many occupational accidents occur when products, in spite of the manufacturer's warnings and cautions, are used in a direct violation of what the product's purpose mandates. Again, in the context of the DEJI Systems Model, quality integration may mean pre-judging the different alternate unapproved ways that a product might be used by the end user.

A systems approach recognises the interplay of people, process, and machines. The lucrative field of human systems integration (HSI) comes to mind in this regard. As often defined, a system is a collection of interrelated elements work together toward a specified goal. The DEJI Systems Model advocates the integration of the various subsystems with respect to the common objective of achieving a higher sustainable quality level. From an engineering perspective, all components of an organisation should be included in the systems framework.

Cross-functional communication is very essential in linking elements throughout the nooks and corners of the organisation. For this purpose, the Triple C Concept introduced by Badiru (2008) is effective for achieving cross-functional communication, cooperation, and coordination.

7 Equation of total cost of quality

Although many inherent elements are involved, the systems approach advocated in this paper provides an opportunity to have a better handle on the total cost of quality as summarised mathematically below:

$$C_{(Total)} = C_{(poor\ quality)} + C_{(good\ quality)}$$

where

- $C_{(Total)}$ encompasses all the various costs incurred in the production of a product, from the raw materials inputs to shipping to the customers. Some pertinent costs may include workforce training, equipment purchase, maintaining a quality plan, running an agile project office, and so on. Each organisation must look critically at all the cost elements that should be included, from a systems perspective.
- $C_{(poor\ quality)}$ includes all the undesirable aspects of contending with an unacceptable product output. Cost of returns, re-work, scrap, loss of customer goodwill, insurance, and so on may enter into this portion of the equation.
- $C_{(good\ quality)}$ represents the legitimate cost of producing the product, if a system such as lean six-sigma is in effect. Ideally, this will degenerate to the total cost of the product. But there is no perfect production system. So, some cost elements beyond the legitimate direct product costs can be expected. Using a systems approach, the goal is to minimise any additional costs that may emanate from poor quality. Legitimate costs of good quality may include inspection cost, process cost, maintenance cost, data acquisition cost, records cost, data analytics cost, market networking, and others.

8 Communication and cooperation in quality integration

The triple C concept (Badiru, 2008) puts communication first and foremost for achieving organisational goals and objectives. Communication, leading to sustainable cooperation, and resulting in functional coordination provide a basis for success in the pursuit of quality integration.

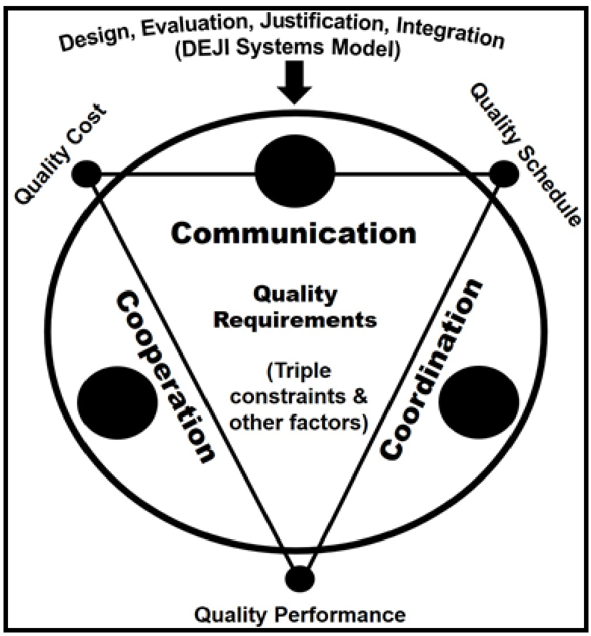
Specific details of communication should include the quality objective, statements of what, who, why, when, where, and how with regard to the quality objective, the cost or losses of low quality, and others. When communicating with the workforce, factors of importance include sympathy, empathy, respect, trust, dignity, credibility, transparency, direct engagement, accountability, equity, and inclusivity. Many projects fail when communication is lacking, particularly across the spectrum of management decisions. Recalling the tenets of Maslow's hierarchy of needs (Badiru and Bommer, 2017), the personal needs of the workforce should be considered along with the needs of the organisation, as a systems integration approach. New projects and new pursuits of quality often bring about changes. For change management to the successful, communication must be executed as a central focus. Communication breeds organisational success.

Once communication has been secured, cooperation is expected to follow naturally. In other words, communication should be elicited via a direct communication. Do not assume that cooperation will happen. It must be earned through direct communication.

Following communication and cooperation, coordination becomes easier to accomplish. Coordination facilitates harmonious and systematic integration of the contribution of each subsystem to the overall quality objectives.

The essence of what how the triple C concept can be implemented within the framework of the DEJI Systems Model is presented in Figure 3. Notice how the typical triple constraints (iron triangle) of project management interfaces with the communication, cooperation, and coordination requirements of the triple C concept (Badiru, 2008). The progressive and hierarchical structure of the DEJI Systems Model facilitates complementary inner workings of the various approaches.

Figure 3 Triple c implementation with DEJI systems model



The premise of the triple C concept is that the critical factors for product quality revolve around people and the personal commitment and dedication of each person, which implies a high level of personal cooperation. No matter how good a technology is and no matter how enhanced a process might be, it is ultimately the people involved that determine product quality. This makes it imperative to take care of people issues first in the overall systems approach to quality integration. Many organisations recognise this, but only few have been able to actualise the ideals of managing people productively. Execution of operational strategies requires forthrightness, openness, and commitment to get things done. Lip service and arm waving are not sufficient. Tangible programs that cater to the needs of people must be implemented. It is essential to provide incentives, encouragement, and empowerment for people to be self-actuating in determining how best to accomplish their job functions and, thus, impart better quality on the product. Some critical factors pertinent for ensuring product quality include the following:

- operational effectiveness
- operational efficiency

- system suitability
- system resilience
- system affordability
- system supportability
- system life cycle cost
- system performance
- system schedule
- system cost.

Systems management tools, techniques, and processes are essential for ensuring a profitable product life cycle within the context of using the SMART approach, which encompasses the following elements:

1. Specific: Pursue specific and explicit outputs.
2. Measurable: Design of outputs that can be tracked, measured, and assessed.
3. Achievable: Make outputs to be achievable and aligned with organisational goals.
4. Realistic: Pursue only the goals that are realistic and result-oriented.
5. Timed: Make outputs timed to facilitate accountability.

A systems approach is particularly essential in the early stages of conceptualising a product in order to avoid having to re-engineer the product during its life cycle. Early systems thinking makes it possible to proactively assess feasibility of meeting customer needs, adaptability of new technology, and integration of solutions into regular operations.

9 Quality commitment

Cooperation must be supported with commitment. To cooperate is to support the requirements of a product. To commit is to willingly and actively participate in product efforts again and again, throughout both the easy times and the hard times. Ready provision of resources is one way that an organisation can express commitment to a product quality, as formulated in the following equation relationship:

$$\textit{Triple C} + \textit{Commitment} = \textit{Product Success}$$

By using a Pareto-type distribution, the cooperation levels of those involved in the pursuit of product quality can be classified into three levels as shown below:

1. top 10% (easily cooperative group)
2. middle 80% (good prospects for cooperation)
3. bottom 10% (uncooperative group).

In terms of where to place efforts to get cooperation, the top 10% do not need much effort while the bottom 10% do not deserve much effort. The top 10% are the motivated individuals who will easily cooperate and advance product quality (i.e., Type Y Workers) while the bottom 10% are the disagreeable individuals who will fail to see reason no matter what is presented to them (i.e., Type X Workers). The best way to deal with those in the bottom 10% is through accommodation or exclusion (i.e., employment disengagement). Product quality efforts should be concentrated where the most gains can be achieved.

10 COVID-19 pandemic and quality integration

Leadership and teamwork play complementary roles in achieving quality integration. In this regard, person-to-person interfaces are essential. Unfortunately, in the era of COVID-19, more people in the workforce resort to working remotely, which disconnect the teamwork interfaces needed to ensure product quality integration. However, remote work is well suited for the service industry. So, while remote work may impede quality integration in physical product environments, it may actually enhance product integration for the service industry. For example, in traffic-congested cities, those working remotely in the service industry may still be able to interact, compare notes, and still move the product along through virtual tools. Not having to contend with the daily grind of traffic could mean having more remote time to work on service product requirements.

11 Conclusions

Quality integration is the basis for organisational survival and advancement. Where quality exists, business growth will follow. The premise of this paper is to advocate a rigorous usage of a systems-based engineering problem solving methodology for the pursuit of quality integration. Organisational outputs, covering physical products, services, and results, all require a structured systems approach to solidify success. There are soft (qualitative) and hard (quantitative) approaches to this charge. Using systems modelling tools, such as the DEJI Systems Model, organisations can be better prepared for quality integration for products, services, and results.

References

Agustiady, T. and Badiru, A.B. (2013) *Sustainability: Utilizing Lean Six Sigma Techniques*, Taylor & Francis CRC Press, Boca Raton, FL.

Badiru, A.B. (2008) *Triple C Model of Project Management: Communication, Cooperation, and Coordination*, Taylor & Francis CRC Press, Boca Raton, FL.

Badiru, A.B. (2012) 'Application of the DEJI model for aerospace product integration', *Journal of Aviation and Aerospace Perspectives (JAAP)*, Fall, Vol. 2, No. 2, pp. 20-34.

Badiru, A.B. and Sharon C.B. (2017) *Work Design: A Systematic Approach*, Taylor & Francis/CRC Press, Boca Raton, FL

Badiru, A.B. (2019) *Systems Engineering Models: Theory, Methods, and Applications*, Taylor & Francis/CRC Press, Boca Raton, FL.

Badiru, I.A., Boatman, V., Gornick, S., Latouf, B., Shear, P. and Krentz, R. (2019) 'Development of evaluation methods for steering loss of assist', *SAE Technical Paper*, 2019-01-1236, DOI:10.4271/2019-01-1236.