Mulholland, S.M., Banasiak, M., Clevenger, C.M., Staton, J., & Brown, Q. (2022). Establishing Design Metrics to Inform Design Change, Increase Project Team Communication, and Reduce Waste: A Healthcare Case Study. *Proceedings of the 30th Annual Conference of the International Group for Lean Construction (IGLC30)*, 1134–1143. doi.org/10.24928/2022/0223

ESTABLISHING DESIGN METRICS TO INFORM DESIGN CHANGE, INCREASE PROJECT TEAM COMMUNICATION, AND REDUCE WASTE: A HEALTHCARE CASE STUDY

Sean M. Mulholland[1], Meredith Banasiak[2], Caroline M. Clevenger[3], Jamie Staton[4], and Qadry Brown[5]

ABSTRACT

This study aims to evaluate via a case study the process in establishing post-construction performance goals and their perceived impact to a design and construction project team's culture. Performance goals were established from an iterative quantitative approach, while the impact to the design and construction team were evaluated by a qualitative method. Preliminary results appear to indicate a likely positive impact to a project team's culture, level of effort, and trust. Specifically, results may indicate a net positive impact from unambiguous post-construction performance goals to a project team's perception of its communication and overall project environment, reduction in traditional sources of process waste, and a positive impact to elements associated with cost, schedule, and quality.

KEYWORDS

Collaboration, Case study, Integration, Value, Integrated Project Delivery

INTRODUCTION

Pediatric inpatient behavioral health facilities have historically been designed to maximize patient safety and staff security, as well as operational efficiency, often at the expense of other healing goals. Such care practices can trigger a patient's experience of trauma during treatment. This induced trauma can create adverse effects on healthcare staff and family members and create barriers to providing patient care. Trauma-informed design recognizes the role the environment plays in supporting trauma-informed care (SAMHSA, 2022). Trauma-informed and family centered design approaches aim to

[1] Assistant Professor, Civil & Environmental Engineering Department, United States Air Force Academy, USA, sean.mulholland@afacademy.af.edu, orcid.org/0000-0002-6598-6830

[2] Director of Research, Boulder Associates Architects, Boulder, USA, mbanasiak@boulderassociates.com, orcid.org/0000-0001-8483-419X

[3] Professor, Civil Engineering, Assistant Director, Construction Engineering and Management, University of Colorado Denver, Denver, USA, caroline.clevenger@ucdenver.edu, orcid.org/0000-0003-2265-8447

[4] Project Executive, GE Johnson Construction Company, Colorado Springs, USA, statonj@gejohnson.com

[5] Cadet, US Air Force Academy, USA, C22Qadry.Brown@afacademy.af.edu

facilitate care which minimizes re-traumatization for the patient and provides family support during treatment and recovery.

The shift in behavioral health to trauma-informed care is relatively new. As such, there are few programmatic and design precedents to draw from which can support this new standard in care delivery. Having defined performance goals post-construction are essential for the design team to propose and test potential design interventions which aim to meet those goals. The importance of trauma-informed care is a significant design element for the architectural and engineering design teams and is therefore assumed to be of significance to the construction trade partners. This assumption is based on the effort and significance that such programming priorities are disseminated throughout a project team and over the project duration. The establishment of these programming priorities provide an opportunity to understand how these priorities may impact project team members.

This study aims to evaluate what, if any, impact there is to a project team's culture, level of effort, and interpersonal trust stemming from clear and measurable post-construction performance goals based on existing and/or industry established systems of measurement (to be referred hereafter as "design metrics). Design metrics were used to quantify how patient, staff and family outcomes were impacted from an existing behavior health design, and how these were used to inform design and construction of a new pediatric inpatient behavior health unit. Though these design metrics are specific to an individual pediatric behavior health unit, intent of this study is to highlight efficiencies gained by design and construction team using measurable and achievable design metrics.

Specifically, this research looks to evaluate the impact of unambiguous design metrics to a project's cost, schedule, level of communication, and level of effort, trust and overall satisfaction of the project team its culture. This research will assume the following in its evaluation:

Proposition 1: Programming design metrics have a positive impact on communication, level of trust, and project culture.

Proposition 2: Programming design metrics assist in reducing waste within a collaborative environment.

Proposition 3: Programming design metric has positive impact on project success (success may be defined in terms of any of the parameter of cost, time, quality or H&S).

LITERATURE REVIEW

There has been limited research into the impacts of design metrics on project team communication and overall collaboration. Established research includes areas specific to designing via project goals/ metrics to increase trust, collaboration and increase communication within the built environment (Hanna, 2016, Abdelaal, 2016; Gibson et al., 2006; Korin & Taplin, 2004). Distinct from this area of research though, and specific to the purpose of this paper is to evaluate the impact of design metrics on a project team rather than the impact of a designed space on occupants' post-occupancy. For instance, Lamb and Shraiky (2013) reviewed post-occupancy data of healthcare classroom environments and identified common design concepts common to facilities that enhance collaboration amongst its users. Leder et al. (2016) evaluated employee and project client satisfaction of green office buildings and found on increased satisfaction when certain green design principals were utilized. Uusitalo et al.(2021) evaluated the impact of design issues and quality to trust, collaboration, and overall communication.

More generally, existing research evaluates the impact and applicability of evidence-based design (EBD) and the effect of design to healthcare environments. Elf et al. (2020) reviewed existing literature of EBD and noted that most of the research to date has reported on patient's and staff's psychosocial experience as compared to medical and/or physiological responses to the environment. Similarly, Anåker et al. (2017) performed an extensive literature review on EBD design quality in healthcare settings and concluded that clear definition of design/project quality is needed to meet the needs of stakeholders. Stakeholder involvement with design/project goals was specific to the research of Sadler et al. (2008) when reviewing the connection between design quality and positive patient outcomes.

Research linking construction metrics and benchmarking to project success are more numerous, but do not necessarily address design metrics to the three research propositions. Construction related metrics such as number of request for information (RFI), change orders, schedule changes, amount of rework, punchlist items, safety issues, behavior/leadership observations and the like have been reviewed by numerous researchers including Umstot et al. (2014), Hanna (2016), Bonilla & Costillo (2020), Bølkviken et al. (2017), Alarcon & Serpell (1996), Korkmaz et al. (2010), Swarup et al. (2011), Azari & Kim (2014), and Esmaeili et al. (2013). Additional research has considered the impact of design to quality issues during and post construction that may impact end-user post-occupancy, such as Lam et al. (2010), Riley and Horman (2001), Hamzeh et al. (2019), and O'Sullivan et al. (2004). None of these though specifically address the purpose of this paper, and/or the three research propositions.

RESEARCH METHODS AND DATA

This research follows a traditional mixed-methods approach utilizing data from a single case study (Guetterman & Fetters, 2018; Korkmaz et al., 2011). Mixed-methods typically indicates a combination of qualitative and quantitative methods and data types (Ladner, 2019). This research method was chosen as an ideal methodology to explore the seemingly inconsistent impact (qualitative) of the project design metrics to the project team by the constant (quantitative) project design metrics. Though it is common in design and construction to use mixed method research to use a quantitative analysis to quantify an issue and then use a qualitative analysis to understand the why (Fellows & Liu, 2015), here we use a qualitative analysis to understand the impact from the results of a quantitative analysis on the project team.

Following the literature review, a two-stage process similar to other case-study research (Ozorhon, Abbott, & Aouad, 2014; Souza de Souza & Koskela, 2014) was conducted to confirm the research propositions. The first stage involved establishing design metrics that met the performance criteria that was of importance to the end-users and justified the business case for the project by the hospital system. This was a quantitative process, based on the data analysis originated from the project owner. Once the design metrics were established and had been in use for the design phases and majority of the construction project, the second stage of conducting a qualitative analysis with the project team was undertaken to understand the impact.

CASE STUDY

This paper presents findings from a $23million Integrated Project Delivery (IPD) (AIA-C191) pediatric behavior-health expansion project located in the Rocky Mountain west of the USA. The hospital provides a complete continuum of psychiatric services including outpatient, partial hospitalization, inpatient and emergency services for children and adolescents, as well as non-behavior services. The project was spread over 4 floors of a building, totaling roughly 80,000sf. Each floor contained separate behavior health care modalities, as well as support administrative spaces. Design began in the fall of 2019, with construction starting during the summer of 2020 and is scheduled to be fully completed during early summer of 2022. The hospital design team was an interdisciplinary team that included psychiatrists, psychologists, clinical social workers, licensed professional counselors, nurses and creative art therapists to address the unique treatment needs of the patients. Design and construction members were selected during the onboarding selection process, while hospital clinical members were selected by hospital leadership and in-house design and construction staff.

STAGE 1 – ESTABLISHING DESIGN METRICS

Project Goals and Design Concepts

The first stage began during the initial phases of design, during the spring of 2020. Input from the owner and end-users were utilized to frame and document the project goals.

The project team focused on the following goals which best framed opportunities for innovating the design of the milieu to support the delivery of trauma-informed care.

Goal 1. To optimize staff safety and health, reduce staff injury

Goal 2. To elevate patient experience, reduce acute stress and aggression triggers

Goal 3. To promote family recovery, engage parents in inpatient care delivery.

For the purpose of this research, only goals 1 and 2 relate to the physical space and will be the focus of study. Goal 3 was intended to be operationally focused, is routinely post-admission, and will not be studied. After the project goals were established, the project team next created design and process concepts to support these goals (Figure 1). In some cases, the design concept drove the need for new operational processes and in other cases, the aim for new care practices drove the need for innovative physical environments.

Figure 1: Impact areas (central core) and project goals (outer ring) associated with supporting trauma-informed and family centered care in a pediatric behavioral health inpatient setting

Design metrics and Analysis

Once the project goals and supporting design concepts were established, diagnostic post-occupancy evaluation (POE) was used to assist in the establishment of the project design metrics. The POE correlates physical environmental measures with subjective occupant response measures for the purpose of creating new knowledge about building performance (Preiser, 2001). This POE utilized multiple methods to provide a more complete assessment to align outcomes with the design. Descriptive statistics were used to analyze data collected across the existing and renovated facilities to evaluate the ability to formulate project design metrics (Table 1). Quantitative analysis of facility and patient (de-identified) data was obtained to set a baseline for future analysis of the new construction, post-occupancy. Once these were established, the project team could then use project design metrics to evaluate design objectives.

Table 1: Data type and source based on project goal

Data Acquisition Question Based on Goal	Data Source	Project Design Metrics
Can staff injury be reduced by decreasing events associated with physical and verbal aggression?	De-identified patient data	Decrease in restraint use: incidences and frequency
	De-identified patient data	Decrease in seclusion use: incidences and frequency
	De-identified staffing and security data	Decrease in staff injury: incidences and frequency
	De-identified patient data	Decrease in staff turnover rate
Can patient acute stress and aggression triggers be reduced	Facility data	Decrease in building repair requests resulting from patient behaviors: number and type of repair
	Facility data	Process maps for behavior events
	Lighting & acoustics survey	Staff ratings of environmental attributes to patient spaces
	Staff surveys	Staff characterization of patient triggers, types, and locations
	Staff surveys	Staff rating of environmental attributes in patient spaces

STAGE 2 – IMPACT ANALYSIS

The second stage of analysis focused on what, if any, impact these design metrics had on the design and construction team. Specifically, did the presence of definable project design metrics change, alter, and/or facilitate communication and/or reduce waste during the design and construction phases? As noted previously, this was abridged to the three research propositions (see Introduction).

To understand the perceived impact, a survey was conducted via Qualtrics and sent to project participants. The survey was sent to a total of 22 project participants, with preliminary responses currently being reported (*final results will be published in time for final submittal*). Questions asked were based on a 5pt Likert scale, with logic being applied to questions based on their familiarity with the project metrics.

Questions asked were:

(1) *(2)* *(3)* *(4)* *(5)*

None at all *A great deal*

a) How familiar ere you with the project design metrics?

For those that responded with a value response of 4 or 5, the following questions were asked:

b) Project Design Metrics increased communication

c) Project Design Metrics assisted in reducing waste

d) Project Design Metrics had a net positive project effect to traditional cost, schedule, and quality aspects

For those that responded with a value response of 1, 2, or 3, the follow questions were asked:

1) (2) (3) (4) (5)

None at all A great deal

a) Familiarity with Project Design Metrics would have increased communication

b) Familiarity with Project Design Metrics would have assisted in reducing waste

c) Familiarity with Project Design Metrics would have had a net positive project effect to traditional cost, schedule, and quality aspects

Results:

Preliminary results shown in tables below. (Note these are preliminary results presented for illustration purposes. Complete results will be available and analyzed in time for final submittal). Table 2 presents a breakdown of responses by project role, namely 50% owner/ owner rep, 33% Designer, and 17% Contractor.

Table 2: Survey Responses by Project Role

Project Role	% Responses
Owner/ Owner Rep	50%
Designer – Arch/ Eng/ Consultant	33%
Contractor – GC/ Sub	17%

Table 3 displays averaged (5pt Likert) results of respondent's familiarity with the project design metrics. Whether responding with a higher familiarity with the project design metrics (83.4%) or no familiarity with the metrics (16.6%), all respondents noted that the project design metrics either had a positive impact on project elements or would have if the respondents were familiar with the project design metrics.

Table 3: Project Design Metrics Impact Survey: 5pt Likert Scale

Statement	Mean Response	Standard Deviation
Your level of familiarity with program metrics	4.5	1.2
Design metrics increased communication	3.8	0.4
Design metrics assisted in reducing waste	3.6	0.9
Design metrics had a net positive impact to cost, schedule, and quality	4.2	0.4
Familiarity with the design metrics would have increased communication if known	4.5	0.7
Familiarity with the design metrics would have assisted in reduction waste if known	2.3	0.6
Familiarity with the design metrics would have had a net positive impact to cost, schedule and quality if known	4.0	0.0

Table 4 shows results for the impact of the project design metrics on communication, for respondents that noted an elevated (survey response of slight or very) familiarity with the design metrics. The majority of responses noted that the project design metrics increased communication during the programming (40% of response) and design phases (40% of responses).

Table 4: Project Design Metric Phase Impact: Communication

What Phase(s) Did Design Metrics Increase Communication	% Responses
Programming Phase	40%
Design Phase	40%
Pre-Construction Phase	20%

Table 5 displays results for the impact of the project design metrics on reducing waste, for respondents that noted an elevated (survey response of slight or very) familiarity with the design metrics. The majority of responses noted that the project design metrics reduced wasted during the programming (40% of response) and design phases (40% of responses).

Table 5: Project Design Metrics Phase Impact: Reducing Waste

What Phase(s) Did Design Metrics Assist in Reducing Waste	% Responses
Programming Phase	40%
Design Phase	40%
Pre-Construction Phase	20%

Table 6 shows results for the impact of the project design metrics on cost, schedule, and quality aspects of the project, for respondents that noted an elevated (survey response of slight or very) familiarity with the design metrics. The majority of responses noted that the project design metrics impacted the construction phase the most (38% of response), followed by pre-construction (25%), project close-out (13%), programming (12%), and design phases (12%) phases.

Table 6: Project Design Metrics Phase Impact: Iron Triangle

What Phase(s) Did Design Metrics Have on Cost, Schedule, Quality Aspects?	% Responses
Programming Phase	12%
Design Phase	12%
Pre-Construction Phase	25%
Construction Phase	38%
Project Close-out	13%

DISCUSSION AND CONCLUSION

Results of the survey show an interesting mix of responses. Most responses either noted the project design metrics had or would have had on impact to the three research propositions, with one exception. For respondents who were unfamiliar with the project design metrics, responses averaged a lower impact to reducing waste. This may be the result of a smaller sample size, or respondents felt that the impact would have been less compared to the impact to communication and cost, schedule, and quality. Either way that this is viewed, the results show a positive impact from establishing project design metrics.

Results seem to suggest that the project design metrics had an impact on outcomes related to programming and design phases, except in the case of "cost, schedule and quality aspects" where respondents acknowledged the benefit to outcomes equally among design and construction phases. For a collaborative IPD team, this may reflect the importance of specific and quantifiable project goals on construction phase outcomes.

Results from this research highlight the importance and potential outcomes across the design and construction process from establishing quantifiable project metrics at the beginning of a project. A qualitative analysis was then conducted to quantify what, if any, impact the project design metrics had on the project team. Based on results from a project team survey, the results appear to indicate a likely positive impact to project team communication, traditional cost, schedule, and quality aspects, as well as possibly reducing project waste.

Due to the relatively small sample size, these results may or may not be generalizable to every project. But based on previous research on the importance of project metrics, it can be assumed that these results would be transferable to similar project structures. Future research may want to review what impact project design metrics have on specific project roles, and impact to project risks.

DISCLAIMER

The views expressed in this article, book, or presentation are those of the author and do not necessarily reflect the official policy or position of the United States Air Force Academy, the Air Force, the Department of Defense, or the U.S. Government

REFERENCES

Abdelaal, M. S. (2016). The Architectural Building Blocks of Innovation: a comprehensive metric for developing innovative spaces. *33rd IASP World Conference on Science and Technology Parks*, 399–423. https://doi.org/10.1108/02580540910943550

Alarcon, L. F., & Serpell, A. (1996). Performance Measuring Benchmarks, and Modelling of Construction Projects. *4th Annual Conference of the International Group for Lean Construction*, 1–10. Birmingham.

Anåker, A., Heylighen, A., Nordin, S., & Elf, M. (2017). Design Quality in the Context of Healthcare Environments: A Scoping Review. *Health Environments Research and Design Journal*, *10*(4), 136–150. https://doi.org/10.1177/1937586716679404

Azari, R., & Kim, Y.-W. (2014). Development and Validation of a Framework for Evaluation of Integrated Design Teams of Sustainable High-Performance Buildings. *Construction Research Congress 2014*, 584–593.

Bolkviken, T., Aslesen, S., Kalsaas, B. T., & Koskela, L. (2017). A Balanced Dashboard for Production Planning and Control. *LC3 2017 Volume II - Proceedings of the 25th Annual Conference of the International Group for Lean Construction*, (July), 621–628.

Bonilla, M., & Castillo, T. (2020). Benchmarking the construction industry: An adaptation of the world management survey methodology. *IGLC 28 - 28th Annual Conference of the International Group for Lean Construction 2020*, 217–228. https://doi.org/10.24928/2020/0057

Elf, M., Anåker, A., Marcheschi, E., Sigurjónsson, Á., & Ulrich, R. S. (2020). The built environment and its impact on health outcomes and experiences of patients, significant others and staff—A protocol for a systematic review. *Nursing Open*, *7*(3), 895–899. https://doi.org/10.1002/nop2.452

Esmaeili, B., Franz, B., Molenaar, K. R., Leicht, R. M., & Messner, J. (2013). A review of critical success factors and performance metrics on construction projects. *Proceedings, Annual Conference - Canadian Society for Civil Engineering*, *1*(January), 574–583.

Fellows, R., & Liu, A. (2015). *Research Methods for Construction* (4th ed.). West Sussex: John Wiley & Sons, Incorporated.

Gibson, G. E., Wang, Y.-R., Cho, C.-S., & Pappas, M. P. (2006). What Is Preproject Planning, Anyway? *Journal of Management in Engineering*, *22*(1), 35–42. https://doi.org/10.1061/(asce)0742-597x(2006)22:1(35)

Guetterman, T. C., & Fetters, M. D. (2018). Two Methodological Approaches to the Integration of Mixed Methods and Case Study Designs: A Systematic Review. *American Behavioral Scientist*, *62*(7), 900–918. https://doi.org/10.1177/0002764218772641

Hamzeh, F. R., El Samad, G., & Emdanat, S. (2019). Advanced Metrics for Construction Planning. *Journal of Construction Engineering and Management*, *145*(11), 04019063. https://doi.org/10.1061/(asce)co.1943-7862.0001702

Hanna, A. S. (2016). Benchmark Performance Metrics for Integrated Project Delivery. *Journal of Construction Engineering Management*, *9*(149). https://doi.org/10.1061/(ASCE)CO.1943-7862.0001151

Korin, K., & Taplin, L. J. (2004). Project Success: A Cultural Framework. *Project Management Journal*, *35*(1), 30–45.

Korkmaz, S., Riley, D., & Horman, M. (2010). Piloting Evaluation Metrics for Sustainable High-Performance Building Project Delivery. *Journal of Construction Engineering and Management*, *136*(8), 877–885. https://doi.org/10.1061/(asce)co.1943-7862.0000195

Korkmaz, S., Riley, D., & Horman, M. (2011). Assessing project delivery for sustainable, high-performance buildings through mixed methods. *Architectural Engineering and Design Management*, *7*(4), 266–274. https://doi.org/10.1080/17452007.2011.618675

Ladner, S. (2019). *Mixed Methds*. Self-published.

Lam, E. W. M., Chan, A. P. C., & Chan, D. W. M. (2010). Qualitative survey on managing building maintenance projects. *World Academy of Science, Engineering and Technology*, *65*(5), 232–236.

Lamb, G., & Shraiky, J. (2013). Designing for competence: Spaces that enhance collaboration readiness in healthcare. *Journal of Interprofessional Care*, *27*(S2), 14–23. https://doi.org/10.3109/13561820.2013.791671

Leder, S., Newsham, G. R., Veitch, J. A., Mancini, S., & Charles, K. E. (2016). Effects of office environment on employee satisfaction: A new analysis. *Building Research and Information*, *44*(1), 34–50. https://doi.org/10.1080/09613218.2014.1003176

O'Sullivan, D. T. J., Keane, M. M., Kelliher, D., & Hitchcock, R. J. (2004). Improving building operation by tracking performance metrics throughout the building lifecycle (BLC). *Energy and Buildings*, *36*(11), 1075–1090. https://doi.org/10.1016/j.enbuild.2004.03.003

Ozorhon, B., Abbott, C., & Aouad, G. (2014). Integration and Leadership as Enablers of Innovation in Construction: Case Study. *Journal of Management in Engineering*, *30*(2), 256–263. https://doi.org/10.1061/(asce)me.1943-5479.0000204

Preiser, W. F. (2001). The evolution of post-occupancy evaluation: Toward building performance and universal design evaluation. In *Learning from our buildings a state-of-the practice summary of post-occupancy evaluation*.

Riley, D., & Horman, M. (2001). The effects of design coordination on project uncertainty. *Proceedings of the 9th Annual Conference of the International Group for Lean Construction (IGLC-9), Singapore*, 1–8.

Sadler, B. L., DuBose, J., & Zimring, C. (2008). The business case for building better hospitals through evidence-based design. *Herd*, *1*(3), 22–39. https://doi.org/10.1177/193758670800100304

SAMHSA. (2022). Concept of Trauma and Guidance for a Trauma-Informed Approach. In *HHS Publication No. SMA 14-4884*.

Souza de Souza, D. V., & Koskela, L. (2014). Interfaces, flows, and problems of construction supply chains - A case study in Brazil. *22nd Annual Conference of the International Group for Lean Construction: Understanding and Improving Project Based Production, IGLC 2014*, *44*(0), 1095–1106.

Swarup, L., Korkmaz, S., & Riley, D. (2011). Project Delivery Metrics for Sustainable, High-Performance Buildings. *Journal of Construction Engineering and Management*, *137*(12), 1043–1051. https://doi.org/10.1061/(asce)co.1943-7862.0000379

Umstot, D., Fauchier, D., & Da Alves, T. C. L. (2014). Metrics of public owner success in Lean design, construction, and facilities operations and maintenance. *22nd Annual Conference of the International Group for Lean Construction: Understanding and Improving Project Based Production, IGLC 2014*, 1495–1506.

Uusitalo, P., Lappalainen, E., Seppänen, O., Pikas, E., Peltokorpi, A., Menzhinskii, N., & Piitulainen, M. (2021). To trust or not to trust: is trust a prerequisite for solving design quality problems? *Construction Management and Economics*, *39*(4), 279–297. https://doi.org/10.1080/01446193.2020.1865553