Visual factory: basic principles and the ‘zoning’ approach

N. BILALIS†*, G. SCROUBELOS‡, A. ANTONIADIS§, D. EMIRIS¶ and D. KOULOURIOTIS†

This research proposes a method of organizing an effective information-transfer system design in a plant-working environment. The method is based on a combination of the visual characteristics principles used in the development of safety systems, visual factory design and advanced training practices. With the visual factory principle, the production area is separated into three task zones ‘A’, ‘B’ and ‘C’. Zone ‘A’ represents the ‘peripheral’ or reference zone, zone ‘B’ represents the ‘access’ or ‘link’ zone and zone ‘C’ represents the ‘main activity’ or ‘production’ zone. When implanted, this system will reduce the probability of worker mistakes and, in combination with CAD, it will provide a tool for effectively managing change in an environment of growing demand for information exchange, revision and update. Thus, the system provides a positive thrust in business continuous improvement. Therefore, the method proposed can serve as an interfunctional tool facilitating the job of the floor workers as well as the plant’s middle and top managers.

1. Introduction

Dedicated thematic audits in the late 1980s showed that, in order for a business to avoid future disasters, it had to focus on essentials, one of which was the effective transfer of information. Although this sounded obvious, practice showed that it was not. Manuals of operating guidelines existed. However, when these guidelines reached ‘the floor’, they were too complex and detailed, leaving company personnel in doubt about what was expected of them. This led to a misconception or even ridiculing of the communication’s scope. In most businesses today, information availability is no longer a problem, but the internal communication of this information seems to be ineffective, despite the fact that its necessity becomes increasingly demanding in a business environment where changes are becoming more frequent, requiring even more effective internal communications (Greif 1991). Management system audits usually facilitate change identification (Harrison 1984) and depict the importance of knowledge in goal achievement in their flowcharts (Zervakis 1996). However, audits are used as a management tool, rarely conveying their information to the floor workers. Moreover, an audit ‘photographs’ a specific instant of the operations practices while its generalizations are dependent on auditor’s experience.

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† Technical University of Crete, Department of Production Engineering and Management, University Campus, Kounoupidiana, Chania 73 100, Greece.
‡ Risk Management Systems, Greece.
§ Technological Educational Institute of Crete, Greece.
¶ University of Piraeus, Greece.
* To whom correspondence should be addressed. e-mail: bilalis@dpem.tuc.gr
In addition, it has been reported that 85% of accidents are behaviour related (Lumbermen et al. 1996, Bird and Germain 1986). Using the ABC model it can be examined why people behave in certain ways. The three components of the ABC model are described below.

1. Activators are cues in the environment that come before behaviours and give direction to the behaviour.
2. Behaviour is a sequence of observable actions sometimes brought about by the activator.
3. Consequences are outcomes that follow behaviours and determine the probability of that behaviour occurring in the future (Bird and Germain 1986).

In general, there are three ways for transmitting information throughout the operations with the objective of achieving behaviour modification and adoption to continual changes.

1. Training.
2. Teamwork.
3. Facility design.

1.1. Training

Training was considered, and still serves as, the primary tool for upgrading the industrial worker’s background and skills. In addition, no identified change must be implemented without prior training for affected personnel (Zervakis 1996); however, while none can doubt the value of training, it seems that, in practice, it often proves ineffective because it is rarely repeated, it is very rarely change-adaptive or change-consistent, it is rarely simple or practical and it is never operations-oriented, thus adding no value to the workers’ background while still leaving them room for improvisation, which does not help behaviour modification to achieve the required consistency for mistake minimization. One of the methods of effective training is imaging, that is conveying clear mental images for the audience. Visual aids have recently been introduced to enhance imaging during training, i.e. the visual stimuli linked to audio-verbal communication. The combination of visual and audio signals brings the best results in the sense that information conveyed is better digested and impressed on the audience’s mind. The best visual aids include, graphical representations, pictures, posters, schematics, symbols, transparencies and colour coding.

1.2. Teamwork

In order to develop a great idea in business, teamwork is essential; it provides an enhanced probability that the objectives will be achieved and the team will survive even in a hostile environment. A basic element of the success is adaptivity in habitual changes, which provides the dynamics for creating a flexible business mentality through behavioural consistency. In order for this mentality to be developed, a training system must be adopted that will achieve a learning process compatible with the emotional skills. Unfortunately, large capita is spent yearly on training programs that are ineffective since they have no result in the development of emotional intelligence. Only 10% of the skills taught in the business training programs are transferred or used on the floor. However, it is unknown how much these programs contribute in improving work efficiency as no such data are collected or
compared (Goleman 1999). Training in the development of emotional skills should include the following.

- Motivation (Why do I need the information provided? Is it obvious that it will help me do my job in a better way?)
- Focus (What are my targets?)
- Evaluation (In what way am I becoming better if I follow the information conveyed?)
- Feedback (Where am I today against my targets?)
- Repeat training (Shall I get better, faster?)

1.3. *Facility design*

In general, poor ergonomic conditions can adversely affect the workers’ efficiency by increasing the probability of mistakes. For example, it is difficult to forecast the psychological impact of workplace noise. In addition, all operators undergo a decision-making process before operating switchgear interacting with indicating lights; a man–machine misinformation exchange could result in erroneous operation. Simplicity in panel design most often restricts flexibility. There are four principles in designing the operator-machine interface: (1) psychophysical (2) encrypted (3) dynamic anatomy and (4) operational anatomy, among which the first two include colour coding and symbol depiction of functions (Kardakaris 1989). Another approach is the lean manufacturing five Ss, which stand for, Sort, Stabilize, Sine, Standardize and Sustain (Hirano 1996).

Once an adequate and safe work area has been provided, the following considerations must be accounted for:

- visual contact with the working machinery and equipment,
- easy oral communication with other workers,
- the type of work to be performed,
- work step performance sequence,
- the required areas for raw materials, intermediate products, finished goods, waste material as well as job-related tools and portable equipment (Kodossakis 1998, McElroy 1980).

2. Organizing and designing an effective information transfer system

2.1. *Information type*

Experience shows that the information readily required during operations can be divided into two main categories.

*Standard (‘S’) information*, which relates to procedures and guidelines that are, by nature, not updated often, but could be supplemented or upgraded; this information may be related to:

- company standards of obligatory nature best practices (safety, fire protection, hygiene, etc),
- standard operating procedures (support auxiliary equipment and installation operation, cleaning procedures, etc).

This information only indirectly contributes to the targets set and therefore is only indirectly target-related or benchmarked.
Variable (‘V’) information, which relates to procedures and guidelines that are, by nature, more or less regularly updated; this information may be related to:

- variable operating procedures (machine operation, panels settings, palletization, etc),
- variable indications (instrument/gauge indicator lights readings, calibration requirements etc).

This information is directly linked to production and is always target-related or benchmarked.

2.2. Information presentation and communication

In order for information to be effectively communicated it must be visible, clear and simple in its presentation without excluding a certain degree of detail, since training cannot be either continuous or everlasting. Practices have been used for information presentation and communication but only sporadically and with no structure. Information must be organized in such way as to provide

- a clear vision of the jobs
- target method and restrictions (dos and don’ts)
- a measure
- result (absolute and against target)
- managerial support

This provides workers with a sense of method objectivity and clarity that feeds their motivation.

S-Info must include, as a minimum:

- safety signs colour-coded and of correct size
- motivational signs such as slogans, the company’s mission, vision etc
- basic safety dos and don’ts as well as job-related dos and don’ts
- mimic diagrams of complicated or special installations
- operating procedures of special installations
- colour-coded boundaries of all areas
- information signs
- directional signs
- hygiene procedures
- cleaning procedures
- start-up and shut-off procedures
- lockout/tag out procedures
- floor layout posters
- evacuation/emergency procedures
- standard settings
- equipment limitations/restrictions

V-Info must include as a minimum:

- operating procedures depending on product
- palletization procedures depending on product
- quality control procedures depending on product
- product specifications information
• production shift rates against target and best achieved rates
• waste generation rates against target and best achieved rates
• energy consumption against target and best achieved rates
• customer satisfaction rates against target and best achieved rates
• incident rates against target and best achieved rates
• variable settings (product-related)
• production, equipment limitation, restrictions depending on product

Information may be preferably presented with symbols as long as symbol interpretation is self-explanatory, widespread or provided in an inbox. Clipart and pictograms facilitate immediate perception of written requirements. Photographic presentation of task performance is preferable when presenting task sequences. Arrows in pictures help workers focus on the important data. Colour coding must be used on all light indicators. All switches must bear functionality labels. Most of the ‘S-Info’ must be fixed or suspended if no physical surface is available. In the case of multiple directions, tarifolds (many-paged instructions) must be used that must, however, be secured in the correct page; alternatively, the proper procedure must be separately posted in different positions.

3. Plant layout separation in zones = ‘zoning’

In order to specify the type of information required to transfer to a plant floor worker, the work area can be divided into ‘zones’. This method adopted the following line of thinking: while a plant floor worker usually moves on a horizontal floor that defines a specific work area that can easily be depicted on a plan view, its main communication sense, vision, and the worker’s manual operations are extended and executed vertically that is on vertical surfaces.

Thus, the above-mentioned information must be distributed not randomly but in an organized manner, from careful design, according to the zones below.

3.1. Plan view zoning

Regarding the operations, most plants are laid out in a similar way (figure 1); this general plan-view design may be divided into three main zones with respect to their functionality (figure 2).

Colour coding is used to define important areas and the standard notations are used.

• Red/white for fire protection equipment.
• Yellow, or yellow/black, for hazards, prohibitions.
• Green for emergency/rescue equipment and routes clearance.
• Grey, black/white, for general-purpose equipment.
• Blue, for obligation signs.

Zone A = ‘A’ctivity zone

This is the zone where the main operations take place; this zone usually covers the central part of the operation facility and includes:

• machinery (production areas),
• equipment (laboratories),
• machine operator area (production),
• metal processing equipment (machine shops).
Figure 1. Floor layout of a generalized production line.

Figure 2. Floor zoning, zone-A (activity area), zone-B (boundary area), zone-C (circulation area).
Zone B = ‘Boundary zone’
This is the zone where materials of auxiliary services are laid out in order to feed zone ‘A’ and it includes:

- staging areas for raw and packaging materials,
- safety equipment,
- fire protection equipment,
- auxiliary/support workstations (production/warehouses),
- supplementary workstations (laboratories),
- support equipment parking areas (warehouses/production).

Zone C = ‘Circulation zone’
This is the zone that is used for operator or vehicle circulation; this zone separates either zones ‘A’ and ‘B’ or divides large-area zones ‘A’ or ‘B’ into sub-zones or both; this zone must usually, by standard design, remain free of any, even temporary, storage of stationary material or equipment.

3.2. Vertical or wall zoning
Regarding installations, most plants are designed in a similar way. This general section-view design may be divided into three main zones with respect to functionality (figure 3).

White zone = Operation zone
This is the zone within the boundaries of which the worker interacts with the machine and is therefore mostly occupied by the main machinery installation or equipment; this zone is roughly ‘machine-high’, or up to 2 m, and it usually extends to bench-height (50–70 cm) but in some cases it may extend to the floor. This zone is directly visible by the floor worker. In some cases, white zones contain black zones (see below) because they are used for installation or material stacking.

![Diagram of vertical or wall zoning](image)

Figure 3. ‘Vertical or wall zoning’ (estimated zone dimensions).
Grey zone = Information zone

This is the zone that is usually either left vacant or is partially occupied with installations or equipment such as fluid or electrical power lines, tanks, panels, access ladders or platforms where a second level is constructed etc. This zone is only indirectly visible by the worker—the visibility grade mainly depending on the installation and or equipment layout design, extending from roughly 2–5 m.

Black zone = Service installation zone

This zone is usually heavily occupied by installation and equipment that services the white zone. This zone may be either completely invisible, if the area has a false ceiling or floor, or hardly visible due to its position (very low, close to the floor, very high close to the ceiling, hidden behind machinery, installation or equipment).

3.3. Effective communication through zoning

Thus, the type of information mentioned in section 2 must be distributed not randomly but in an organized manner, from careful design, according to the zones above. Since all useful information has been decided and collected and the plant areas divided into zones, a study must be conducted to select and allocate each piece of information to the specific zone. For simplicity reasons this combination is presented in table 1.

<table>
<thead>
<tr>
<th>Floor zones</th>
<th>Wall zones</th>
<th>Information type</th>
<th>Posting method</th>
<th>Information category</th>
<th>Examples of communication posts/signs</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Black Grey</td>
<td>S</td>
<td>Fixed</td>
<td>Safety, Motivational, Environmental</td>
<td>Safety Signs, Do’s and Don’ts</td>
</tr>
<tr>
<td></td>
<td>White</td>
<td>S &amp; V</td>
<td>Fixed and Suspended</td>
<td>Safety, Environmental</td>
<td>Sticker signs, LOTO Procedures (S), Cleaning Procedures (O), Panel Operation Procedures (O), Waste Disposal (E)</td>
</tr>
<tr>
<td>B</td>
<td>Black Grey</td>
<td>S</td>
<td>Fixed</td>
<td>Safety, Motivational, Environmental</td>
<td>Mission (M), Slogan (M), Signs (S), Posts (E, S)</td>
</tr>
<tr>
<td></td>
<td>White</td>
<td>S &amp; V</td>
<td>Fixed</td>
<td>Operational</td>
<td>Floor Layouts (S,O), Palletization Directions (O), Pallet Stacking heights (O)</td>
</tr>
<tr>
<td>C</td>
<td>Black Grey</td>
<td>S</td>
<td>Suspended</td>
<td>Safety</td>
<td>Exit Routes (S), Signs (S)</td>
</tr>
<tr>
<td></td>
<td>White</td>
<td>S &amp; V</td>
<td>Fixed</td>
<td>Safety, Environmental Operational</td>
<td>Area Boundaries Colour Coding (O), Exit Routes (S)</td>
</tr>
</tbody>
</table>

Table 1. Effective communication data design.
Figure 4. Vertical or wall zoning with respect to the functionality of an area section.

Figure 5. Zone ‘A’ ‘vertical zoning’ design for a machine operator (example). V-INFO: Variable information (operations-related), S-INFO: Standard information.
Such a study and the resulting design imply employee involvement and extensive trial and error. CAD facilitation is essential in providing alternative solutions. All zones should be drawn in different levels and all information should be inserted in at least two separate levels, for the S-Info and V-Info. In this way, the design will be flexible for editing and continuous improvement and it can also serve as a training tool.

CAD may also be used to produce ‘V-info’ related signs, such as (figure 4):

- mimic diagrams
- machinery 2-D or 3-D representations
- area layouts

This makes the information transfer livelier and user-friendlier. The analysis can go into the detail required by the team and such a detailed diagram for a Zone A, vertical zoning design for a machine operator, is shown in figure 5. The diagram shows all the places where information can be suspended, the type of information medium used and the type of information presented on each sign.

Furthermore, in figure 6, a Zone B, vertical zoning, example is shown for a multiple area adjacent to the wall. Again, all the available area is shown and the type of information that can be presented is shown in the diagram.

In figures 7–12, one can see several examples of the practices used in some well-organized factories. Information contained in the manuals or in the instruction books is generated directly from the CAD system.

![Figure 6](image.png)

Figure 6. Zone ‘B’ ‘vertical or wall zoning’ (example) design for a multiple area adjacent to the wall.
Figure 7. Palletization information at the end of a production line before the beginning of the conveyor belt leading to the packer, created in AutoCAD. (White ‘A’ zone V-Info). Eye-level tarifold for easy reference containing information on pallet size and box layout.

Figure 8. Electrical shop’s safety information layout (Grey ‘A/B’ zone S-Info). The information is not at the electrician’s eye-level as it serves only as a reminder; however, it is placed directly above the working counter, near the clock.
Figure 9. Line demarcation of liquid raw materials (installation white ‘B’ zone S&V-Info). Well-demarcated lines providing information of the contents, flow direction and storage tank origin.

Figure 10. Electrical shop’s safety and operational information layout. (White ‘A/B’ zone S&V-Info.) The lock-out/tag-out equipment and the keys are placed at the eye-level near the working counter.
Figure 11. Electrical shop’s operational information layout. (White ‘A/B’ zone S-Info.) Well-demarcated eye-level-placed working panel directly above the working counter.

Figure 12. Machine-settings and palletization information. (White ‘A’ zone V-Info.) Eye-level pockets attached to the operator’s workstation; colours are used to enhance perception of the requirements.
Conclusions

Summarizing, in order to set an effective communication system, the following stepwise approach is recommended.

- Collect and layout in a CAD system drawings of the entire facility.
- Given the existing areas' functionality, installations and equipment, identify the A, B and C zones.
- Create CAD sketches of selected area sections.
- Given the existing areas' functionality, installations and equipment, identify the white, grey and black zones.
- Identify and list the type of information required per area divided into S-Info and V-Info.
- Use the CAD system to create area representations of the info distribution and layout with the aid of table 1.

The result should be checked through the availability in the company management systems, approved in cooperation with all interested parties and then posted; in this way this information will be:

- well selected and screened,
- the result of teamwork,
- well documented in soft form and thus easily subject to editing and improvement,
- a powerful multidirectional communications tool from top management to floor worker level.

References


