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AN EXPLORATORY STUDY ON VISUAL MANAGEMENT AND PROCESS TRANSPARENCY IN CONSTRUCTION

Mauricio Neyra[1], Michelle Diaz[2] and Sulyn Gomez[3]

ABSTRACT

Several managerial approaches have emerged to address current construction challenges. Among them, information management addresses construction hurdles through process transparency, a core function of Visual Management (VM). Research on VM in construction has focused on its theoretical development and practical implementation. Conversely, research on process transparency has focused on highlighting its significance for construction through transparency strategies. This study aims to extend the research on process transparency and VM by identifying their current applications, measuring their degree of implementation, and highlighting their impact on team performance in two case studies based on observational protocols in Peru.

The main findings are: (1) Process transparency implementation was mainly driven by internal team efforts for job facilitation, while VM primarily served job facilitation, site signage and transparency functions, (2) One site had a higher degree of process transparency while the other had a slightly higher degree of VM, and (3) team performance improvement was associated with visual practices serving the functions of transparency and job facilitation. Some recommendations for the implementation of VM systems on construction sites and for future research were also presented.

KEYWORDS

Lean Construction, information management, process transparency, Visual Management, team performance.

INTRODUCTION

Construction is a project-based industry with relatively high complexity and low efficiency (Vrijhoef & Koskela, 2008). Construction projects often face problems such as misunderstanding of tasks, lack of process integration, delays, and unfulfillment of quality requirements (Galsworth, 2017). Researchers have studied different managerial approaches to mitigate the current challenges of the construction industry, e.g., safety management (Levitt & Samelson, 1987), production management (Koskela, 2000), risk management (Mills, 2001). Among them, information management (Adekunle et al., 2022) is of high relevance given that:

1. Construction projects involve a vast and dynamic amount of information often limitedly displayed or inefficiently updated (Valente & Costa, 2014; Saldias, 2010).

[1] Graduate Researcher, Faculty of Civil Engineering, National University of Engineering, Lima, Peru, mauricio.neyra.p@uni.pe, orcid.org/0009-0007-7379-5798

[2] Student, Faculty of Environmental Engineering, National University of Engineering, Lima, Peru, mndiazv@uni.pe, orcid.org/0000-0002-7711-1695

[3] Quality Leader, DPR Construction, Redwood City, USA, sulyng@dpr.com, orcid.org/0000-0003-2367-9880

2. Every task within a construction project should be fully understood to ensure that the overall production system operates as a continuous stream of activities (Brady, 2014).
3. Reassignment of personnel between work sectors, changes in product specifications, and adjustments to construction site settings make the immediate and accurate dissemination of information necessary (Formoso et al., 2002).
4. Information deficit in the workplace is highly associated with production waste (waiting, defects, over-processing, etc.) in construction processes (Formoso et al., 2002).

Information management aims to provide all project stakeholders with up-to-date, accurate, accessible, understandable, and relevant information (Reinbold, 2020). Enhancing process transparency increases information availability by making the attributes of construction processes visible to everyone. It is defined as “the ability of a production process (or its parts) to communicate with people” (Dos Santos et al., 1998). Process transparency seeks to deal with poor process orientation, ineffective decision-making, and prominent levels of waste and variability in construction processes (Formoso et al., 2002).

Tezel et al. (2016b) presents the improvement of process transparency as one of the main functions of a sensory strategy for information management called Visual Management (VM), which aims to “improve organizational performance through connecting and aligning organization vision, core values, goals, and culture with other management systems, work processes, workplace elements, and stakeholders, by means of stimuli” (Tezel et al., 2009a). The improvement of process transparency through VM is expected to have an influence on waste reduction (Koskela, 1992; Formoso et al., 2002), which enhances team performance for quality during process execution. This paper presents the first findings of an extensive research project that aims to assess the impact of implementing a visual management system on process transparency and team performance for quality in construction. The scope of the paper is limited to presenting the findings of analyzing the current applications, degree of implementation, and impacts on team performance of process transparency and VM in 2 construction sites from a railroad project in Peru.

LITERATURE REVIEW

VISUAL MANAGEMENT

VM is a managerial strategy that emphasizes short-range sensory communication (Tezel et al., 2016b). Communication is not limited to visual messages, but involves all 5 senses: taste, touch, smell, hearing, and sight (Liff & Posey, 2004). VM is achieved in visual workplaces (Galsworth, 1997). A visual workplace presents an information field integrated with the work setting, where the actual information need might occur, thus extending access to information to a larger number of people (Tezel et al., 2011). VM supports managerial practices (Tezel et al., 2009a) such as Health, Safety, Security & Environment (HSSE), production, quality, inventory, and knowledge management. VM also provides specific functions at an operational level: (1) transparency, (2) discipline, (3) continuous improvement, (4) job facilitation, (5) on-the-job training, (6) shared ownership, (7) management by facts, (8) simplification, and (9) unification (Tezel et al., 2009b).

Taxonomies and typology

Numerous VM taxonomies have been proposed based on its purpose, such as regulating human behavior (Galsworth, 1997) or presenting information to users (Bititci et al., 2016). For instance, Tezel et al. (2015) proposed a taxonomy of visual practices, which are visual elements implemented in the field to improve a specific aspect of construction operations (see Table 1).

Table 1: Taxonomy of Visual Practices (Adapted from Tezel et al., 2015).

Purpose	Examples
Removing visual barriers	Site layout organization, using chain-link fences, etc.
Standardize identification and location	Marked pathways, site maps, ID cards, etc.
Systematic site order	5S implementation.
Production control	Material tag control, scaffolding control, Kanban, etc.
Production leveling	Heijunka boards, simple colored beats, etc.
Prototyping and sampling	Product prototypes, material samples, etc.
In-station quality	Colored boards, Andon boards, etc.
Site signage	Safety signs, safety information, desired practices, etc.
Performance management	Overall progress boards, productivity metrics, etc.
Improvising Visual Management	Aids for on-site quality control and assurance.
Work facilitation	Visual work instructions, project drawings display, etc.
Mistakeproofing	Poka-yoke devices.
On-site prefabrication	Prefabricated construction elements.
Distributing system-wide information	Visual information for the workforce.

By integrating VM taxonomies, Brandalise et al. (2022) proposed a typology that classifies visual elements by complexity and context dependence in 3 levels and 7 attributes (Figure 1).

Level 1: Device	A visual display designed to achieve a certain degree of control by its visual appeal only for a certain period (e.g. permanent safety signals).
(1) Degree of control	*Visual indicator,* which shares information with voluntary compliance. *Visual signal,* which catches attention and generates a reaction. *Visual control,* which impacts behaviors by limiting physical quantities. *Visual guarantee,* which ensures desired outcomes by mistake-proofing.
(2) Visual expression	Static (immutable) or dynamic (updated over time).
Level 2: Practice	A visual device designed to fulfill a specific function with a communication, collaboration, or managerial integration role (e.g. Kanban, Andon, 5S).
(3) Main function	Control artifact, execution procedure, target specification, material delivery, prototype, or others (specified in Tezel et al. (2015)).
(4) Communication role	One-to-one, one-to-many, many-to-one, or many-to-many.
(5) Collaboration role	Collaborative (stimulating interactions) or non-collaborative.
(6) Integration role to management routines	Integrated or not integrated.
Level 3: System	Two or more integrated visual practices with greater impact on the project.
(7) Integration of practices forming a system	Integrated or not integrated.

Figure 1: Typology of Visual Elements (Adapted from Brandalise et al., 2022).

Visual Management Implementation

Some VM practices adapted for construction projects are well described in the literature, such as 5S (Tezel & Aziz, 2016), Kanban (Costa & de Burgos, 2015), and Andon (Kattman et al., 2012). At the beginning of its adoption in construction, VM was mostly applied in site offices to support managerial decisions, and only health and safety warning boards, focused on information giving, were usually found in construction site working areas (Tezel et al., 2016a). However, recent studies have shown the application of many other visual practices in construction sites (Moser & dos Santos, 2003; Tezel & Aziz, 2016; Tezel et al., 2015).

PROCESS TRANSPARENCY AND LEAN

Lean Construction, guided by Lean Thinking, aims for continuous improvement and value flow (Womack & Jones, 1996). To achieve this, construction processes should be easily understood by everyone involved (Dos Santos et al., 1998). Process transparency involves making the main process flows visible and comprehensible from start to finish (Koskela, 1992), allowing for easy problem identification within the production system (Moser & dos Santos, 2003).

Koskela (1992) outlines six strategies for enhancing transparency: (1) reducing interdependence between production units, (2) using visual artifacts that allow immediate recognition of process status, (3) making the process directly observable, (4) incorporating information into the process, (5) maintaining a clean and orderly work site, and (6) representing invisible attributes through measurements. Formoso et al. (2002) suggested 10 performance indicators to evaluate process transparency (see Table 2).

Table 2: Process Transparency Indicators (Adapted from Formoso et al., 2002).

Transparency indicator	Definition / Criteria
(1) % of workstations presenting no interference from another process	Sharing space, equipment, or materials with other crews.
(2) Number of visual indicators	They only provide information.
(3) Number of visual signals	They aim to generate a response.
(4) Number of visual controls	They limit physical quantities.
(5) Number of visual guarantees	They ensure outcomes through mistake-proofing.
(6) % of process stages observed from the most favorable viewpoint	Stages clearly observed throughout the whole process.
(7) % of process stages clean and tidy	Minimum material waste and visually organized.
(8) Number of process performance indicators collected regularly	Adress the ease to collect indicators from the process.
(9) Number of workstations analyzed	Required for the 1st indicator.
(10) Number of process stages	Required for the 2nd indicator.

METHODOLOGY

This paper presents an exploratory research based on two case studies of construction sites in Peru using 3 sources of evidence: participant observation, document analysis, and unstructured discussions (Yin, 1994). Participant observation was selected due to the role of the first author as field supervisor, with data primarily collected during quality inspections. Unstructured interviews, characterized by undetermined questions and answers (Minichiello et al., 1990), complemented participant observation and involved conversations with site managers to enhance data collection. Documentation consulted included field notes, photos, daily reports, and weekly reports.

The first author collected data from the Site A from January 3rd to January 13th, 2024, and from the Site B from January 15th to January 28th, 2024. The scope of study for VM analysis was the construction field and its execution procedures. For transparency analysis, two main construction processes were sampled from each site, taking time constraints into consideration.

Data on VM and process transparency was compiled in observation protocols. The VM protocol (Figure 2) classified visual elements through a checklist (Tezel et al., 2009a; Brandalise et al., 2022; Galsworth, 1997; Bititci et al., 2016; Tezel et al., 2015), and analyzed them through guided questions (Valente et al., 2019). The process transparency protocol (Figure

3) identified transparency indicators (Formoso et al., 2002) along with transparency strategies (Koskela, 1992). Team performance for quality was assessed through field notes on defects and rework activities. A grading system is provided to ease the comparativeness of the units studied. Inferences were drawn from the relationships between the indicators, potential causes of significant results, and the primary VM functions observed in the field.

VISUAL ELEMENT			
Name:		**Location:**	
Affects processes? Which ones?	◉	◉	◉
CLASSIFICATION			
Function (Tezel et al., 2009a): Select all that apply.	☐ Transparency ☐ Discipline ☐ Continuous improvement ☐ Job facilitation ☐ Unification ☐ On-the-job training ☐ Shared ownership ☐ Management by facts ☐ Simplification		
Level (Brandalise et al., 2022):	☐ Visual device	☐ Visual practice	☐ Visual system
Degree of control (Galsworth, 1997)	☐ Visual indicator ☐ Visual signal ☐ Visual control ☐ Visual guarantee		
Visual expression (Bititci et al., 2016)	☐ Static ☐ Dynamic		
Purpose (Tezel et al., 2015)	☐ Removing visual barriers ☐ Standardize identification and location ☐ Production leveling ☐ Systematic site order ☐ Performance management ☐ Work facilitation ☐ Mistakeproofing ☐ Prototyping and sampling ☐ Distributing system-wide information ☐ On-site prefabrication ☐ Improvising Visual Management ☐ Site signage ☐ In-station quality ☐ Production control		
Role of communication	☐ One-to-one ☐ One-to-many ☐ Many-to-one ☐ Many-to-many		
Role of collaboration	☐ Collaborative ☐ Non-collaborative		
Role in managerial routines integration (If so, in which ones?)	☐ Integrated with management routine ☐ Not integrated with management routine ☐ HSSE ☐ Production ☐ Quality ☐ Inventory ☐ Knowledge ☐ Other: ___________		
Other practices of the system	◉	◉	◉
ANALYSIS (Valente et al., 2019)			
1) Visual attributes	- What is the content to make available?	- Which kind of coding is used?	
2) Visual implementation	- What is the frequency of use?	- Who is responsible?	
3) Visual information	- Which type of data is used?	- Where is information placed?	
4) Problem solving	- Which type of problems are avoided?	- Is there a standard procedure?	

Figure 2: Visual Management Protocol (Summarized).

CONSTRUCTION PROCESS						
Name:			**Location:**			
Stages (Indicators #6, #7 and #10 - Formoso et al. (2002)):	**O**	**K**			**O**	**K**
1)			3)			
2)			4)			
O: Observable from the most favorable viewpoint | **K**: Kept clean and tidy						
Transparency approaches (Koskela, 1992)						
	Reducing interdependence between production units. *(If identified, how is it applied?)*					
	Using visual artifacts that allow immediate recognition of process status. *(If identified, how is it applied?)*					
	Making the process directly observable. *(If identified, how is it applied?)*					
	Incorporating information into the process. *(If identified, how is it applied?)*					
	Maintaining a clean and orderly work site. *(If identified, how is it applied?)*					
	Representing invisible attributes through measurements. *(If identified, how is it applied?)*					
Transparency indicators (Indicators #1 to #5 - Formoso et al. (2002))						
1) Is there an interference with other processes? Which ones?			2) Is process information displayed? How? (Visual indicators)			
3) Are there any visual signals? Which ones?			4) Are there any visual controls? Which ones?			
5) Are there any visual guarantees? Which ones?						

Figure 3: Process Transparency Protocol (Summarized).

RESEARCH FINDINGS

Two construction processes were analyzed at each construction site and a total of 19 different visual elements were identified, 8 of them being observed in both sites.

PROCESS TRANSPARENCY

In both sites, the execution of masonry walls of concrete blocks was studied. Site A was re-starting activities after a pause period, so only the first stages of its processes could be studied. The denomination for each process is shown below:

- (A1) Execution of off-site prefabricated slabs and on-site compression slabs in Site A.
- (A2) Execution of masonry walls of concrete blocks in Site A.

- (B1) Waterproofing and backfilling of street-level slab in Site B.
- (B2) Execution of masonry walls of concrete blocks in Site B.

Figure 4 and Figure 5 illustrate some stages of the construction processes mentioned above.

Figure 4: Main Stages of the Construction Processes A1 and A2.

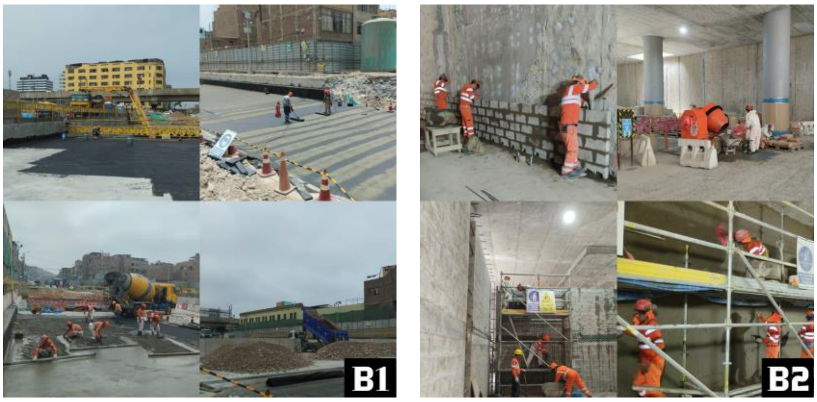

Figure 5: Main Stages of the Construction Processes B1 and B2.

The application of the six transparency strategies is verified through a check/cross marking and their specific ways of implementation are explained if the strategy is applied (see Figure 6).

TRANSPARENCY APPROACHES OF PROCESSES A1, A2, B1, B2					
1) Reducing interdependence between production units.			4) Incorporating information into the process.		
A1	✓	Use of safety barriers in the surroundings of the process.	**A1**	✓	Labeling of precast slabs.
A2	✓	Use of safety barriers in the surroundings of the process.	**A2**	✓	Markings for block positioning.
B1	✓	Use of safety barriers / Labeling of materials.	**B1**	✗	
B2	✓	Use of safety barriers in the surroundings of the process.	**B2**	✓	Markings for block positioning, wall height, concrete pouring level, span dimensions, and inspection status.
2) Using visual artif. that allow immediate recognition of p. status.			5) Maintaining a clean and orderly work site.		
A1	✓	Sound alarms during lifting.	**A1**	✓	Identification of a waste disposal area.
A2	✗		**A2**	✓	Identification of material collection area.
B1	✓	Lateral markings to identify layers of backfilling.	**B1**	✓	Material waste constantly disposed.
B2	✓	Markings for inspection status.	**B2**	✗	
3) Making the process directly observable.			6) Representing invisible attributes through measurements.		
A1	✓	Illumination improvement / Rebar markings for anchorage.	**A1**	✗	
A2	✓	Rebar markings for anchorage.	**A2**	✗	
B1	✗		**B1**	✗	
B2	✗		**B2**	✓	Metrics for placed blocks (not too clear).

Figure 6: Transparency Strategies of Processes.

Figure 7 shows the identification of transparency indicators #6, #7 and #10. Each one of the process stages studied is verified according to its compliance with the observability and cleanliness indicators through a green check (complies) or red cross (does not comply).

	Stages (Indicators #6, #7 and #10):	O	K		O	K
A1	1) Arrival of prefabricated slabs	✗	✓	5) Hook release	✓	✓
	2) Preparation for lifting	✗	✓	6) Concrete chipping of the main slab	✓	✓
	3) Lifting of slabs	✗	✓	7) Perforation of holes for steel anchorage	✓	✓
	4) Positioning of slabs	✓	✓	8) Steel anchorage in main slab	✓	✓
A2	1) Scarification of concrete at the base of the walls	✓	✓	4) Preparation of mortar mixture	✓	✓
	2) Perforation of holes for steel anchorage	✓	✓	5) Application of mixture and placement of blocks	✓	✓
	3) Vertical rebar anchorage in slab	✓	✓	6) Horizontal reinforcement between block rows	✓	✓
B1	1) Repair of cracks and imperfections on concrete surface	✓	✓	5) Waterproofing test	✓	✓
	2) Priming of bituminous material	✓	✓	6) Placing of geotextile	✓	✓
	3) Placing of 1st waterproofing layer	✓	✓	7) Mortar pouring	✓	✓
	4)Placing of 2nd waterproofing layer	✓	✓	8) Backfilling and compacting	✓	✓
B2	1) Scarification of concrete at the base of the walls	✓	✓	9) Steel reinforcement in pilasters and beams	✓	✓
	2) Perforation of holes for steel anchorage	✓	✓	10) Formwork for pilasters and beams	✓	✓
	3) Vertical rebar anchorage in slab	✓	✓	11) Concrete pouring in pilasters and beams	✗	✓
	4) Preparation of mortar mixture	✗	✗	12) Formwork stripping of pilasters and beams	✓	✓
	5) Application of mixture and placement of blocks	✓	✗	13) Scarification of concrete on pilasters and beams	✓	✓
	6) Horizontal reinforcement between block rows	✓	✓	14) Preparation of mortar mixture	✓	✗
	7) Preparation of liquid concrete	✗	✗	15) Wall plastering	✓	✓
	8) Concrete pouring in wall cavities	✗	✗			
	O: Observable from the most favorable viewpoint | K: Kept clean and tidy					

Figure 7: Transparency Indicators of Process Stages.

Table 3 enumerates the transparency indicators #1 to #5 of each process and presents an interference rating (IP, 0 = With interference, 1 = No interference), and a visual display rating (VD, 0 = not implemented, 0.5 = partially implemented, 1 = well implemented). To quantify the degree of process transparency, Table 4 presents a general 5-scale rating.

Table 3: Transparency Indicators of Construction Processes.

Process	Process interf.	Visual indicators	Visual signals	Visual controls	Visual guarant.
A1	No (1)	Slab labels (1)	Safety signs (1) Sound alarm (1)	Steel marks (0.5)	No (0)
A2	No (1)	Slab marks (1)	Safety signs (0.5)	Steel marks (0.5)	Prototype (0.5)
B1	No (1)	No (0)	Hot work sign (1)	Layer marks (0.5)	No (0)
B2	No (1)	Wall marks (0.5) Span marks (1) Status marks (0.5)	Safety signs (1)	Pouring level (0.5)	No (0)

Table 4: Process Transparency Observation Results.

Process	Fraction of observable stages (OS)	Frac. of stages clean/tidy (SK)	Fraction of implemented strategies (IS)	Interference rating (IP)	Sum of average VDs (SVD)	Total process transparency degree (TD)
A1	5 / 8	8 / 8	5 / 6	1	2.5 / 4	4.08
A2	6 / 6	6 / 6	4 / 6	1	1.5 / 4	4.04
B1	8 / 8	8 / 8	3 / 6	1	1.5 / 4	3.88
B2	11 / 15	10 / 15	4 / 6	1	2.2 / 4	3.62

According to the grading system, process A1 is the most transparent (TD = 4.08), while process B2 is the least transparent (TD = 3.62).

VISUAL MANAGEMENT STATUS

Out of the 19 different visual elements identified, Site A presented 4 unique elements, Site B presented 7, and both sites presented 8 repeated elements. Both construction sites had implemented visual systems for HSSE management, and some visual practices for quality and performance management. A single visual device without managerial role was also identified in site B. Figure 8 presents the elements classified according to their level and location.

Level	Site A	Site B
System	(1) Color coded safety signs, (2) Labelling of enclosed areas, (3) Safety cone retractable barriers for enclosed areas, (4) Plastic jersey barriers, (5) Solid waste storage signs, and (6) Inspection elements of scaffoldings.	
	(7) Labeling of liquid materials, and (8) Visual reminders for safety meetings.	(9) Safety plan board on-site.
Practice	(10) Markings for block positioning, and (11) Construction element labeling.	
	(12) Markings on steel rebars for anchoring, and (13) Temporal prototype of concrete block reinforcement.	(14) Lateral markings for backfilling layers, (15) Markings for masonry wall height, (16) Concrete pouring level, (17) Markings of span dimensions on masonry wall, and (18) Markings for metrics of placed blocks.
Device	-	(19) Markings of inspection status.

Figure 8: Visual Elements Identified.

Figure 9 presents the functions (Tezel et al., 2009b) and purpose (Tezel et al., 2015) of each element identified.

Level	Element	Site	Functions	Purpose
System	(1)	A and B	Discipline	Site signage
	(2)		Transparency / Job facilitation / Shared ownership	Standardize identification and location
	(3)		Discipline	Removing visual barriers
	(4)		Discipline	Standardize identification and location
	(5)		Transparency / Discipline	Site signage
	(6)		Transparency / Discipline	Production control
	(7)	A	Transparency / Job facilitation	Standardize identification and location
	(8)		Transparency / Discipline / Simplification / Unification	Distributing system wide information
	(9)	B	Transparency / Discipline / Simplification	Distributing system wide information
Practice	(10)	A and B	Transparency / Job facilitation	Work facilitation
	(11)		Transparency	Standardize identification and location
	(12)	A	Transparency / Job facilitation	Work facilitation
	(13)		Transparency / Job facilitation / On-the-job training	Work facilitation
	(14)	B	Transparency / Job facilitation	Work facilitation
	(15)		Transparency / Job facilitation	Work facilitation
	(16)		Transparency / Job facilitation	Work facilitation
	(17)		Transparency / Job facilitation	Work facilitation
	(18)		Transparency / Continuous improvement / Management by facts	Performance management
Device	(19)	B	Transparency	-

Figure 9: Functions and Purpose of Each Visual Element.

A 20-scale rating was developed to assess the degree of VM of each element:

- *Level:* Visual device = 2, visual practice = 4, and visual practice of a system = 8.
- *Degree of control:* Visual indicator = 1, visual signal = 2, visual control = 3, and visual guarantee = 4.
- *Visual expression:* Static = 0, and dynamic = 1.
- *Role of communication:* One-to-one = 1, many-to-one = 2, one-to-many = 2, many-to-many = 3.
- *Role of collaboration:* Non-collaborative = 0, and collaborative = 2.
- *Role in managerial routines integration:* Not integrated = 0, and integrated = 2.

Figure 10 presents the remaining classification and VM score of each element identified.

Level	Site	Element	Degree of control	Visual expression	Role of communication	Role of collaboration	Role in managerial routines integration	VM Score
System	A and B	(1)	Visual signal	Static	One-to-many	Non-collaborative	Integrated	14
		(2)	Visual signal	Static	One-to-many	Non-collaborative	Integrated	14
		(3)	Visual control	Dynamic	One-to-many	Non-collaborative	Integrated	16
		(4)	Visual control	Dynamic	One-to-many	Non-collaborative	Integrated	16
		(5)	Visual signal	Static	One-to-many	Non-collaborative	Integrated	14
		(6)	Visual signal	Dynamic	One-to-many	Non-collaborative	Integrated	15
	A	(7)	Visual signal	Static	One-to-many	Non-collaborative	Integrated	14
		(8)	Visual signal	Dynamic	One-to-many	Collaborative	Integrated	16
	B	(9)	Visual indicator	Static	One-to-many	Non-collaborative	Integrated	13
Practice	A and B	(10)	Visual control	Static	One-to-one	Non-collaborative	Not integrated	8
		(11)	Visual indicator	Static	One-to-many	Non-collaborative	Not integrated	7
	A	(12)	Visual control	Dynamic	One-to-one	Non-collaborative	Not integrated	9
		(13)	Visual guarantee	Static	One-to-one	Non-collaborative	Not integrated	9
	B	(14)	Visual control	Static	One-to-one	Non-collaborative	Not integrated	8
		(15)	Visual control	Static	One-to-one	Non-collaborative	Not integrated	8
		(16)	Visual control	Static	One-to-one	Non-collaborative	Not integrated	8
		(17)	Visual indicator	Static	One-to-one	Non-collaborative	Not integrated	6
		(18)	Visual indicator	Static	One-to-one	Non-collaborative	Not integrated	6
Device	B	(19)	Visual indicator	Static	-	-	-	6

Figure 10: Classification and VM score of visual elements.

According to the rating system, elements (3), (4) and (8) have the highest VM score in the study.

TEAM PERFORMANCE FOR QUALITY

The team performance study was addressed by observing the incidence of defects or rework during the execution of construction processes and the quality inspection of process stages.

- *Process A1*: One defect in the alignment of pipe holes on the precast slabs and one rework activity due to vertical displacements in 5 anchorage perforations were observed.
- *Process A2:* No defects or rework were identified. However, we observed overprocessing and overproduction wastes on the scarification of concrete at the base of the walls by covering larger areas and exceeding roughness requirements.
- *Process B1:* Four defects of lack of adherence of waterproofing layers were identified.
- *Process B2:* There were 4 defects pertaining to the depth of holes for rebar anchorage, 2 exposed horizontal reinforcement of masonry walls, excess height on 2 walls, excess thickness on 1 beam, and excess scarification in 2 pilasters.

DISCUSSION

Regarding the applicability of process transparency, the following inferences are drawn:

1. No interferences were observed among the studied processes during the period of observation, facilitating smoother operations and improved cleanliness, as noted by Formoso et al. (2002). However, process B2 exhibited significant untidiness (SK = 10/15), which was attributed to simultaneous work in sectors of the same process, highlighting the relevance of minimizing interferences within the process itself.
2. Stages not observable from an optimal viewpoint, indicated the existence of visual barriers (Formoso et al., 2002), observed in processes A1 (OS = 5/8) and B2 (OS = 11/15). In A1, distant lifting equipment was an unremovable barrier, while in B2, drum mixer location was a removable barrier and built masonry walls were unremovable.
3. We observed some systematic applications of the 1st and 5th transparency strategies within the visual systems in HSSE management, promoting continuity, standardization, and overall improvement. However, the 2nd strategy, seen in processes A1 and B2, lacked consistency to be considered systematic. Meanwhile, subcontractor initiatives drove the implementation of the 3rd and 4th strategies, aimed at facilitating construction

processes. Solely process B2 adopted the 6th strategy, employing simple markings to indicate daily block placements, but their clarity and comprehensibility were limited.

4. Processes studied at Site A exhibited higher process transparency (4.06) than Site B (3.75). This difference may stem from Site A having fewer processes, facilitating better management. Adjusting results for the total number of processes may be necessary.

The main VM functions applied where transparency, discipline, and job facilitation. Meanwhile, both sites presented standardized identification and location, work facilitation, and site signage as main purposes. The total VM score of site B (159) was slightly higher than site A (152).

The study identified visual systems associated with the HSSE managerial practice, highlighting the advantages of integrating visual systems with managerial routines. The quality of the system design was driven by external safety and environmental regulations. However, the implementation followed a rigid top-down approach, as found in Tezel et al. (2015).

Addressing performance deficiencies observed during the study involved implementing visual practices and transparency strategies. While process B2 (TD = 3.62) presented 4 defects pertaining to the depth of holes for rebar anchorage, A2 (TD = 4.04) prevented them by a transparent control through marks in the rebars (VM score = 9). Similarly, exposed horizontal reinforcement in masonry was detected twice in process B2, while A2 clarified it through a displayed prototype (VM score = 9). Within process B2, exceeding wall height was prevented with reference markings (VM score = 8), and excess beam thickness was controlled by marking pouring levels (VM score = 8). Further structured analyses are needed to validate these findings.

Finally, we highlight that implementing VM implies structuring the site as a visual workplace aligned with management agreements, while process transparency requires a particular focus on construction processes and their relationships. Therefore, studying each independently clarifies their distinct features, enabling more efficient analysis and application.

CONCLUSIONS

Past research on process transparency and VM provides a solid basis for methodically studying transparency strategies and visual practices on construction sites. Their applications are process-oriented and site-oriented, respectively. Process transparency strategies were identified as an indirect consequence of internal team efforts for job facilitation, considered a basic level of implementation lacking systematization and visual communication. On the other hand, VM implementation mainly addressed the functions of transparency, discipline, and job facilitation.

The ratings developed to measure the degree of process transparency and VM allowed the comparison between the sites studied. Processes studied at Site A presented a higher degree of process transparency than Site B. However, the global VM score of Site B was slightly higher than Site A. Therefore, we conclude that implementing process transparency and VM do not imply a single effort, but different methods of development.

Improvements on team performance were observed in the prevention and control of defects and rework wastes associated with the implementation of visual practices serving the functions of transparency and job facilitation, and with the implementation of the transparency strategies of incorporate information into the process and make it directly observable.

The exploratory study provided a basis for further research on the influence of VM and process transparency on team performance. Its main contributions are the individual parallel analyses of process transparency and VM to address their differences, the development of observation protocols based on existing indicators and parameters from the literature review, and the introduction of a grading system to measure the degree of process transparency and VM for both study inquiries and implementation efforts. Furthermore, it highlighted the importance of visual systems integrated into management practices that lack visual representation in the field such as production management, knowledge management, and quality management.

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