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FEATURES OF A BEHAVIOR-BASED QUALITY SYSTEM (BBQS)

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ABSTRACT

Meeting quality expectations is vital to the successful delivery of construction projects. Still, the levels of quality achieved in practice are often unsatisfactory, resulting in rework or acceptance of poor work, and impacting the project cost, schedule, safety, team morale, reputation of the organizations and individuals involved in the project, and overall customer satisfaction. Quality management research has relied on statistical process control, tolerances, and standards development. In the last years, though, attention has been shifting towards theoretical and philosophical foundations of quality, and the role people play in planning to define quality expectations and achieving them. The contribution to knowledge of this paper is to expand on the literature on Behavior-Based Quality (BBQ) by introducing the Behavior-Based Quality System (BBQS) and presenting some of its features. We present theoretical foundations of this system and illustrate some of its features through a case study. The purpose of this paper is twofold, (1) to promote more systemic thinking about the management of quality, and (2) to present features of a system that supports such thinking.

KEYWORDS

Quality, lean, Behavior-Based Quality (BBQ), Behavior-Based Quality System (BBQS), psychological safety.

INTRODUCTION

Crosby (1979 p. 6) saw quality as a "catalyst that makes the difference between success and failure." The importance of meeting quality expectations is not up for debate; the vast number of research papers and books on the subject are evidence of it. Literature on quality ranges on a spectrum from being technical-oriented to human-oriented. The technical-oriented literature pertains, for example, to tolerances and standards applicable to specific scopes (e.g., Milberg 2006, ASTM 2020). The human-oriented literature pertains, for example, to management

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practices (e.g., Crosby 1979, Deming 1986, Juran and Gryna 1988), methods and tools to minimize mistakes due to human error (e.g., Shingo 1986, Godfrey et al. 2005, Tommelein 2019), and the culture and behaviors of those involved in the quality process (Flynn 2001, Thomas et al. 2002, Howell et al. 2004, Pounds et al. 2015, Oakland and Marosszeky 2017, Spencley et al. 2018, Gomez et al. 2019, 2020).

Researchers and industry practitioners proposed Behavior-Based Quality (BBQ) as an approach to quality that highlights the human factor (e.g., to err is human, beliefs) of all people involved in the quality delivery process, from those planning the process to those executing it and assessing whether quality expectations are met. Yet, publications to date describe BBQ's intent but do not expand on how to apply it. The system described in this paper, Behavior-Based Quality System (BBQS), embraces BBQ; specifically, this paper provides a systemic overview of the BBQS and expands on BBQS's features using illustrations from a case study.

LITERATURE REVIEW

QUALITY IN CONSTRUCTION

Crosby (1979) proposed one of the most well-known definitions for quality, "conformance to requirements." He said that requirements need to be "clearly stated so that they cannot be misunderstood." In construction, ensuring that requirements are clearly stated is challenging and time-consuming because of the multiple stakeholders involved in the design and construction of a project. Many associations have developed standards, codes, and regulations that provide valuable information for designing and building construction projects (e.g., Arditi and Gunaydin 1997, ASCE 2012). However, quality issues persist, resulting in rework that can amount to as much as 12% of the total project costs (Love et al. 1999) and delay a schedule by as much as 9.8% from the original target (Dougherty et al. 2012). Despite the need to improve the delivery of quality, Koskela et al. (2019) described a decline in the quality movement due to apparent weakness in the theoretical and philosophical foundations of the subject. With this paper, we aim to contribute further to those foundations of quality.

FROM BEHAVIOR-BASED QUALITY (BBQ) TO A BEHAVIOR-BASED QUALITY SYSTEM (BBQS)

Extensive research has been conducted on Behavior-Based Safety (BBS) in construction (Geller 2001, 2005, Li et al. 2015). A search on the topic of "behavior-based safety" in the Web of Science database and Google Scholar shows 366 and 7,080 articles to date, respectively. BBS foundations suggest that safety on a project can be improved by fostering behaviors needed for safety, such as wearing protective gear or using an equipment guard (Geller 2001). BBQ is built on similar foundations, focusing on behaviors to improve the delivery of quality by fostering alignment and minimizing quality issues once work is built (Spencley et al. 2018).

Spigener (2001) described BBQ as an approach to quality that consists of engaging personnel in quality and fostering the "right behaviors" while moving away from disciplinary actions as tools for improvement. This resonates with Deming's (1986) principle of eliminating fear from the workplace to deliver quality. Researchers explored BBQ and its connection to Lean, especially to respect for people and reliable promises (Gomez et al. 2019, 2020). When managing quality, for instance, Gryna et al. (2005 p. 127) suggested to "treat all people with dignity", which reflects the Lean principle of respect for people. Similarly, understanding, aligning, and meeting certain quality expectations requires making and keeping commitments, which reflects reliable promising (Winograd and Flores 1986, Macomber and Howell 2003).

Over the past two decades, several studies have highlighted the importance of fostering psychological safety in the work environment due to its impact on team performance and learning (Edmondson 1999, Carmeli 2007, Huang and Jiang 2012). In construction projects,

performance is measured in terms of cost, schedule, quality, etc. Researchers explored the connection between Lean and psychological safety (Howell et al. 2017, Gomez et al. 2020) and proposed psychological safety as a foundational principle for BBQ (Gomez et al. 2020). Psychological safety for BBQ is viewed from a team perspective (Edmondson 1999, Edmondson and Lei 2014). In construction, a team member is everyone involved in the project delivery, from the client, to the architects who design the project, to the contractors building it. Within a construction project team, psychological safety allows the project team members to (1) talk about mistakes when these occurred instead of trying to hide them, and plan to avoid their reoccurrence, (2) ask questions to clarify expectations before building, and (3) share their concerns when requests are not feasible or achievable within the project constraints, etc.

Crosby (1979) highlighted the need to design systems to manage quality that prevent defects. Gordon et al. (2021) proposed that a more systematic view of BBQ could deliver better project outcomes. However, what such a system might look like hasn't been defined yet. Inspired by Ballard and Tommelein's (2021) work in articulating a benchmark to meet and improve upon, the first author is currently working on research to describe a BBQS and its features. An extensive literature review on quality cannot be presented here due to page length limitations; please refer to Gomez' (2023 forthcoming) dissertation. The following section presents a framing of the features that one might desire to have in a system for managing quality.

WHAT DOES THE SYSTEM LOOK LIKE?

We propose BBQS features while thinking of those doing the job; aiming to facilitate BBQ adoption. The features of the system we propose include:

1. Functions of the system: the job needed in the service of delivering quality
2. Presuppositions to be aware of: assumptions people bring when managing quality
3. Principles and behaviors that are the foundations of the system: the rules of action and the behaviors desired for quality
4. Processes involved: the steps and people involved in delivering quality
5. Methods and tools: methods and tools that facilitate the processes to deliver quality

Table 1 describes the behaviors desired of people using the system to manage quality in their everyday work. In the text that follows we illustrate how these were observed, and what processes, methods, and tools the team used to deliver quality. The remaining features are expanded on in Gomez (2023).

FINDINGS FROM PRACTICE

METHODOLOGY

We used a descriptive case study approach (Yin 1993) to explore some of the system's features and how these may have influenced the quality outcomes. We documented this case after the project was built. The General Contractor (GC) who built it considers it one of their best-in-class projects. This case is a Design-Build (DB) Tenant Improvement project with lab areas, a vivarium, and office spaces. Due to the collaborative nature of DB projects, the GC and trades such as mechanical, electrical, and plumbing, were onboarded during design. In addition, most of the GC' staff had worked together for 1-3 years on another project, prior to this one.

The first author surveyed 22 team members asking questions with responses scored on a 7-point Likert scale. In addition, she interviewed 10 of the same team members, from the architect to the drywall- and taping foremen, and asked them to describe and illustrate the following: 1) What actions did project team members take that relate to BBQ? (2) Did the team use any BBQ processes? Which ones? (3) What methods and tools fit the quality delivery process?

Table 1: Behaviors Desired for Quality in the BBQS

Behavior	Focuses on
Being respectful	Treating others with dignity and courtesy and helping them develop their capabilities (Fuligni et al. 2005, Lalljee et al. 2007)
Active caring	Looking out for the people doing the work and the quality of the work (Roberts and Geller 1995, Randall 2013, Spencley et al. 2018, Gomez et al. 2019)
Making reliable promises	Making and keeping commitments (Winograd and Flores 1986, Stoljar 1988, Macomber and Howell 2003)
Speaking up	Sharing ideas and expressing freely any question, concern, suggestion, etc., relevant to the work in discussion (Premeaux 2001, Hilverda et al. 2018)
Being diligent	Being careful, probing, not just accepting information or resources given, as is, without checking (Bernard et al. 1996, King et al. 2012, Powell 2017)
Active listening	Trying to hear not only the words that are said but the message being communicated (Bodie 2011, King et al. 2012)
Active learning	Applying the Plan-Do-Check-Act (PDCA) cycle of continuous improvement (Edmondson 1999, Kostopoulos et al. 2013)

The examples illustrated in this paper focus on drywall installation and are part of a larger study in progress. However, our hunch is that many of the features described are likely applicable to other scopes of work as well. We explore the team's psychological safety as a preamble to analyzing the features of the system in a context.

TEAM PSYCHOLOGICAL SAFETY

The GC's leadership described this team as a high-performing team. In this case, we hypothesized that the team members would show high psychological safety due to the relationship described in the literature between psychological safety, learning, and team performance. Indeed, all participants interviewed reported feeling psychologically safe to speak up and share their mistakes so that the whole team benefited from it and learned together.

"I believe we make it safe for everybody to discuss." – Drywall Project Manager (PM)

"We can rely on one another. We admit our mistakes and shortcomings." – Architect

"I'm not shy reporting any mistakes that I make, and no one here is... Everyone can speak up here." – GC Assistant Superintendent

Early in the project, the project team hosted a series of team building workshops provided by an external consultant. All the staff members who were onboarded at that time were invited to participate in these workshops. The consultant assessed each member's personality and used their responses to help them get to know each other better.

"From the profiles that [the consultant] generated, he was able to say, 'you are this kind of person, you'll say hi to everyone, and you'll do this or that.' It really helped us all to understand people better at those early stages in the project." – Architect

Although these workshops were held only at the beginning of the project, the team continued organizing activities such as happy hours and team lunch-and-learn sessions to continue strengthening the relationships between them, especially with those who joined the project later.

Through the survey, we also explored whether there was any difference between how psychologically safe craft and staff team members felt. Table 2 shows that craft scored lower; therefore, an opportunity exists to foster psychological safety more at the craft level. The drywall company belongs to the GC, so craft workers may tend to have longer job tenure, and any improvements would benefit the team in the short- and long term.

Table 2: Team Psychological Safety for Craft and Staff (1=low, 7=high psychological safety)

Psychological Safety in Relation to	Craft Perception	Staff Perception
Team leader/supervisor	5.418	6.720
Peers/other members of your team	5.947	6.500

We speculate that the staff-craft gap in psychological safety may have a connection with (1) staff members receiving more people skills training and opportunities to connect at a more personal level, (2) experiences where craftworkers were mistreated, yelled at, sent to do most tedious work in retaliation of a mistake they made, (3) craftworkers being paid hourly may feel that their jobs are more instable and avoid taking interpersonal risks for self-protection, etc.

TEAM BEHAVIORS DESIRED FOR QUALITY

We present evidence of the BBQS behaviors as described by the project team members:

Being Respectful

Participants reported being treated with respect and receiving opportunities to keep developing their capabilities. The Lean principle of respect for people is reflected in the team's effort to learn to appreciate diversity and be aware of other team members' perspectives while helping them continue expanding their technical knowledge.

"All the ideas were always heard, whether you were an engineer or a manager, everyone was heard equally, and I'd say that as a great sign of respect… [when using the layout robot, the GC asked users:] Did you feel it was useful? Was it confusing to you? What else do you think we should layout with this?... there was definitely a lot of feedback after each area [was completed], and we kept iterating the [layout] process to make it better and more useful." – Virtual Design and Construction (VDC) Engineer

Active Caring

Participants described many actions the team took showing active caring, e.g., by preventing or minimizing trade damage to the extent possible, and engaging team members in quality conversations. The team hosted conversations about so-called Distinguishing Features of Work (DFOW) for various scopes of work; drywall was not one of them, but still, they planned the scope well, heavily relying on the experience of the drywall division.

"This is the first job where I found it easy to find the information we needed... The GC superintendent helped us a lot in that aspect; all walls had QR codes with all relevant information [we needed to build]." – Drywall Foreman

"It was refreshing having a young, energetic team that was out there to do a great job." – Architect

MAKING RELIABLE PROMISES

Participants reported doing well in making and keeping promises, e.g., agreeing to apply level 5 finish to a drywall wall, considering the resources available of manpower and time required to complete the work as per the acceptance criteria.

"We are good about saying when something is not achievable. They [other team members] might not agree with this, but there it is." – Drywall PM

"On this project, requests were talked about in our group; sometimes [the GC] would say this area has to be done tonight, then we would talk about it, [and make a counterproposal], and we would agree to finish half of it that day and the rest the following day." – Drywall Superintendent

Speaking Up

Participants reported being confident when expressing their thoughts, concerns, questions, etc. We noticed, however, an overreliance on others to speak up. As shown in Table 1, craft felt less psychologically safe than staff members; being deliberate in designing means for craft members to communicate with minimal or no barriers could help them speak up.

> *"I like to ask; I prefer to ask or be asked rather than having to do the thing again." – Drywall Foreman*

> *"Most people have felt empowered to say, 'I think I've got an issue here; can I just talk to you about it?', even if it's just as simple as: 'am I being crazy?', can you just take a look at this real quick one?" – Architect*

Being Diligent

Participants described in detail the process they followed in planning and building for quality. For instance, typically checking the information to ensure it is complete, accurate, etc. In the field, similarly, checking expiration dates, materials, etc. Diligence requires being constant. Even when things are going well, it is important to keep checking and not become complacent.

> *"I dedicate myself to doing QC and making sure we don't miss things." – Drywall Foreman*

> *"We did two weekly office hours… we sat down and went through any open questions; like there is a window here and you can get daylight on this wall, so we're going to see any imperfection [due to light conditions on the wall so this wall better have a level 5 finish]." – Architect*

Active Listening

Participants reported they tend to pay full attention to the speaker, trying to understand what this person says, and what not.

> *"Our team does a really good job, we've got experienced people, but they don't let their ego or pride get in the way, and they are willing to listen." – Drywall PM*

> *"If you have an idea to share, everyone listens and pays attention. If you have a problem, you'll get an ear to listen to you." – GC Assistant Superintendent*

Active Learning

Participants described strategies they took to learn, from experimenting with the layout robot to documenting quality issues on PlanGrid. The team could use, however, a strategy to analyze root causes, such as 5 whys or cause mapping, to avoid having the issue reoccur.

> *"Everyone was very open to trying new processes, or innovate, and make something better… For the robot, we had a lot of iterations on what was good, what was not useful, and what was actually not good at all and confusing to people." – VDC Engineer*

> *"When we find a mistake on a floor, we try to avoid it on the upper floors… Still, we've had repeating mistakes that occurred. It wasn't a lot but some stuff that slipped our minds… During the daily rush that we have in the field, it's impossible to follow [remember] all the lessons learned." – GC Assistant Superintendent*

PROCESSES

The quality process, from design to production, requires multiple steps and involves many people. We limit our description of this section to subprocesses that the team thought really helped them manage quality beyond their typical practice.

User Flythrough Sessions

These sessions were an extension of what is typically done in BIM coordination. In these sessions, the focus was on including the end-users in the model review. End-users had the opportunity to virtually see what the requirements in the project drawings and specifications look like when built. This project had four different user groups (1) environmental health and safety, focused on constructability and safety, (2) biology lab users, focused on lab usability, including, for example, applicable requirements for their lab equipment, (3) vivarium lab users, also focused on lab usability, and (4) general facility management, focused on accessibility and maintenance. All these groups participated in the flythrough sessions and provided feedback.

Distinguishing Features of Work (DFOW)

The GC introduced the DFOW process to the client, architects, and trade partners early in the project. Even though no specific DFOWs conversations were scheduled for drywall work, the project team had conversations about various aspects of that scope during construction:

> *"[we talked about] what's coming up that they need our input on; for example, we're going to be building this feature wall next week; what do you want to see? When do you want to come and take a look at it? What kind of things are you concerned about here? Are there any details or junctions that drywall needs to pay attention to?" – Architect*

Trade Damage Control

Trade damage is a tough topic of conversation between subcontractors. Typically, the amount of damage is assessed and allocated to subcontractors, based on the number of people they had on the project, when the GC is closing out contracts. In this case, the team defined a process (Figure 1) that allowed them to distribute damage costs monthly. Doing this periodically allowed them to accurately assess whose responsibility it was and provided cost clarity for trades since they were getting monthly updates regarding their portion of the costs.

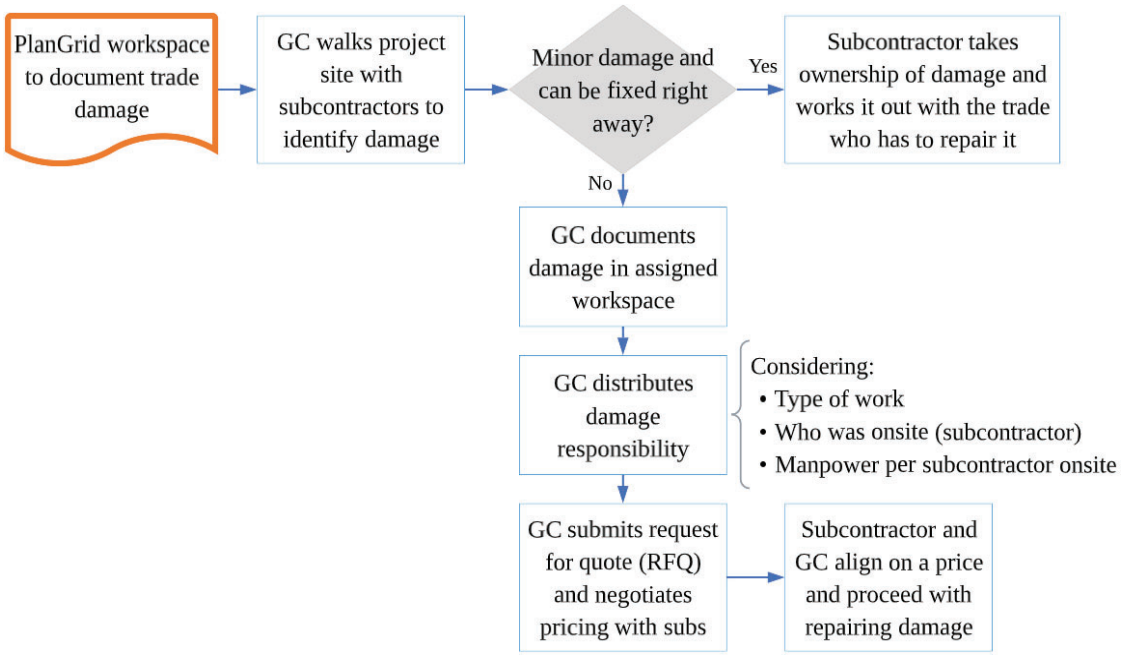

Figure 1: Quality Control: Trade Damage Management Process

The process established by the team resulted in a better distribution of damage costs:

> *"We have the biggest crew on the jobs, so we have the most manpower. In past projects, trade damage costs would be divided based on how many men you had on the job, so we would have the highest trade damage cost. Here [the GC] didn't do that. The GC took the daily reports to figure out who was in the area [assigning the damage to the ones who caused it]." – Drywall PM*

Architect Site Walks for Quality Control

The architect participated in scheduled walks to provide feedback on the acceptance of work throughout construction.

> *"We did regular walks once or twice a week with GC superintendents and produced weekly architectural field observation reports. Those walks and the field observation reports were used for corrective action with the trade partners" – Architect*

Methods and Tools

This section describes the project-specific methods and tools used to support the delivery of quality.

Automating Walls Layout

The GC used a robot they designed themselves to print layout information on the floors (from a CAD file), using lines, symbols, and different colors and inks as needed. This robot was first used on a large scale on this project. The robot laid out things that contractors needed with greater detail and faster than the manual layout.

> *"We had four lines for each wall [Figure 2]. So, if a pipe has to go exactly in the center of a wall, you'll have laid out one layer of sheetrock or two layers of sheetrock [to see verify pipes don't clash with the drywall board]." – VDC Engineer*

Figure 2: Wall Layout Painted on Floor Slab by Robot

Lean methods and tools involved in the adoption of this automated process include, for example, (1) mistakeproofing by using one specific ink color on the floor per contractor, so they do not get confused with the lines of other contractors, (2) visual management by printing the lines of each drywall board to be installed, so things that are to be embedded on the wall such as pipes do not clash with where the wall is to be installed, and (3) PDCA and collaborative design of operations by gathering feedback from the users (craft and foremen) to improve the use of the robot to better suit the needs of the field.

Facilitating Information in the Field through Dynamic QR Codes

The superintendent, who struggled on previous projects having to search more than a dozen drawings to inspect the work on one wall, developed an initiative that the GC carried to other projects after the success of this case. This initiative consisted of developing PDF packages with all relevant information to build and inspect a wall, and post these packages using dynamic QR codes in the field. Anyone on the project with a smartphone or iPad could use the QR code and access the information package. Each package included, for example, the architectural plan, electrical, mechanical, and piping plans, lighting plan, snapshots of the 3D model, and elevation views. Dynamic QR codes allowed the team to modify the content in each package without replacing the physical QR code posted onsite.

> *"The superintendent used it [QR code] a lot because every time she walked; she could say 'hey you can't close this wall because something is missing here.' Once you close the wall, there is a lot of rework. Compared to her previous jobs, where she had to open the wall for changes, here we had very few cases where we had to open something for a change." – VDC Engineer*

Before closing walls, the GC's assistant superintendent walked the site to inspect the work and took pictures of where the pipes were located (Figure 3). When a wall is closed up, and some other contractor or the owner needs to install something and screw something into the wall, they know exactly where the pipe is located and can avoid damaging the pipe by drilling into it.

Lean methods and tools for such information available include, for example, (1) visual devices comprising QR codes on each wall with all the information pertaining to that specific wall (and not the entire floor), (2) standardization by developing a format with the expected content in each PDF package so that the development of the packages could be done by a third party instead of an assigned superintendent or project engineer.

Visually Communicating Expectations and Outcomes

The team adopted visual management to communicate the expectations of delivered work and whether the work conformed with the acceptance criteria defined. For instance, when preparing for city inspections in the framing stage, the drywall contractor spray-painted the fasteners on the framing bottom track (Figure 4). When the city inspector walked the site, he quickly verified

that fasteners were installed, conforming with the agreed acceptance criteria. The inspector appreciated the drywall team doing this because it helped them to conduct inspections faster.

> *"The [city] inspector asked me to paint all the [fasteners on the bottom track] so that he didn't have to spend time looking where they are; he just wanted to walk and quickly see where they were installed." – Drywall Foreman*

Figure 3: Photo Included in PDF Package Showing Pipe Location with Respect to Corner

Figure 4: Fasteners Ready and Spray-Painted Green for Inspection

DISCUSSION

The system we introduced in this paper, the BBQS, is one way to approach BBQ from a systems perspective. While building the BBQS, we identified a set of features to facilitate BBQ understanding and adoption. Because every project team is unique, practitioners may apply some of the BBQS features more than others and to a different extent. For instance, in our case study of a project that successfully delivered quality expectations, we analyzed how the behaviors feature was observed by the participants involved and what opportunities for improvement can be explored further. In terms of active learning, although the interviewees reported doing well in learning from issues and experimentation, the learning process itself could have been improved. Participants acknowledged that some defects were repeated because it had 'slipped my mind' to develop countermeasures. The team could have documented the lessons learned more systematically and reviewed those lessons before moving to the next work area.

The BBQS features we presented are intertwined. For instance, the processes developed by the team supported the behaviors they displayed and vice versa. For example, when using the QR codes, the team enabled every trade to do their quality control and encouraged them to raise any issues while checking their work. Also, trade damage discussions fostered discipline in documenting damage, and created a fair and transparent environment that contributed to team collaboration and an increase in active caring for the work of others, ergo minimizing damage. The BBQS features of a quality system based on Lean foundations are meant to be further refined and augmented.

CONCLUSIONS

Few publications have addressed the role of the human factor from a behavioral perspective of those participants involved in defining quality expectations and meeting them. Some emphasized the need to develop a more behavior-based approach to managing quality, proposing BBQ for construction projects. Acknowledging that behaviors matter for the delivery of quality expectations, this paper answered the question: How do we take the main idea of BBQ and make it actionable so that project teams can implement it? This paper contributes to

the literature by proposing a more systemic thinking about BBQ and presenting the features of a system, the BBQS, that supports such thinking.

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REFERENCES

American Society of Civil Engineers (ASCE). (2012). Quality in the Constructed Project: A Guide for Owners, Designers, and Constructors. Reston, VA, USA.

American Society for Testing and Materials (ASTM). (2020). Annual Book of ASTM Standards. American Society for Testing and Materials, Conshohocken, PA, USA, 4.

Arditi, D., & Gunaydin, H.M. (1997). Total Quality Management in the Construction Process. Int. J. of Project Management, 15(4), 235-243. doi.org.10.1016/S0263-7863(96)00076-2

Ballard, G., & Tommelein, I. (2021). 2020 Current Process Benchmark for the Last Planner® System of Project Planning and Control. University of California, Berkeley. https://escholarship.org/uc/item/5t90q8q9

Bernard, H., Drake, D., Paces, J., & Raynor, H. (1996). Student-Centered Educational Reform: The Impact of Parental and Educator Support of Student Diligence. School Community Journal, 6(2).

Bodie, G. (2011). The Active-Empathic Listening Scale (AELS): Conceptualization and Evidence of Validity within the Interpersonal Domain. Communication Quarterly, 59(3), 277-295. doi.org/10.1080/01463373.2011.583495

Carmeli, A. (2007). Social Capital, Psychological Safety and Learning Behaviors from Failure in Organizations. Long Range Planning, 40(1), 30-44. doi.org/10.1016/j.lrp.2006.12.002

Crosby, P.B. (1979). Quality is Free: The Art of Making Quality Certain. McGraw-Hill, New York, NY, USA, 309.

Deming, W.E. (1986). Out of the Crisis. MIT Press., Cambridge, MA, USA, 524.

Dougherty, J.M., Hughes, N., & Zack, Jr., J.G. (2012). The Impact of Rework on Construction and Some Practical Remedies. Navigant Construction Forum, 21.

Edmondson, A.C. (1999). Psychological Safety and Learning Behavior in Work Teams. Administrative Science Quarterly, 44(2), 350-383. doi.org/10.2307/266699

Edmondson, A.C., & Lei, Z. (2014). Psychological Safety: The History, Renaissance, and Future of an Interpersonal Construct. Annu. Rev. Org. Psychol. Org. Behav., 1(1), 23-43.

Flynn, K. (2001). Behavior-Based Quality – Connecting People to the Systems. Behavioral Science Technology Annual Spring Conf. Proc., Chicago, IL, USA.

Fuligni, A.J., Witkow, M., & Garcia, C. (2005). Ethnic Identity and the Academic Adjustment of Adolescents from Mexican, Chinese, and European Backgrounds. Dev. Psychology, 41(5), 799-811. doi.org/10.1037/0012-1649.41.5.799

Geller, E.S. (2001). Behavior-Based Safety in Industry: Realizing the Large-Scale Potential of Psychology to Promote Human Welfare. Applied and Preventive Psych., 10(2), 87-105.

Geller, E.S. (2005). Behavior-Based Safety and Occupational Risk Management. Behavior Modification, 29(3), 539-561. doi.org/10.1177/0145445504273287

Godfrey, A.B., Clapp, T.G., Nakajo, T., & Seastrunk, C.S. (2005). Application of Healthcare-Focused Error Proofing: Principles and Solution Directions for Reducing Human Errors. Proc. ASQ World Conference on Quality and Improvement, Seattle, WA, USA, 335-340.

Gomez, S. (2023). Behavior-Based Quality System. [Unpublished Doctoral Dissertation],

University of California, Berkeley, forthcoming.
Gomez, S., Ballard, G., Arroyo, P., Hackler, C., Spencley, R., & Tommelein, I.D. (2020). Lean, Psychological Safety, and Behavior-Based Quality: A Focus on People and Value Delivery. Proc. 28th Ann. Conf. IGLC, Berkeley, CA, USA, 97-108. doi.org/10.24928/2020/0056
Gomez, S., Huynh, R., Arroyo, P., Ballard, G., Tommelein, I.D., & Tillmann, P. (2019). Changing Behaviors Upstream to Achieve Expected Outcomes. Proc. 27th Ann. Conf. Int. Group for Lean Const., Dublin, Ireland, 13-24. doi.org/10.24928/2019/0216
Gordon, E., Rawlinson, K., Eldamnhoury, E., Marosszeky, M., & Reed, D. (2021). The Impact of Implementing a System Approach to Quality: A General Contractor Case Study. Proc. 29th Ann. Conf. IGLC, Lima, Peru, 893–902. doi.org/10.24928/2021/0193
Gryna, F., Chua, R.C.H., & DeFeo, J.A. (2005). Juran's Quality Planning and Analysis for Enterprise Quality, 5th Ed. Tata McGraw-Hill Education, New York, NY, USA.
Hilverda, F., van Gils, R., & de Graaff, M.C. (2018). Confronting Co-workers: Role Models, Attitudes, Expectations, and Perceived Behavioral Control as Predictors of Employee Voice in the Military. Frontiers in Psychology, 9. doi.org/10.3389/fpsyg.2018.02515
Howell, G.A., Ballard, G., & Demirkesen, S. (2017). Why Lean Projects Are Safer. Proc. 25th Ann. Conf. IGLC, Heraklion, Greece, 895-901. doi.org/10.24928/2017/0116
Howell, G.A., Macomber, H., Koskela, L., & Draper, J. (2004). Leadership and Project Management: Time for a Shift from Fayol to Flores. Proc. 12th Ann. Conf. Int. Group for Lean Const., Helsingør, Denmark.
Huang, C.C., & Jiang, P.C. (2012). Exploring the Psychological Safety of R&D Teams: An Empirical Analysis in Taiwan. J. of Mgmt. and Organization, 18(2), 175-192.
Juran, J.M., & Gryna, F.M. (1988). Juran's Quality Control Handbook, 4th Ed. McGraw-Hill, New York, NY, USA.
King, G.A., Servais, M., Bolack, L., Shepherd, T.A., & Willoughby, C. (2012). Development of a Measure to Assess Effective Listening and Interactive Communication Skills in the Delivery of Children's Rehabilitation Services. Disability and Rehabilitation: An Int., Multidisciplinary J., 34(6), 459-469. doi.org/10.3109/09638288.2011.608143
Koskela, L., Tezel, A., & Patel, V. (2019). Theory of Quality Management: Its Origins and History. Proc. 27th Ann. Conf. Int. Group for Lean Const., Dublin, Ireland, 1381-1390. doi.org/10.24928/2019/0259
Kostopoulos, K., Spanos, Y., & Prastacos G. (2013). Structure and Function of Team Learning Emergence: A Multilevel Empirical Validation. J. of Mgmt., 39, 6, 1430-1461
Lalljee, M., Laham, S.M., & Tam, T. (2007). Unconditional Respect for Persons: A Social Psychological Analysis. Gruppendynamik und Organisationsberatung, 38(4), 451-464.
Li, H., Lu, M., Hsu, S.C., Gray, M., & Huang, T. (2015). Proactive Behavior-Based Safety Management for Construction Safety Improvement. Safety Science, 75, 107-117.
Love, P.E., Mandal, P., & Li, H. (1999). Determining the Causal Structure of Rework Influences in Construction. Const. Mgmt. & Econ,, 17(4), 505-517. doi.org/10.1080/014461999371420
Macomber, H., & Howell, G.A. (2003). Linguistic Action: Contributing to the Theory of Lean Construction. Proc. 11th Ann. Conf. Int. Group for Lean Const. Blacksburg, VI, USA.
Milberg, C. (2006). Application of Tolerance Management to Civil Systems. Doctoral Dissertation, University of California, Berkeley, CA, USA.
Oakland, J.S., & Marosszeky, M. (2017). Total Construction Management: Lean Quality in Construction Project Delivery. Routledge, New York, USA.
Pounds, J., Werner, T., Foxworthy, B., & Moran, D. (2015). Quality, Behavior, and the Bottom Line: The Human Side of Quality Improvement. CreateSpace Independent Publishing Platform, South Carolina, USA.

Powell, T.C. (2017). Strategy as Diligence: Putting Behavioral Strategy into Practice. California Management Review, 59(3), 162-190. doi.org/10.1177/0008125617707975

Premeaux, S.F. (2001). Breaking the Silence: Toward an Understanding of Speaking Up in the Workplace. Doctoral Diss., Louisiana State U. and Agri. & Mech. Coll., Baton Rouge, LA.

Randall, P.A. (2013). Actively Caring About the Actively Caring Survey: Evaluating the Reliability and Validity of a Measure of Dispositional Altruism. [Master Thesis] East Tennessee State University, Johnson, TN. https://dc.etsu.edu/etd/2275

Roberts, D.S., & Geller, E.S. (1995). An ‘‘Actively Caring” Model for Occupational Safety: A Field Test. Applied and Preventive Psychology, 4(1), 53-59.

Shingo, S. (1986). Zero Quality Control: Source Inspection and the Poka-Yoke System. Portland, Oregon: Productivity Press.

Spencley, R., Pfeffer, G., Gordon, E., Hain, F., Reed, D., & Marosszeky, M. (2018). Behavior-Based Quality Closing the Knowing-Doing Gap. Proc. 26th Ann. Conf. Int. Group for Lean Const., Chennai, India, 1170-1181. doi.org/10.24928/2018/0532

Spigener, J. (2001). Quality – The Next Step is Getting to the Level of Behavior. SAE Transactions, 244-248.

Stoljar, S. (1988). Promise, Expectation and Agreement. Cambridge Law J., 47(2), 193-212.

Thomas, R., Marosszeky, M., Karim, K., Davis, S. & McGeorge, D. (2002). The Importance of Project Culture in Achieving Quality Outcomes in Construction. Proc. 10th Ann. Conf. Int. Group for Lean Const., Gramado, Brazil.

Tommelein, I.D. (2019). Principles of Mistakeproofing and Inventive Problem Solving (TRIZ). Proc. 27th Ann. Conf. IGLC, Dublin, Ireland, 1401-1412. doi.org/10.24928/2019/0129

Winograd, T., & Flores, F. (1986). Understanding Computers and Cognition: A New Foundation for Design. Norwood, NJ: Ablex.

Yin, R. (1993). Applications of Case Study Research. Beverly Hills, CA: Sage.