

**SCRI Research Report**

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# **Visual Management in Construction** **Study Report on Brazilian Cases**

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## Visual Management in Construction Study Report on Brazilian Cases

### Foreword

People are exposed to various information transactions in their work environments. Information overloads or deficiencies may lead to undesirable consequences. Some organisations utilise simple, yet cognitively effective visual tools, particularly for operational purposes, to manage different aspects of work, to organise their workplace, to facilitate human effort and to distribute system wide information. This conscious effort of managing information in daily transactions, using visual tools, is called Visual Management (VM). The work setting, in which VM is realised and different visual tools/systems exist is a visual workplace. VM can serve different functions depending on the extent it has been used, the most important of which for an organisation is perhaps increased transparency.

Lean production—a production philosophy originated from the automotive industry - explicitly underlines the importance of VM. This importance is to such a degree that the system itself can sometimes be referred synonymously with a visual tool it utilises; the kanban. The reflection of lean production on construction naturally results in the application of VM in construction. This report contains a comprehensive compilation of VM practices in the construction environment, based on case studies conducted in Brazil. The information presented in this report was gathered through various interviews with construction site personnel and company management, and documentation using photos/archives.

Firstly, the functional existence and effective use of VM in construction in different production management areas were identified. It was also found that VM can be a highly intuitive practice and has been traditionally in use in construction production through some conventional tools. The conceptualisation of the topic and its extended possible use are generally not clear for the interviewed construction practitioners. Simplicity and inexpensiveness were noted as the most important features of VM tools. The transparency that VM creates can in some cases be for a specific group of people and sometimes for everyone (including the visitors) in a construction setting. Some transparency increasing aspects of VM concepts, such as sampling, prototyping, mistake-proofing and prefabrication were documented.

There are parameters affecting the use of VM in construction, such as construction technology, contractual relations and project specific variables (e.g. construction site topography). For some tools, repetitive standard construction (e.g. multi-storey building with a standard number of brick types) can be necessary for an effective implementation. The application process is seen as a part of the lean construction effort and rather from top to bottom. A champion of the application generally exists in the companies. The companies collaborate with each other and academia to develop their operational practices, which provides them with different modes of learning.

The authors hope that the report will give the reader an insight into the application, dissemination and further development of VM in construction.

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## 1 Introduction

People constantly face torrents of data from their environments (Endsley, 2003), which are sometimes the by-products of complexifying technology and innovation, meant for easing their lives, and constantly increasing expectations (Hollnagel and Woods, 2005). Some manufacturing and service organizations have been consciously using simple, yet cognitively effective visual tools to filter this torrent of data and make quality information (necessary, relevant, correct, immediate, easy-to-understand and stimulating) flow for people to use in their day-to-day work transactions (Harris and Harris, 2008). This effort is generally called Visual Management (VM). Visual Management can be defined as a management system that attempts to improve organizational performance through connecting and aligning organizational vision, core values, goals and culture with other management systems, work processes, workplace elements, and stakeholders, by means of stimuli, which directly address one or more of the five human senses (sight, hearing, feeling, smell and taste) (Liff and Posey, 2004). Ho (1993:88), in discussion of the Japanese management techniques for British manufacturers, uses this explanation:

The principle behind VM is that people are usually attracted by what they see. In Japanese firms VM is well accepted. It can be in the form of a notice board, slogan, indication light, card (Kanban), visual display unit, etc. The objective is to use visual aids to make communication simple and attractive. An extension of VM is Colour Management. Japanese firms are very good at using colour for the identification of jobs. For instance, both Toyota and Fanuc's production lines make use of coloured bins and light signals to control production flow. Visual and colour aids cost little but have a useful psychological effect; they are worth adopting for the workplace in the U.K.

Managing projects and groups of people with visual clues is not a new concept and dates back almost 4500 years with The Egyptian Royal Cubit, a visual measuring standard on construction sites. Robert Owen, as a pioneering industrialization figure from Manchester, resorted to highly visual artefacts (e.g. the Silent Monitor) to manage human resources in the early 19th century. In 1977, Sugimori et al (1977), the Toyota managers, and Ashburn (1977) published the first papers in the English language on the highly acclaimed Toyota Production System (TPS), which extensively integrates Visual Management in its operational and managerial activities (Liker, 2004). The most frequently cited of these lean related works is perhaps the book "The Machine that Changed the World" by Womack et al. (1990). It is based on Massachusetts Institute of Technology's five-year study on the future of the automobile. The research team coined the term "lean" to refer to the production system at Toyota. The book shows the striking productivity difference between Toyota and the prominent western automobile manufacturers until then in figures and explains the reasons behind it.

## 2 Visual Workplace

Visual Management is realized in visual workplaces, which are structured with information giving, signalling, limiting or guaranteeing (Mistake-proofing/ Poka-Yoke – see Shingo (1989) ) visual devices to communicate with “doers”, so that places become self-explanatory, self-ordering, self-regulating and self-improving (Galsworth, 1997). Visual elements create an information field for people to pull the necessary information from and help people make sense of the organizational context at a glance by merely looking around (Greif, 1991). According to Schmenner and Tatikonda (2005), today a factory (a manufacturing setting) is flexible because it is proactive through advancing in removing waste, incorporating new technologies and moving information to where it can be used best. In his important work, Gerwin (1987) contrasts the “flexible” factory (which quickly adapts to realised uncertainty) versus the “proactive” one (which tries to control uncertainty through advance planning). Flexibility can take different forms as mix flexibility, changeover flexibility, volume flexibility and so on. (see Gerwin (1987) for details). In a visual workplace, this information move (or information flow as explained later) is constantly striven for to promote proactive flexibility.

Visual Management serves different functions within an organisation, namely transparency, discipline, continuous improvement, job facilitation, on the job-training, creating shared ownership, management by facts, simplification and unification (see Tezel et al (2009) for details).

### 2.1 Transparency

Transparency can be defined as “the ability of a production process (or its parts) to communicate with people” (Formoso et al., 2002:38). Transparency involves a separation of the network of information and the hierarchical structure of order giving, in other words, an increase in self-control, which in classical organisation theory are identical (Greif, 1991). The goal is thus to substitute self-control for formal control and related information gathering. It is a dual mechanism working for both managers and employees through different messages. According to Spreitzer (1995), access to more information (especially about the mission and performance) and sense of self control facili-

tate psychological empowerment. Employees are allowed to control execution by comparing current conditions to given production objectives (Steudel and Desruelle, 1992). Moser and Santos (2003) summarise the practical impacts of transparency in a work environment as follows: the simplification and greater coherence in decision making, the stimulation of informal contacts throughout different hierarchical levels, the contribution to introduction of decentralisation policies, assistance in broadening employees’ participation and autonomy in management, more effective (overlapping) distribution of responsibilities, an increase in employee morale, greater effectiveness in production scheduling, the simplification of production control systems, rapid comprehension (by making problems apparent) and response to problems (a controlled speed in decision making and responsiveness), increase in the motivation of workers for improvement and visibility of errors. Flexibility, versatility and mobility within work teams can also be included (Greif, 1991). A correct message giving visibility that helps people construct mental models and provides the feedback of their actions are the essentials of user centred design as well (Norman, 1998).

### 2.2 Discipline

Visual Management reflects people’s adherence to the expectations of processes by transforming the abstract concept of discipline into directly observable concrete practices (Mann, 2005). Anyone, even a newly hired, inexperienced employee, should be able to distinguish between normal and abnormal conditions at a glance and start taking the correct steps, developing an intuitive, habitual correctness, without being dependent on another entity. Discipline means “following standardised procedures” (Hirano, 1995:38) and is defined as “making a habit of properly maintaining correct procedures” (Hirano, 1995:283).

### 2.3 Continuous Improvement

Continuous improvement (or kaizen in the lean terminology) is a highly dynamic capability and can be defined as “an organisation-wide process of focused and sustained incremental innovation (Bessant and Francis, 1999).” Visual Management serves as a base for continuous improvement (Suzaki, 1993; Imai, 1997), and perhaps more importantly stimulates employee involvement to manage and improve quality (Greif, 1991; Schonberger, 1992; Flynn et al., 1994).

### 2.4 Job Facilitation

Job facilitation can be defined as a conscious attempt to physically and/or mentally ease people's efforts in routine, already known tasks by offering various visual aids. Visual Management facilitates routine job tasks for people by offering a quick, correct and holistic understanding of their job requirements (Greif, 1991; Suzaki, 1993; Galsworth 1997). When the amount of information required to complete a task pushes the capacity of working memory, it must be made available in the physical world through visual displays (Norman, 1998).

### 2.5 On-the-Job Training

On-the-Job training includes learning from experience (Mincer, 1962). Integrating working with learning is a competitive imperative for organisations (Sumner et al., 1999). Information in the environment enables on the job training, which is an effective way of learning, as it is integrated in actual work and helps employees learn by practical experience. It is a cost effective, less work disruptive, encouraging, and easy to assess (for supervisors) organisational learning practice that employs Visual Management (Aik, 2005).

### 2.6 Creating Shared Ownership

Psychological ownership can be defined as a feeling of possessiveness and being psychologically tied to an object (material or immaterial) (Pierce et al., 2001). Visual Management is used to create and designate territories and work teams (Greif, 1991 and Suzaki, 1993). One other function of Visual Management is image creation for stakeholders (Liff and Posey, 2004). It is particularly effective in creating a desirable organizational impression on potential/existing employees, customers and other shareholders. Visual elements are extensively used for internal marketing efforts and change management practices to convey a desired message, to persuade people and to alter the perception for creating ownerships (Davis, 2001; Ahmad and Rafiq, 2002).

### 2.7 Management-by-Facts

Management by facts is based on the use of facts and data based on statistics (Gunasekaran et al., 1998). Visual Management is partially about opening the objective organisational reality to the relevant people through the flow of information (Greif, 1991; Liff and Posey, 2004; Galsworth, 2005; Mann, 2005). This reality is free from personal bias and/or subjective experience or understanding of individuals. Openness, or willingness to share ideas and information willingly, frankly and accurately, is a condition for obtaining employees' trust in management (Clark and Payne, 1997; Lewicki et al., 1998).

### 2.8 Simplification

The management of information in dynamic and complex environments sometimes goes beyond the efforts and abilities of individuals. Organisations mainly use strategic information to make decisions, to make sense of changes and developments in their external environments and to generate new knowledge through organisational learning (Choo, 1996). In cascading strategic information from the upper organisational levels to lower levels, some mechanism is necessary for monitoring, processing and presenting the vast amount of information for people to make sense of.





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## Visual Management in Construction

### Study Report on Brazilian Cases



Figure 2: Visual Management and Its Relations

In a visual workplace, signs, labels, borders and shadows (perhaps with a sketch or picture of the element if necessary) are highly used for home addressing for localisation within the workplace organisation/housekeeping methodology known as the 5S (Galsworth, 1997; Hirano, 1995; Monden, 1998). This is a form of standardisation of localisation and quantity of the workplace elements (answers the what, where and how many questions). Graphs are used to communicate the related performance indicators (quality, cost, training, safety, the 5s etc – quantitative information) to the operators (Suzaki, 1993; Greif, 1991). In offices, various performance metrics are put in rooms called “the war rooms” for managers and employees (Liff and Posey, 2004). In continuous improvement efforts, they take the form of Pareto charts, decision trees etc (Greif, 1991; Suzaki, 1993). The continuous improvement process (Plan-Do-Check-Act) is summarised on a highly visual A3 paper to communicate it to relevant people (LMA, 2005b; Sobek and Smalley, 2008). Tables are used for production tracking, quality control, tabulating problematic issues with corresponding efforts and ownership problems (e.g. safety, quality, cost etc), and human resource management (e.g. skill matrices) (Mann, 2005). Electronic status displays (the Andon) show the real and planned production levels in a work cell (LMA, 2005a) and warn of any deviations or abnormalities (Galsworth, 2005; Monden, 1998).

Warning lights are also utilised as signals for pull production (traffic-light pull production) and indications of problems in a work cell, mostly accompanied with a buzzing sound (Galsworth, 2005).

Pull-production in small-batches is realised and coordinated through visual signals (the Kanban), such as cards (Monden, 1998) or computerised systems (LMA, 2003). Best practices are spread throughout the production area using highly visual (graphs and photos) documents called “single-point-lessons” (LMA, 2002). Filming and photography are common for documenting processes, standards and deviations (Suzaki, 1993). They are also used to show the situation before and after an application, such as the 5S (Suzaki, 1993). Posters and highly graphical sketches are used to communicate various information (e.g. the mission statement, strategic goals, critical issues, important events, past efforts and successes) (Liff and Posey, 2004; Suzaki, 1993). Sketches, drawings and photos also find a place in highly visual work instructions and specifications (Galsworth, 2005). In assembly and maintenance operations, visual clues (aids) are used for feedback and controlling of goals (e.g., a piece of tape put on top of a part to indicate it is finished) (Helander, 2006).

In a visual workplace, auditory information is used to alert operators/superintendents about a problematic situation in different workstations (through different tones for each workstation), as part of the automation system (Liker, 2004). For individual operators, warning buzzers are commonly integrated in mistake-proofing systems, to prevent the occurrence of defects (NKS, 1987). In assembly operations, auditory feedbacks for different tasks, like a clicking sound of a switch as an auditory feedback in parts and hand tools to indicate task completion are commonly used to reduce information processing time (Helander, 2006).

Tactile means, such as vibration and temperature, can provide alternative solutions, when auditory displays are problematic or the environment is noisy. The sense of touch is used to provide feedback on the location and status of controls (Dul and Weerdmeester, 2008). Tactile controls do not require the object to be in the visual field of the operator. However, they generally require a higher operator proximity to the touched object. Texture, shape, and size can be some other tactile information coding dimensions (Bridger, 2003). Taste, smell and temperature should be used only to indicate alarm conditions; however they are inadequate for

multiple use (Dul and Weerdmeester, 2008). This is because it is hard for most people to distinguish between two different smells or tastes present at the same time.

Some of the visual systems and tools used to create a visual workplace, like the Kanban production control for pull production efforts, were so different (perhaps “counter-intuitive” as Ohno (1988) indicated.) and distinctive for their time that many people attributed the Toyota Production System (which is still occasionally called the kanban production system) to these systems (Shingo, 1989). The visual systems in reality are the means of realising the fundamental principles of the production system as a whole. The current means can be changed, modified or abandoned altogether when a more desirable method emerges or perhaps when the fundamental principles change. As Spear and Bowen (1999:104) explained:

Toyota does not consider any of the tools or practices – such as kanbans or andon cords, which so many outsiders have observed and copied – as fundamental to the Toyota Production System. Toyota uses them merely as temporary response to specific problems that will serve until a better approach is found or conditions change.

These “canonical” principles of the TPS are: the reduction of waste (*muda* in Japanese) to decrease costs through increased capacity utilisation (do more with less – get rid of anything superfluous) (Ohno, 1998; Liker, 2004; Monden, 1998; Womack et al., 1990), reduction of variability (*mura* in Japanese) (as maintaining the stability of the job while working on relatively scarce resources gains extra importance) (Ohno, 1998; Liker, 2004; Monden, 1998; Womack et al., 1990), and respect for the human element (to cope with alienation, to increase involvement and of course to decrease waste and variability- see Treville and Antonakis (2006) for details). Adler (1999) classifies this kind of “balanced” organisational structure as “enabling bureaucracy” Ideally; anything that claims to be lean should take these principles into account. The TPS, which is supposed to be the “purest” form of the production system at Toyota, was born out of various scarcities in post Second World War Japan (Fujimoto, 1999). Conditions mainly dictated the production mindset.

Both the concept of transparency and efforts in adapting Visual Management practices from manufacturing operations into the construction environment have promoted VM research in construction. The principles of transparency (creating and maintaining uninterrupted information flow) in a construction setting were defined by Koskela (1992:22):

- Reducing the interdependence between the production units;
- Using visual devices to enable immediate recognition of process status;
- Making the process directly observable through appropriate layout and signage;
- Incorporating information into the process;
- Maintaining a clean and orderly workplace;
- Rendering invisible attributes visible through measurements.

### 3 Visual Management in Construction

As has happened to many other production management core ideas, the principle of increasing process transparency has largely been developed in a long process of trial and error (Koskela, 1992). Formoso et al. (2002) conducted research investigating the transparency principles proposed by Koskela (1992) through the brick laying process. It was found that the nature of production units (mobility), lack of awareness and the construction end-product itself partially hinders increased transparency efforts.

In order to shed a light on the application of VM in construction, an exploratory field research was conducted in the Northeast and South of Brazil targeting the VM practices. As it was reported by the Brazilian academics, some companies located in these regions have considerably advanced in VM in their construction management efforts. Nine different building construction sites (generally with a reinforced concrete (RC) load bearing structure and brick partitions) from nine different construction companies were visited. The companies are small/mid size local companies mainly operating in their own states in Brazil. A research protocol which had been devised in the UK was fully completed with five companies, and with the rest of the companies a partial completion of the protocol could be achieved, and in all of the companies the site visit was documented with photographs. The researcher was assisted by the local academia, whose sincere help is greatly appreciated. See Table 1 for the case summaries.

In this part of the report, a compilation of the operational VM practices, which comply well with the principles of transparency defined by Koskela (1992), from the nine companies studied in Brazil is presented. It does not mean that all of the practices mentioned here have been/are being utilised by the same company/companies. It is a collection and classification of practices, describing their function and operation briefly. It is also impossible to cover every visual tool in great detail within the scope of this report. The examples are accompanied by related photos, generally in picture sets, following the textual description. The identity of the companies and people has been kept confidential in accordance with ethical regulations. All of the companies have a lean construction background to varying degrees.

#### 3.1 Site Layout and Fencing

Site layout and fencing should support transparency well. The main function of these items is to provide transparency through making processes observable (Koskela, 1992) and enabling information flow. Glass as a translucent material is used for increased transparency on the perimeter walls and doors of the site office buildings. Increased transparency through glass is also used for marketing purposes to display a maquette of the completed project to potential customers. The frequently preferred fencing types are those which permit seeing and being seen through, along with providing a safe enclosure, such as chain link or welded wire fences. Site perimeters, warehouses, allocated areas (e.g., dining areas, elevator control rooms, workstations and material storage zones etc.) are deliberately enclosed with those specific types of fences, where climate and construction conditions permit. See Figure 3.



Figure 3: Site Layout and Fencing

Table 1 – The Case Summaries

Case	Company	Project
Southern Brazilian Case 1 (The research protocol was fully completed)	Employs 300 people. Been operating in residential and commercial building constructions for 27 years. In 1998, they implemented the Last Planner, in 2001 the Look-ahead, and in 2002 more visual tools.	20.000 m <sup>2</sup> –High rise commercial building for IT establishments (7.93 M £)
Southern Brazilian Case 2 (The research protocol was fully completed)	Employs 1200 people. Been operating in residential and commercial building constructions for 35 years.	27.000 m <sup>2</sup> -Two high rise residential buildings with 350 employees (10.81 M £)
Southern Brazilian Case 3 (The research protocol was partially completed)	Been operating in residential and commercial building constructions for 30 years.	High rise residential building.
North-eastern Brazilian Case 1 (The research protocol was fully completed)	Employs 57 people. Been operating in residential and commercial building constructions for 21 years. The lean initiative started around 2002 and gained momentum after 2008.	7.000 m <sup>2</sup> - High rise residential building with 50 employees (3.13 M £)
North-eastern Brazilian Case 2 (The research protocol was fully completed)	Employs 150 people. Been operating in residential and commercial building constructions for 28 years. The lean initiative started around 2006.	6.000 m <sup>2</sup> - High rise residential building with 42 employees (2.46 M £)
North-eastern Brazilian Case 3 (The research protocol was fully completed)	Employs 500 people Been operating in residential and commercial building constructions for 25 years. The lean initiative started around 2002.	35.000 m <sup>2</sup> - Four high rise residential buildings with 350 employees (9.82 M £)
North-eastern Brazilian Case 4 (The research protocol was partially completed)	Been operating in residential and commercial building constructions for 16 years. The lean initiative started around 2002.	7.750 m <sup>2</sup> - High rise residential building with 50 employees (2.4 M £)
North-eastern Brazilian Case 5 (The research protocol was partially completed)	Been operating in residential and commercial building constructions for 22 years. The lean initiative gained momentum around 2004.	19.00 m <sup>2</sup> - High rise residential building with 260 employees (5.22 M £)
North-eastern Brazilian Case 6 (The research protocol was partially completed)	N/A	13 two-storey residential villas.

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### 3.2 Standardisation of the Workplace Elements

The standardisation of the site elements; people, materials, machines, carts, tools, workstations, temporary mobilisation units, transportation routes, temporary storage and process areas and the project end products, in terms of their identification (e.g., tagging, naming, numerical labelling etc.) and localisation through visual clues, makes up an important portion of the VM activities in construction. It is also a fundamental and initial part of lean efforts (Liker, 2004; Galsworth, 1997).

The people on the site (workers, foremen, gang leaders, site management and visitors) are identified by using coloured helmets, sometimes with some additional information (company name, project name, personnel name, work area etc.) written on. See Figure 4.



Figure 4: The Colour Coded Helmets

The transportation routes (the “flow routes” as they are sometimes referred to) for frequently used materials, such as brick and tile, are clearly marked with different colours and separated from the walking routes for the flow of these materials. When the construction site is large enough, this practice marks the routes distinctively like motorway lanes. The application of this visual practice depends on the site layout and operational planning. Sometimes the walkway for people can be marked with safety barriers. See Figure 5.



Figure 5: Marking the Transportation Routes

The location and identification of frequently used construction materials (e.g. cement, aggregate, timber, tiles, scaffolding/formwork materials, pallets, reinforced concrete (RC) steel, brick etc) and various tools are standardised through name tagging and occasionally with a photo ID and technical specification information attached. These materials cannot be stored in the construction warehouse in high quantities and are stocked on the site within the site layout design. Sometimes the location of these materials is also marked on the ground with coloured lines, when the location is more permanent. The name tags are generally designed to be mobile in order to relocate the storage area to a different position as the construction progresses. See Figure 6.



Figure 6: Locating and Identifying the Construction Materials

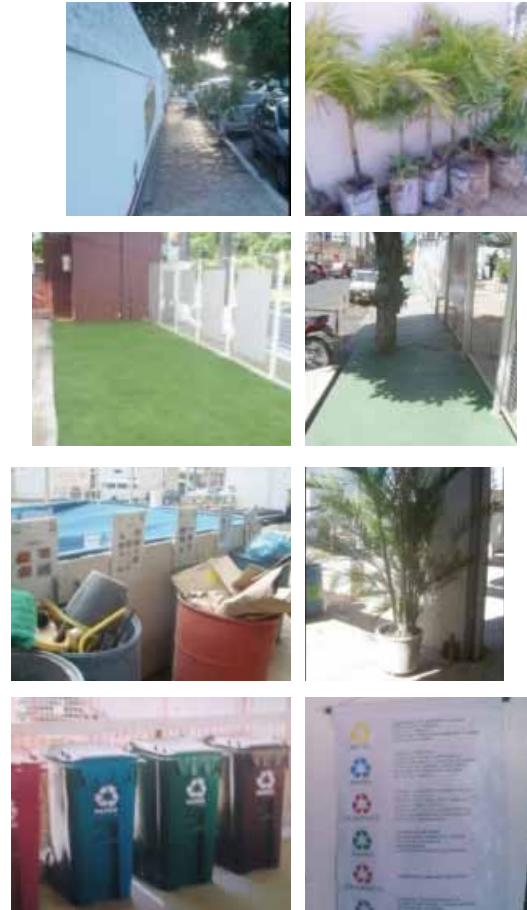


Figure 7: Creating a Clean and Neat Workplace

Keeping the site and its perimeter clean, neat and orderly are among the important concerns for the management. Regular cleaning, efforts for creating a pleasant work environment (through site painting, planting etc) and waste management for recycling are important activities that help to create a visually attractive and more transparent work environment. Waste containers are grouped, colour coded and decorated with pictures, according to what they should contain. The separation rules for waste materials are posted around the construction site. For larger waste, a suitable area on the site is allocated and clearly identified by visual means. See Figure 7.

Spatial elements, including construction end products (e.g. building, floor, beams, columns etc) and temporary construction production units (e.g. workstations, warehouses etc) are all identified. The site layout is shown on a plan, with building and other units identified, and this is posted at a suitable place on the site for everyone to see it easily. The temporary construction facilities are shown with direction signboards. In high-rise building constructions, each floor is identified with a name tag attached at the entrance to the floor (a sign reading "you are here!") in the staircase showing clearly where the person is and helping in orientation. Workstations and construction site facilities are marked. Construction end products (e.g. brick walls, columns, reinforced concrete walls etc.) are marked with numbers to communicate their identity to the people working on the site in a simple manner. See Figure 8.

# 3

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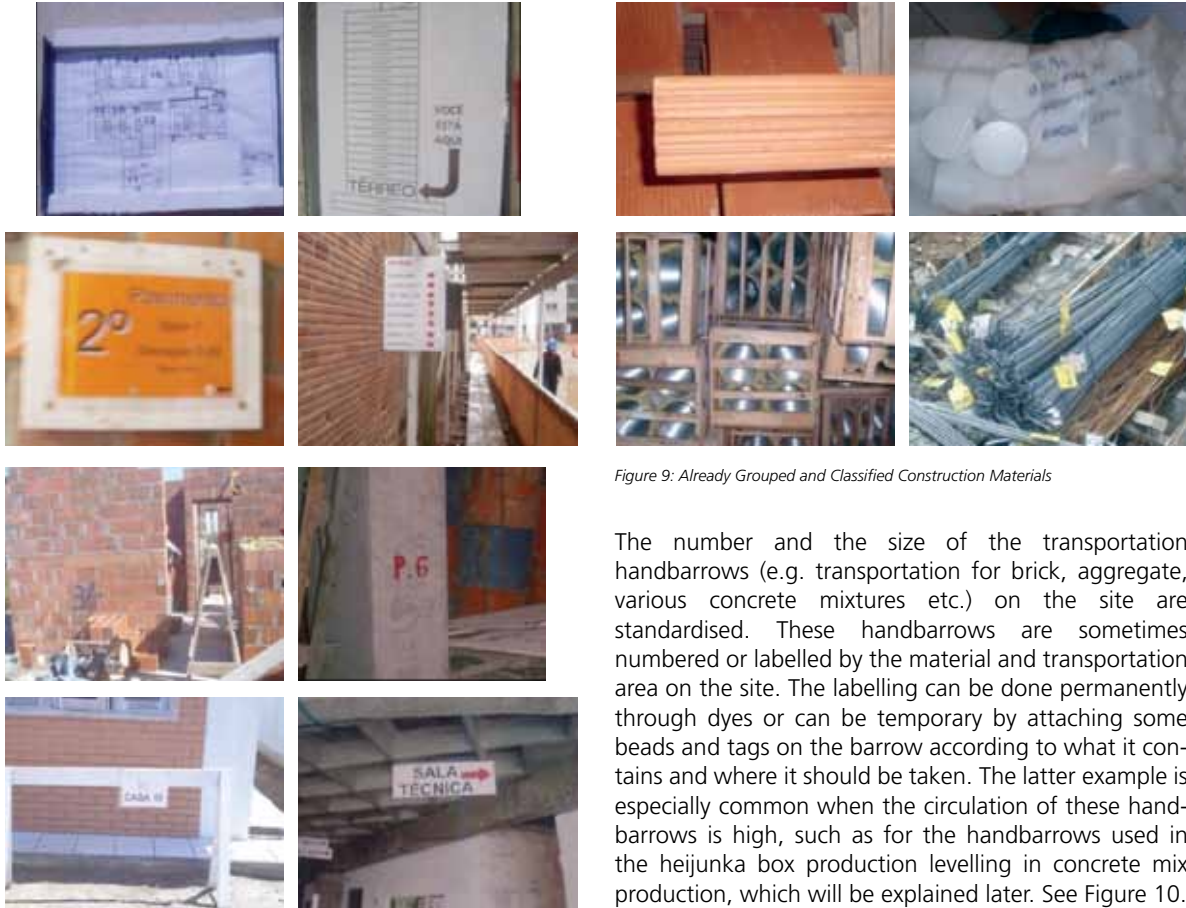


Figure 9: Already Grouped and Classified Construction Materials

The number and the size of the transportation handbarrows (e.g. transportation for brick, aggregate, various concrete mixtures etc.) on the site are standardised. These handbarrows are sometimes numbered or labelled by the material and transportation area on the site. The labelling can be done permanently through dyes or can be temporary by attaching some beads and tags on the barrow according to what it contains and where it should be taken. The latter example is especially common when the circulation of these handbarrows is high, such as for the handbarrows used in the heijunka box production levelling in concrete mix production, which will be explained later. See Figure 10.

Figure 8: The Identification of the Spatial Elements

Some construction materials (e.g. brick, reinforced concrete (RC) steel, some mechanical and electrical materials) are already purchased being grouped, classified and sometimes having the necessary information inscribed (e.g. on the brick). Suppliers are obliged to provide that service. This practice saves managerial time in creating a workplace where communication within the production elements is high. See Figure 9.



Figure 10: The Identification of the Transportation Handbarrows



The hand tools related to some workstations are hung around for easy reach and identification. The responsibilities in work stations and offices are identified with their pictures, names and jobs. See Figure 11.



Figure 11: The Identification and Order in the Workstations

### 3.3 In the Warehouse

The warehouse contains various visual elements. The supply items (consumables) in the warehouse are classified and stored in specific bins/racks. Necessary information (e.g. material name, technical specifications, picture etc) are attached to these bins/racks as tags, stickers or badges. Sometimes the bins only contain a barcode that enables the computer based stock tracking and digital information display system. See Figure 12.



Figure 12: The Classification of Materials in the Warehouse

Hand tools are grouped and organised on racks, on walls (sometimes for smaller hand tools, on wall boards) or in pigeonholes. Tools that belong to a specific person or a group (e.g. keys) are sorted on wall boards with the person's or group's name written under. This provides classification and understanding at a glance. See Figure 13.

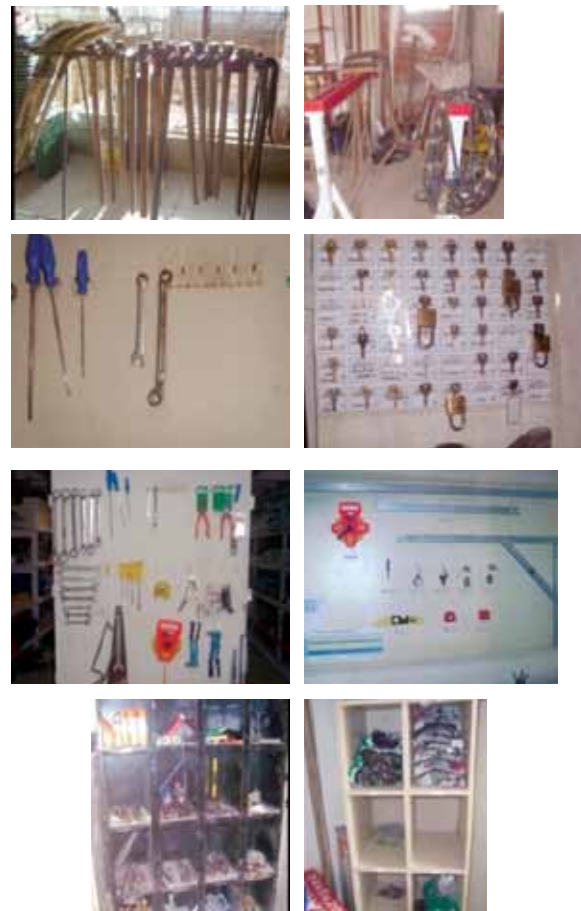


Figure 13: The Order of Tools and Equipment

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A consumables control board that displays the stock level of commonly used materials and tools (e.g. nails, cement bags, gloves etc.), providing elementary information for everyone who does not work at the warehouse on the site was observed. It was situated just outside the principal site warehouse. Some colour coded marks are in place to indicate the stock level (green for satisfactory stock, yellow for minimum stock, red for below minimum stock and black for no stock). See Figure 14.



Figure 14: A Consumable Control Board

A large matrix-like tool/equipment control board shows the names of the workers on the left and hand tools/equipment (e.g. drills, saws, shovels etc), which may have high circulation between workers and can be used by different work gangs, at the top. The board is located in the principal site warehouse. It facilitates hand tool/equipments control for the warehousemen to see at a glance who is using what hand tool at any given moment. See Figure 15.



Figure 15: A Tool/Equipment Control Board

Access to the warehouse for workers is allowed between certain times and this information is posted, along with some general information about the warehouse and project related issues, around the warehouse. The reception of the warehouse is designed like a store counter. The aisles in the warehouse are free of clutter, allow easy access and are marked with coloured lines. See Figure 16.



Figure 16: The Warehouse Layout and Organisation

### 3.4 The 5S

In some companies the 5S (seiri, seiton, seiso, seiketsu, shitsuke), a systematic housekeeping methodology born in the manufacturing world, is in place to ensure order and cleaning on their sites.

The 5S encompasses many visibility (transparency) increasing practices targeting standardisation of the workplace elements (space, machinery, jigs, tools, inventory) in terms of classification (naming), location, quantity, type etc (e.g. 'bordering, colour-coding, home addressing, layout and workplace ergonomic redesign, cleaning for visibility— see Hirano (1995) for a detailed explanation).

The implementation of the 5S is considered as the first step to the other lean manufacturing practices and to creating a visual workplace (Hirano, 1995; Galsworth, 1997). Keeping the plant clean and orderly plays a key role in the reduction of variability. Disorder and dirt causes quality problems, hinders problem solving opportunities and may lead to undesirable ergonomic and safety situations (Davy et al., 1992; Forza and Choo, 1996). Moreover it increases efficient utilisation of space through standardisation and encompasses routine maintenance for line workers (increased capacity utilisation through multi-tasking) (Hirano, 1995; Galsworth, 1997).

According to a site manager in one of the construction companies implementing the 5S, the most difficult part of the 5S application is to sustain the effort throughout the construction phases. Indeed, there are various parameters affecting its implementation on a construction site, including the workers' ownership. For example, in one case the client had bought and stocked all the reinforced concrete (RC) steel required for the project at the beginning, according to the contract, later the mass of steel created a disorganised situation on the construction site for the contractor, who was trying to implement the 5S. This is an example of the effect of the relationship between the contract partners on the order of the workplace. See Figure 17.



Figure 17: The Disorder Caused by the RC Steel Piles Due to Contract Constraints

The 5S effort is displayed, underlined and reinforced with some visually attractive communication means (e.g. mascots, tablets, 5S boards etc.) in these companies. 5S teams are created to sustain the effort. See Figure 18.



Figure 18: Disseminating and Sustaining a 5S Programme

An important indicator of a successful 5S programme is clean and orderly changing rooms, with lockers and equipment identified and the provision of necessary information (e.g. safety, quality, process, performance related), and toilets for workers. See Figure 19.

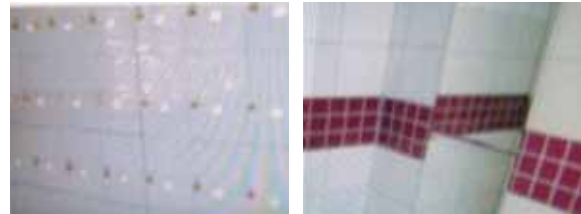


Figure 19: Clean and Orderly Changing Rooms and Toilets

### 3.5 In the Elevators

In high rise building construction, two separate elevators, one for human and the other for material transport are used. People are not permitted to use the elevators allocated for materials. The different elevators and their entrances on each floor are identified with name tags. Their allowed weight limit is clearly shown with necessary warnings, displaying a picture of each material and its corresponding weight including the transportation barrow or the number of people allowed. The elevators for material are monitored with cameras by the operator at the control station, since only the transportation wheelbarrow loaded with the corresponding material, no other accompanying worker, is carried in these elevators. Their control panels are central, highly visual (with a monitor) and colour coded for ease of use. Moreover, they are equipped with walkie-talkies for increased information flow. The human elevator is controlled by an operator inside the elevator with some visual aids (e.g. an elevator stop arm, colour coded controls, floor numbers posted on the floor entrance doors etc). See Figure 20.



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Figure 20: Visual Elements in the Elevators

### 3.6 Pull Production through the Kanban

Pull production, in which production is controlled by the workers themselves through some signals (in this case, with some small cards or the kanban), is applied on many construction sites. In a pull production system, the inventory is reduced and work in progress does not exceed demand (Monden, 1998). Bricklayers, painters, electricians etc order a standardised amount of material from the stock on the site each time they use their kanban cards. This can be defined as an internal system as it takes place within the same company. The kanban cards generally contain a picture of the ordered material, the identity of the production unit issuing the order and the amount to be transported to the production unit. Material transport is not allowed unless a kanban order is issued by the production workers to the transportation workers. This also makes it easier for the management to track the actual production and material consumption on the site.

The pull production philosophy can be applied to various consumables (bricks, stones, electrical and mechanical materials, paints, fixtures, wall, ceiling and floor finishes etc.) on the construction site. These cards are sometimes carried between floors in specific drawers that include the kanban cards, and colour coded and visually rich projects for the production workers. Generally, management experiments with the consumption in the beginning, for example on the first floor of a high rise building, and gets an idea of the approximate consumption of materials for each floor, block or house, if the construction process is repetitive. Excessive consumption, if it is the case, is tracked and questioned accordingly. In one company, the site manager underlined that the variety in the brick types

required for the project, according to him, made pull production control impractical. See Figure 21.



Figure 21: The Internal Kanban System

Along with production, site stock replenishment (generally for frequently used materials, such as brick, cement) is also realised with the pull philosophy. A card with two colours on its two sides (generally green for the normal stock level and red for replenishment) is put in front of the site material stock. When the material stock drops to a certain amount by having been pulled, workers turn the red side of the replenishment card in order to inform the purchaser to replenish the stock before their production falls short in material. This highly visual practice binds the purchaser (management) to the site on a real time basis, without having to ask, write, inquire, calculate, guess or talk. See Figure 22.



Figure 22: The Replenishment Kanban

Signalling for production has also been extended to internal processes (e.g. preparation and/or cleaning of some scaffolding elements). See Figure 23.



Figure 23: The Kanban in Processing

### 3.7 Production Levelling through the Heijunka Box

In many of the companies visited, site-mix concrete and its derivatives (e.g. screed, plaster etc.) are preferred, rather than ready-mix concrete. Thus, the work levelling at concrete mixtures is quite important for a feasible production. Work levelling is realised by using a visual table called the "heijunka box". The heijunka box is essentially a matrix with time divided in half an hour intervals on the x-axis at the top and different concrete mixtures on the y-axis on the left. These boxes are located in front of mixture operators. One day before production, the production workers put their special cards in the corresponding hole of the matrix, which indicates: "I want this type of concrete mixture at that time to the indicated floor written on the card". The following day, the mixture operator starts the concrete production in accordance with the cards. When a particular mixture is completed, the card corresponding to that order is turned around to indicate the completed production. The actual production can easily be monitored by the management by counting the number of the turned cards on the board. Then the mixture is put in a special barrow, and a tag is attached indicating the floor number to which the wheel should be transported with a bead symbolising the mixture type. The mixture operator is provided with a highly visual table that shows the mixture content in percentages (cement, aggregate, water, add-mixtures etc.) for each mixture type and a wall clock as visual aids to track the scheduled time. See Figure 24.



Figure 24: Production Levelling through the Heijunka Box

### 3.8 In-Station Quality (Jidoka) through the Andon

When the work is standardised to a considerable level, minor deviations can create multiplying effects. In order to spot any deviations immediately and pinpoint the real cause of a deviation, the andon system is used. It constitutes an important part of the "in-station quality" or jidoka efforts in a lean production system (Liker, 2004). The andon is a Japanese term for the lantern and it shows the status of operations in an area and signals the occurrence of abnormalities. It sometimes comes in the form of a panel, particularly in high rise building constructions. A green light on the control panel installed at the site management office will turn on for every floor. The green light indicates that all materials, information, project details and labour force are in place to start production. Later in the day, worker gangs might anticipate the problems they would face within the next few hours, such as shortage of materials, lack of a more refined project detailing or unexpected difficulties with tools, equipment and labour skills. Based on this perception, gang's leader will press the yellow button and correspondingly a yellow light will turn on, calling management attention at the site office.

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Site personnel will get in touch by walkie-talkie with operatives at that work station seeking how to best solve the problem. A red button would be pressed when problems are being faced straight away at the work station. A red light will turn on at the management office. This is an alert to immediately get in touch with the gangs at the work place, eventually pay a visit there and redirect part of the management effort on site to fix the problem (see Kemmer (2006) for a more detailed explanation).

Another dimension of the andon system is the ultimate aim of identifying the real cause of the problems that led to a red button being pressed to prevent reoccurrence. This is an alternative to a reactive fire-fighting practice in management. These causes can later be turned into an issue of continuous improvement. One of the site managers interviewed explicitly complained that they occasionally found it hard to get to the real cause of problems in a construction environment. These electrical boards are not very sophisticated and can be produced on-site, yet the system requires a stabilised and standardised production conditions. See Figure 25.



Figure 25: The Board Andon System

The andon system does not necessarily have to be electrical or complicated at all. In one of the construction companies visited, simple coloured cards were used to signal any abnormalities in the concrete mixture in a villa. This is of course easier when the construction is a house or villa (not high rise) and the site permits visibility. However, this basic system does not provide any signalling that immediately catches the attention of the management. See Figure 26.



Figure 26: A Simple Card Based Andon System

Another type of andon is the mobile floor andon, which can be located anywhere on a floor, unlike the fixed positioned andon buttons. Their mobility allows them to be used in highly mobile works, such as the construction of the facade elements. These systems provide both visual and audible signalling, which makes it easier to precisely identify the location of a problem. See Figure 27.



Figure 27: The Floor Andon

### 3.9 Prototyping and Sampling

Prototyping is in place in some of the construction companies to help people do their jobs better and more easily through complete visualisation of the end product. In prototyping, a repeating part of the end product (e.g. a complete flat prototype in a building construction or the piping system of a toilet that should be constructed again and again in a project) is put on display for workers and management. The effect of these prototypes can be enriched, in terms of information, with, for example, pipe numbers and diameters written on the materials and some posted projects around. See Figure 28.





Figure 28: Prototyping

Sampling is commonly used to couple materials with their location of use and equipments with their corresponding work gangs. It is used to match different production elements (material/space or equipment/personnel) by using a real sample of the material and/or equipment in question. A tile board displaying a sample of each tile type with its corresponding area of use in the project and technical specifications can be an example of the former. In terms of equipment sampling, warehousemen are provided with a sample of each mask type in different colours for the different work gangs that the masks should be given to. These visual aids are located close to their point of use. See Figure 29.



Figure 29: Sampling

### 3.10 Visual Signs

Some highly visual posters or signboards, which contain the company specific mascots or characters, are used to underline the desirable practices (e.g. "use your helmets", "do not waste material", "put on your earmuffs"), for internal marketing efforts (e.g. the 5S posters) and to change management practices, to convey a desired message (e.g. "we work in teams", "recycle for a greater cause", the picture of a confused worker looking at some scattered tools and materials saying "it is difficult to understand what I need" in order to promote order of the site etc), to persuade people and alter perception to create ownerships. In addition to these visual elements, different quotes, keywords (e.g. "value", "cellular production", "first in first out" etc.), and more strategic level, companywide information, such as the politics of quality, company values, and company vision can be seen around the construction site by anyone. More general information, like a 5S poster or company politics, is located in the shared areas (e.g. entrances, warehouses, dining halls etc) so that their coverage can be wider. See Figure 30.



Figure 30: Various Visual Signs

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### 3.11 Visual Work Facilitators

There are visual elements that have been designed essentially to facilitate the jobs of several workers (worker gangs) as visual aids. Process charts of the current operational works and highly visual step by step "how to" sketches of important construction tasks (e.g. concrete mixing and casting, reinforced concrete (RC) steel works, bricklaying, facade works etc.) and some informative posters about the lean practices and production model are located around the communal areas on the site (e.g. dining areas, entrance to the management site office, changing rooms etc.). See Figure 31.



Figure 31: The General Work Facilitators

There are also some other tools that have been designed to facilitate the job of a specific workstation/managerial level or a work gang or even a single worker/manager. Some of many examples are visual sketches displaying the standard output types at a workstation, colour coded and information-rich projects posted at a floor of a building on which production is going on, pictures of an expected production output for a worker, a floor plan distributed to the tile workers that shows the planned tile stock on that floor. These tools can be found at a specific workstation, on a building floor and sometimes even in workers' pockets. See Figure 32.



Figure 32: The Specific Work Facilitators

Some visual aids have been specifically designed to target the people at the managerial level to facilitate their jobs. Particularly in management (e.g. a specifically designed project holder with the project types written on the holder, a designated area for the collection of all legal documents with an index at the top of the collection) and production management visual aids (e.g. colour coded projects showing the concreting sequence and area or tiling plan of a floor, balanced production maps, a building plan showing the types of work and coloured line of balanced charts, real and planned durations of different tasks and so on) posted on a board in the managerial room. See Figure 33.



Figure 33: The Facilitators for the Management



Some traditional visual aids generally placed on the floor, facade and walls to give a direction (e.g. the direction of floor tiles) and level (e.g. the thickness of floor screed, wall plaster or facade elements) of reference for production are still in use in the companies visited. See Figure 34.



Figure 34: The Traditional Work Facilitators

### 3.12 Improvisational Visual Management

Integrating information into the environment is a rather spontaneous, intuitive phenomenon that may lead to many improvisational examples on a construction site. Scratching a gypsum wall to show the location of some heating pipes or writing a big "OK" on a brick wall to indicate that it complies with the quality standards, putting a tick on a wall with a chalk to indicate that electrical fixtures have been located correctly or incorrectly, writing a big "N" on a ceiling to communicate that it is not supposed to be painted are some of the simple examples of this improvisation. It can also be said they are more frequently seen within quality check or quality assurance efforts and their reflections on the site. See Figure 35.



Figure 35: The Improvisational Visual Practices

Another intuitive practice example is in the reinforced concrete (RC) steel production/material control. When the steel worker finished preparing a pile of reinforced concrete (RC) steel for assembly, the tag provided by the supplier is attached to display the technical information of that specific reinforced concrete (RC) steel pile. In that way, anyone can see how many and what type of piles have been processed so far. See Figure 36.



Figure 36: An Improvisational Steel Production Control

### 3.13 Explaining the Work Schedule

In one of the construction companies, construction plans and schedules are simplified for the workers through highly visual magnetic boards, colours and sketches. These boards are created and updated by the management according to the line of balance or any other construction scheduling method and the site plans. Each house in the project is given a number and represented on the magnetic board with different worker groups symbolised with different coloured dots using the same colour coding as in the line of balance. In that way, the management and workers can understand which worker group is supposed to work in which house, at any given moment. This is timely and easy to understand information for the operational people. See Figure 37.

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Figure 37: The Work Schedule Explained to the Workers

### 3.14 Performance Management through Visual Management

In another company, a construction progress board in bar chart format is used, showing the dates of the final completion and the last update. The board, which can easily be seen from outside the construction site, is mainly for potential customers and is put on display for marketing purposes. See Figure 38.



Figure 38: The Construction Progress Board

The evaluation of the suppliers' performance by different metrics (e.g. quality, security, contract compliance etc) is put on display either at the entrance for anyone on the construction site or on the perimeter fences for the people outside as well (public benchmarking). In addition to the conventional practice of putting the names and signboards of the suppliers on the site, their performance can also be seen instantly. The distinction is a matter of how transparent the management wants this information to be. The design of these boards is sometimes colour coded (green for good, yellow for average and red for poor performance) and generally highly visual as well. A manager in one of the companies using both the supplier and sub-contractor evaluation

boards thinks that these boards (explicitly showing the performance) create an extra motivation for a better performance. See Figure 39.



Figure 39: The Supplier Performance Board

The performance of worker gangs and individual workers with their pictures are displayed on the boards located at the communal areas on the site. Sometimes these boards are carried to the floor on which production is taking place. See Figure 40.



Figure 40: The Team and Individual Performance Displays

A summary of the general metrics is put on boards on the site for everyone and generally located at the entrance to the site or office buildings. These metric boards can be customised to include the key performance indicators (KPIs), the work schedule, sub-contractors' performance matrix, PPC values (Percent Plan Complete) in the Last Planner System (see Ballard (2000) for more on the Last Planner) for the company and sub-contractors, general project metrics for workers, good practice evaluation boards and security information. These boards can sometimes be designed with more mobility and can be easily moved as the construction progresses. See Figure 41.



Figure 41: The Project Performance Displays

### 3.15 Distributing System Wide Information

System wide information, whether it is directly related to construction production or not, is put on display for everyone working on the site to enhance transparency. Some examples of production related system wide information are visual diagrams showing the dates and amounts of past concreting in a high rise building construction, a table displaying the delivery situation of an expected material in the building (ordered for the 2nd floor, waiting for the 15th floor etc); a monthly calendar printed on standard A3 paper summarises all kinds of important events and milestones (e.g. the visit of an academic to the site, an intern starts working, the start of the 2nd floor painting, the monthly company breakfast etc) coming from internal or external sources a month in advance, the stages of the construction in pictures, the salaries of every type of employee working on the site (the manager, the intern, the foreman, the workers, the operators etc), a board showing the planned dates of the concrete casting on each floor for different structural elements (e.g. the column, the beam etc), a board used to control and track the alterations of important tasks for each apartment in the building and productivity information. Even some profitability figures can be shared with workers.

This type of information is shared among people so that they become more aware of their environment. Information sharing opportunities are immense, therefore, after a certain point, increased transparency becomes dependent on the managerial character, preferences, approaches, environmental conditions and human beings' creativity. Understanding the mindset is important in this case. See Figure 42.



Figure 42: The Production Related System Wide Information

In order to create a better understanding or even arouse some empathy, construction consumables (e.g. nail or timber), which may be wasted easily on the site depending on how carefully they are used, are shown together with a worker's important life consumptions (e.g. bread, sugar etc) to establish a connection between the two. For example, it is explicitly shown in the communal areas on the site that 1 kg of nails cost the same as 19 units of bread. See Figure 43.

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Figure 43: The Connection Between a Worker's Life and Production



Figure 44: The Secondary System Wide Information

Secondary system wide information, which may not have a direct or important relation to the production on the site, is also tracked and distributed on the site. Examples of this kind can be some relevant newspaper articles, the company's organisational scheme, pictures of different activities, technical visits and company events (e.g. a technical visit to a manufacturing plant known for being advanced in lean production practices), flyers informing people on how to avoid HIV or malaria and the birthdays of the personnel. In one company, system wide information has been distributed through a specific company newsletter or as they call it "journalean". The covers of some relevant production management books are also put on the main boards to inform people about the literature. Some of these information displaying practices can mainly target the managerial level and others may be more for the construction workers. See Figure 44.

### 3.16 Human Resources Management

Many of the practices that were explained in previous sections can be considered within the human resources connections of VM. To summarise some of the practices, workers and work groups are identified by their helmets, their planned location on the site is communicated to them with highly visual boards and signs, the workers and work gang members are visually identified, the standard salaries of workers are on display, company events are organised and the pictures from these events are distributed throughout the site, workers can easily see the amount of money they earned by using the computer station located on the wall of a site office, information related to worker health and wellbeing is posted all through the site (as explained in the next section), a worker emotions board on which workers can express their emotions explicitly using red, yellow or green faces for different emotional moods, a neat, organised and clean construction environment is provided, exceptional workers are identified by different measures and praised publicly in the company newsletter or on boards, necessary work training is provided which is supported by highly visual presentations and films and workers receive a training certificate afterwards, there is also a transparent suggestion box located in the lunching area. See Figure 45.





Figure 45: Human Resources Management

### 3.17 Safety Management

Safety performance is widely displayed using VM. An overall indicator of safety and project wide information is put on display (e.g. the number of days without accident, the safety politics, the identification of responsibility for safety, the safety procedures etc). Safety signs, mobile safety signs indicating a possible danger (e.g. the fall of an object), an "almost accident" desk, a safety board showing what health and safety equipment each profession has to use on the site, a safety equipment control board, easy to locate, easy to access (generally on the wall) health and safety kits (e.g. fire extinguishers, first aid kits, stretchers etc), graphical description of how to use the safety tools, informative posters about work ergonomics, "wash your hands" reminders on water taps, safe walkways, dangerous areas enclosed with transparent fencing, guests are welcomed with tablets displaying the safety and general rules on the site, and keeping a neat and orderly construction site to comply with possible health and safety issues. See Figure 46.



Figure 46: Safety Management

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### 3.18 Poka-Yoke (Mistake Proofing) and Prefabrication

There are two interesting phenomena within the companies visited, which are worth mentioning: Poka-Yoke (mistake-proofing) and prefabrication on-site. Poka-Yoke is a Japanese term for mistake-proofing (literally yokeru – to avoid and poka - inadvert) (NKS, 1997). It is generally classified under the zero quality control movement proposed by the Japanese industrial engineer and Toyota’s prominent training consultant Shigeo Shingo in the early 1960s (the Poka-Yoke philosophy was conceived and devised at Yamada Electric in Nagoya in 1961 for the first time) (Shingo, 1987). A Poka-Yoke is any mechanism that either prevents a mistake or defect occurring or makes any mistake or defect obvious at a glance (Fisher, 1999). Poka-Yoke devices are one of the means, along with elimination of root causes of problems and standardisation, used to reduce variability in a production system (Koskela, 1992). These devices can virtually eliminate the need for statistical process control. They enable self inspection in repetitive tasks by the line operator (requiring some vigilance and memory) through error prevention by using relatively simple and cheap mechanical, electrical and visual mechanisms. This is one of the most powerful tools of quality in the 21st century (Bhote and Bhote, 2000).

Construction management literature has been calling for increased Poka-Yoke efforts in the construction industry (Santos, 1999; Tommelein, 2008). Knowing the Poka-Yoke mindset, the workers in one of the companies devised adjustable metallic shores that keep benches in their place during construction for more precision, safety and productivity. See Figure 47.



Figure 47: A Poka-Yoke System – The Adjustable Metallic Shores

Another example is creating protrusion with some nails on pipe heads for more precise installation. See Figure 48.



Figure 48: A Poka-Yoke System on the Pipe Head

On-Site prefabrication has been performed in some of the companies. The prefabrication of the mortar at a specifically designed station to guarantee homogeneity for a high quality mixture or the prefabrication of the electrical hardware (the junction box) within bricks before brick laying to reduce the interdependencies between tasks and excessive work are good examples of prefabrication applied in these companies. See Figure 49.



Figure 49: On-Site Prefabrication

### 3 Conclusion

In the concluding section of the report, the general observations and findings from the interviews with the people at managerial level (company managers, site managers and foremen) will be summarised.

The conceptualisation of the research theme (VM) was hard for the interviewer and interviewees. It remains as a vague term and can sometimes be confused with different management efforts. It appeared that the interviewees found the tools helpful, but they had not given much thought to the purpose of their application. VM is perceived and developed as a part of the “lean initiative” and understood together with the term “transparency”. It is true that VM frequently finds a place in “lean literature” and visual tools play an important supportive role in the lean production philosophy. Perhaps the popularity and prevalence of lean production highlighted some commonly known VM related tools and methodologies, such as the 5S, Andon, Kanban etc. However, this is not to say that a lean production background is absolutely necessary to implement VM. It is probably more important to understand the theoretical background and possible functions of VM. The somewhat limited view of Visual Management as a production control and performance management tool may restrict the extended use of VM, within its identified functions.

The simplicity and financial feasibility (as these tools generally do not cost much) of visual tools were cited as their most important features. They create an “easy to see and understand” work environment for both the management and the workforce. Of course, these tools assist the workforce in managing and controlling their work and environments on their own to a degree, yet they also help management track, disseminate information and control the work with lesser effort. Thus, there is a dualism in the functionality of these tools. Additionally, two types of transparency; process transparency for everyone (the motorway analogy) and transparency for some or a specific individual/group of people (the control panel of a car for the driver on the motorway) were observed.

According to the management, visual systems are effective because the workforce is poorly educated (even illiterate in some cases) and visual tools present easy to understand visual communication media. This claim needs to be checked against the opinions of the workforce.

The application process is usually from top to bottom. People are allowed to make modifications on visual systems but whether or not they do so in reality is open to discussion. Training people to work with the visual elements is important, though it may take some time and patience in the beginning, especially with the workforce to modify their conventional working habits. It is essential to get the foreman’s and site management’s participation and consent, as they are the ones who are directly responsible for the execution of VM in application. The perceived common barrier in application, according to the management, is the low education level of construction workers. The worker turnover may also be a problem, particularly regarding the trained workforce. The application of some tools may depend on the construction type, construction properties, contractual relationships and technology used. For example, there may be no need for a heijunka box, if the company decides to go for the ready-mix concrete altogether. In one case, the client had contractually bought all the reinforced concrete (RC) steel needed and stocked it on the site, which in turn created considerable clutter and disorder on the site, seriously contradicting the 5S efforts of the construction company. Some application opportunities (such as on-the-job training) were found to be relevant but not in use; there is surely some room for development and variability in application. The main application areas (as perceived by the management) are safety, dashboards and production control in many cases.

Some important VM related concepts, such as transparency through design, sampling, prototyping, mistake proofing, and prefabrication were documented. VM can also be a highly intuitive practice, which is realised through some improvisational tools devised by the management and the foremen. Some traditional practices, which can be classified as visual work facilitators were observed to be in use. The close cooperation between the companies, particularly in the Northeast of Brazil (sharing the operational practices with one another on a regular basis through formal meetings and workshops), and with academia in general provides the companies with different modes of learning. Therefore, some of the practices are very similar in different companies, which creates a degree of regional standardisation in application.

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The companies have been trying to capture and document their VM efforts, so that they can be transferred from one project to another and communicated to newcomers in a systematic way. In terms of IT, the companies do not possess complex IT systems but they rely heavily on the prominent business software. The management underline that any proposed IT systems to replace the current VM tools should be affordable, easy to use and resistant to the harsh conditions of construction.

The functional existence and effective use of VM in construction in different production management areas were identified. Some of the companies who are advanced in VM/ lean construction serve as local benchmarks for other construction companies. They are proud of what they have achieved and intend to sustain their VM efforts. Frequently, the companies provide a setting for academic research as well. Although these positive aspects in application may lead to strong arguments in the dissemination of VM in construction, parameters affecting different contexts (e.g. the application of VM in the UK) should be carefully considered.



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## 3

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