

# WORKPLACE DESIGN METHODOLOGY - AID TO PROGRAMME DEVELOPMENT

Occupational risk prevention must be integrated right from the functional specification (programme) preparation phase for a workroom, workshop or industrial building because a number of options become irreversible thereafter. The client requires programme preparation tools allowing him to envisage and assess quickly different layout scenarios for both building and process layout and flow organization, to identify far upstream the options offering optimum performance on engineering-economic and occupational risk prevention levels. To do this, information and tools with widely varying areas of application and of different degrees of complexity are available to him [1, 2, 3, 4, 5]. The prevention institution has specifically edited a workplace design guide [5], which considers all prevention aspects ranging from internal movement to work station ergonomics. However, this guide refers the designer to various documents, technical guides or computer software, which are often ill-suited to the programme phase because they require excessively detailed knowledge of the project and are too heavy to implement [6, 7].

Use of a computing tool allowing rapid preparation of a project "model", identification of potential risks, proposal and assessment of different prevention means should facilitate the client's work in preparing the programme. This is the purpose of the MECOLTRA project, currently under development by INRS and introduced in this paper.

## METHOD

The method focuses on important, irreversible design factors: process layout, natural lighting, noise, ventilation and thermal comfort. It first analyses the process by means of a layout study, then identifies potential risks and concludes by proposing solutions for reducing these risks. Potential risk assessment is performed on the basis of a scoring system.

A score is a numerical indicator which allows programme quality to be assessed from a hygiene and safety

standpoint. It characterises the increase in risk to which employees working in a specified workshop are exposed, compared with a workshop optimised for prevention. MECOLTRA therefore uses five types of score, corresponding to each discipline concerned. The score permits identification of the impact of any programme modification on the scores in other disciplines, e.g. the influence of room acoustic treatment on the score for natural lighting. The score therefore facilitates the search for a compromise between different prevention requirements.

MECOLTRA is structured in the following way. The user describes first his design project using a "layout" module. Industrial process analysis then leads

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- Design
- Software

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him to define the different layout sectors (manufacturing, movement, unfavourable physical or chemical environments, manufacturing support, transport, etc.). The user then defines nearness or distance constraints, as well as material flows, for these sectors and composes an initial layout to which a score is attributed. The operator can then modify the sector arrangement to optimise the layout by monitoring the score which rates the displacements made.

The user then submits the project for analysis of the other modules (acoustic, ventilation and natural lighting) and, based on their respective scores, assesses the impact of successive corrective actions (dimensions and layout of external openings, installation of encasement, local exhaust, sector partitioning, etc.).

The thermal score represents the energy requirements for achieving thermal comfort. It depends on both the building, the natural lighting and the ventilation. It is therefore examined at the end of the cycle.

If the layout score has been excessively downgraded at the end of the first cycle, further iteration, taking into account the different corrective actions referred to above, may be envisaged. The user stops the iterations when he considers the solutions offered by the different modules are satisfactory.

## SCORE CALCULATION PRINCIPLES

### General layout score

This is a numerical indicator enabling assessment of the nearness and distance constraints for the different sectors associated with the process and its implementation under safe conditions [8].

### Acoustic score

Each sector is allocated a recommended ambient sound level (office or workshop) and an ambient sound level generated by activities performed in different sectors (quiet, noisy and very noisy). This rating of both recommended and generated ambient sound levels allows an elementary noise score to be attributed to each sector using a correspondence chart. The sum of these scores, weighted by the number of employees in the sector, gives an overall

acoustic score. This overall score can be reduced by installing light or heavy acoustic treatment. Hooding would correspond to light acoustic treatment, whatever the activity encased. On the other hand, resorting to special acoustic treatment processes (floating slab, overall encasement, special sealed room, etc.) for an activity would be considered as heavy acoustic treatment.

### Ventilation score

This score measures the impact of sector activities on ventilation requirements in all sectors defined by the layout module. A basic score, determined by simply evaluating the harmful effects induced by the activity (dangerousness of products used) is attributed to each sector. The project overall score is derived from the numbers of employees and the different sector basic scores. This overall score can be reduced by implementing a ventilation system: encasement and collection, induction collection, general ventilation.

### Thermal score

Calculation of the thermal score is based on a simplified thermal balance for the workroom. It corresponds to the heat loads and losses required to keep the room at the specified internal temperature.

### Natural lighting score

A lighting requirement for the activity exercised is associated with each sector. The calculation method involves determining the external opening areas to be implemented (on walls defined by the user) to check as closely as possible the lighting requirements for the whole year. The final score is representative of the minimum lighting requirements to be complied with.

#### REMARK

Scores were standardised against a 0 – 100 scale, with 100 as optimum, to be able to assess interactions between the different modules.

## SCORE CALCULATION METHOD

For the sake of conciseness, the score calculation method will only be illustrated by an example involving three of the five prevention areas considered by MECOLTRA, namely “layout”, “ventilation” and “thermal comfort”.

### Layout score

Laying out of an industrial project is performed in four stages.

**Stage 1:** Definition of entities or sectors to be laid out (workshops, workshop sections, machines, equipment, etc.).

**Stage 2:** Tabulation of nearness or distance relationships between sectors.

Nearness constraints are defined using the following five levels.

- NAI – Nearness absolutely necessary,
- NVI – Nearness very important,
- NI – Nearness important,
- DAI – Distance absolutely necessary,
- DVI – Distance very important.

**Stage 3:** Functional layout design.

The software provides a functional layout diagram independent of sector areas (cf. Figure 1).

**Stage 4:** Sector general layout design.

The software provides automatically a general layout design based on the areas, partial scores and sector areas (cf. Figure 4). This can subsequently be modified by the user through the graphic interface, the software indicating at each stage the corresponding change in the “layout” score (cf. Figures 2 and 3).

### Ventilation score

This is based on the ventilation systems implemented for preventing chemical risk and discomfort due to convective thermal sources.

### Chemical Risk

The hazard is assessed from the labels on products used in the process. Four classes of hazard have been retained.

- products whose labels feature no risk phrase (type 1),
- irritant products (type 2),
- toxic products (type 3),
- CMR-type products (carcinogenic, mutagenic, reprotoxic - type 4).

Type 4 products fall outside the MECOLTRA methodology application area, the regulations imposing a specific

prevention approach (articles R. 231-56 to R. 231-56-12 of the French employment code).

For each sector, a basic score is allocated depending on product dangerousness (type) and the number of employees effectively present. The workroom overall score is the sum of the scores for the different sectors comprising the workroom.

### Prevention measures

The score can then be improved by implementing prevention means based on ventilation and local exhaust.

Three types of general ventilation applicable to the whole workshop are foreseen, namely:

- simple hygienic air supply for employees present in the room (VG1),
- general mechanical air extraction from workshop (VG2),
- mechanical extraction with mechanical compensation system for extracted air (VG3).

For each sector, two types of local exhaust are foreseen, namely:

- induction-based exhaust with or without mechanical compensation of extracted air (CL1),
- encasement-based exhaust with or without mechanical compensation of extracted air (CL2).

General ventilation airflows or local exhausts can be adjusted by the user according to need: a 3-level scale for general ventilation and a 4-level scale for local exhausts. When airflow values are known, these can be also be entered into the software programme. Score improvement progresses when VG1, VG2, VG3, CL1 or CL2 systems are sweeping or when airflows are increased. Combined general ventilation and local exhaust is recommended.

### Convective Thermal Sources

Processes emitting heat by convection can cause thermal discomfort. Their prevention requirements can be met by general ventilation and local exhaust.

In MECOLTRA, these thermal sources are considered as type 2 pollutant sources.

Convective thermal sources and associated prevention means are included in ventilation score calculation.

### Thermal score

Thermal score calculation results from a simplified balance of thermal exchanges within the workshop. This score is optimum when the calorie inputs or outputs required to obtain the set-point temperature within the room are zero.

This balance takes into account thermal exchanges due to:

- air renewal,
- transmission through walls/partitions,
- internal load (process),
- solar inputs through glazed areas (summer score).

Input data for the building concern:

- wall and roof insulation (4 insulation levels),
- type of glazing in wall and rook openings (4 types),
- presence of screening on areas exposed to the sun.

Data for internal thermal sources are provided by information given when performing the ventilation score calculation. Source power can be defined according to a scale of five levels or can be provided by the user.

Air renewal-based exchanges are evaluated from ventilation flows implemented to reduce the chemical risk (ventilation module).

## APPLICATION EXAMPLE – RUBBER COMPONENT PRODUCTION WORKSHOP

### BRIEF DESCRIPTION OF PROJECT

A rubber component production workshop comprises the following sectors.

- Extrusion – sector grouping together continuous hot-air vulcanisation lines and a few extrusion lines for producing parts, which are subsequently autoclave-vulcanised.
- Autoclaving – sector in which autoclaves are installed for vulcanising products from the “Extrusion” sector.
- Salt immersion - sector in which processes involving continuous vulcanisation by immersion in molten salt baths are performed; these lines are little used.

■ Injection – sector including injected component production in injection moulding machines.

■ Storage – sector in which products are stored prior to shipment.

### Nearness constraints

Depending on the type of parts produced, the nearness constraints between production and storage are defined as follows.

- NAI: storage – autoclaving,
  - NVI: storage – injection,
  - NI: storage – salt immersion,
  - NI: salt immersion – extrusion.
- Salt immersion and extrusion sectors are run by the same operators, so an NI-type link between these two entities was retained.

■ NVI: extrusion – autoclaving.  
Products from the extrusion sector are then vulcanised in autoclaves, so an NVI-type link was established between these two sectors.

### Assessment of chemical product-related risks

All sectors, except storage, involve vulcanisation processes, which cause heat and pollutant emission.

Examination of vulcanisation processes and products allowed us to confirm that the potentially emitted chemical products are toxic (type 3), but are not classified CMR.

## LAYOUT

### Entry of data concerning process layout

- ▣ definition of sectors and associated areas;
- ▣ definition of nearness and distance constraints.

### Performing a functional layout using MECOLTRA

Figure 1

### Performing an initial layout (considering sector areas)

The score is 80%, the injection – storage nearness constraint is not satisfied (cf. Figure 2).

### Improvement of layout

Manual modification of sector layout allows all constraints to be satisfied and gives a score of 100% (cf. Figure 3).

FIGURE 1

Functional layout diagram given by software programme  
Links: red NAI; green NVI; blue NI

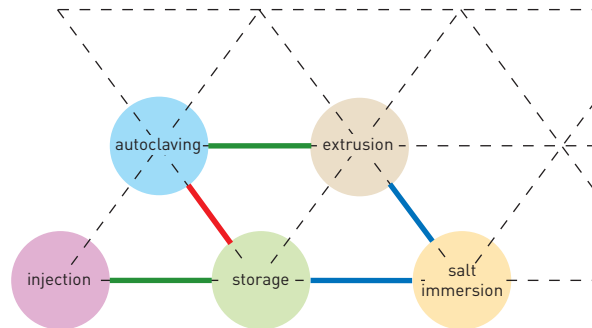


FIGURE 2

Initial layout – score 80%

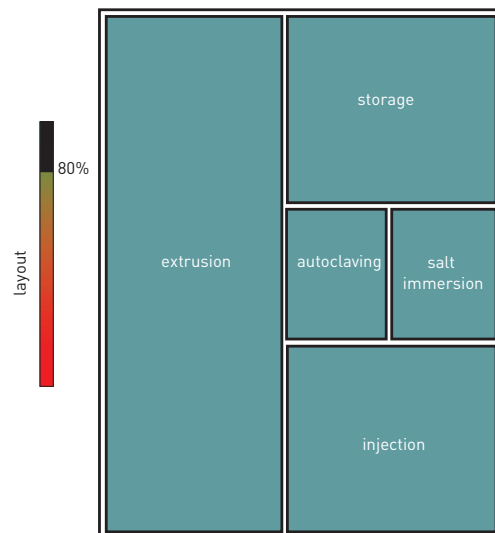
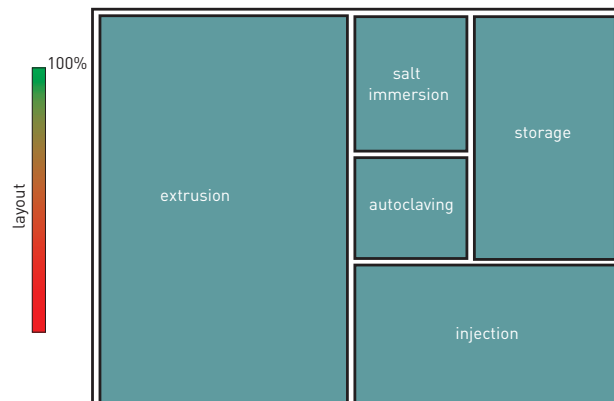


FIGURE 3

Correction of layout – score 100%



## VENTILATION - THERMAL COMFORT

### Entry of data concerning sources of danger (chemical pollutants) and discomfort (thermal)

Extrusion - type 3 pollutant and 460 kW thermal source.

Autoclaving - type 3 pollutant and 20 kW thermal source.

Salt immersion - type 3 pollutant and 60 kW thermal source.

Injection - type 3 pollutant and 45 kW thermal source.

Storage - products whose labels feature no risk phrase (type 1) and no thermal source.

### Ventilation and thermal scores without general ventilation and local exhaust

The general ventilation score is 0,3% and the sectors that penalise most appear in red; they correspond to areas in which the process creates pollutant and thermal sources. The thermal score is 82% (*cf. Figure 4*).

### Case 1 - Installation of general ventilation (level 3 flow)

The first planned prevention measure corresponds to installing high-level general ventilation. The general ventilation score has improved slightly (6,8%), but the thermal score has decreased because of the high flow of fresh air to be heated in winter (*cf. Figure 5*).

FIGURE 4

Ventilation and thermal score without prevention means

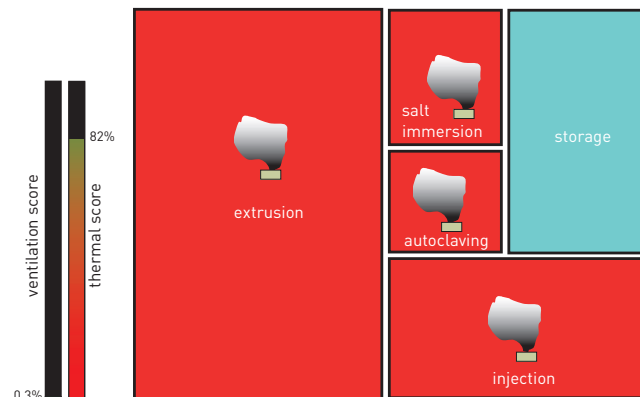
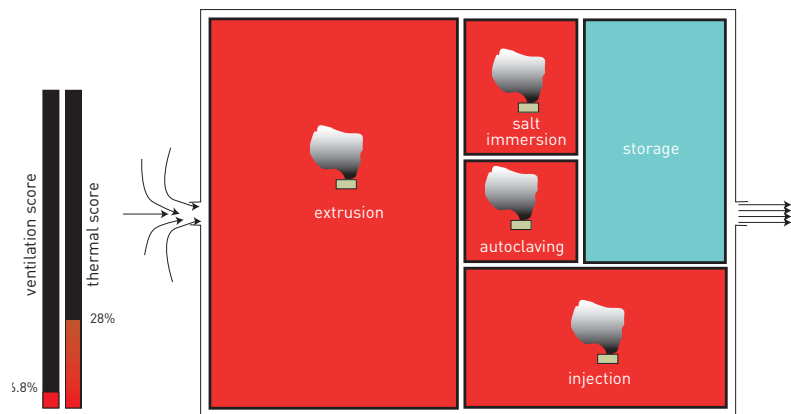


FIGURE 5

Case 1 – ventilation and thermal scores



**Case 2 – Level 1 general ventilation and level 1 inductive local exhaust at all sources**

The second proposal involves installing an inductive local exhaust near each thermal and pollutant source and reducing the general ventilation flow. Both general ventilation and local exhaust flows are level 1.

The ventilation score is now 77%. The software programme enables the operator to be effectively guided towards the prevention means most suited to the workshop configuration, namely an inductive local exhaust near each source combined with general ventilation designed to dilute residual pollution, ensure supply of compensation air and meet the operators' need for fresh air.

Improvement of the ventilation system efficiency allows the airflows to be reduced, resulting in a better thermal score, now 79% (cf. Figure 6).

**Case 3 – Same as case 2, but with installation of thermal insulation on upper floor walls**

The thermal score can be further improved by installing thermal insulation of the building envelope (level 1 insulation). This last modification allows us to reach a score of 88% (cf. Figure 7).

After each prevention means modification provided in the programme, MECOLTRA displays a spider's web diagram with five scores (cf. Figure 8).

This example has allowed us to illustrate software operation, programme interactive improvement and possible interaction between prevention means associated with different disciplines.

FIGURE 6

Case 2 - ventilation and thermal scores

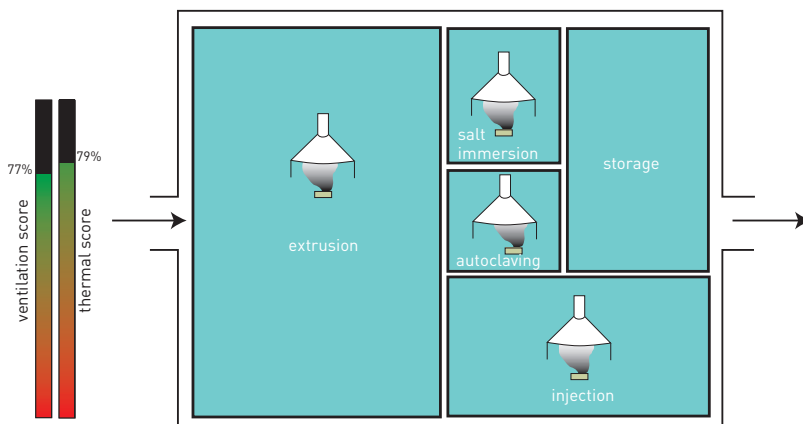


FIGURE 7

Case 3 - ventilation and thermal scores

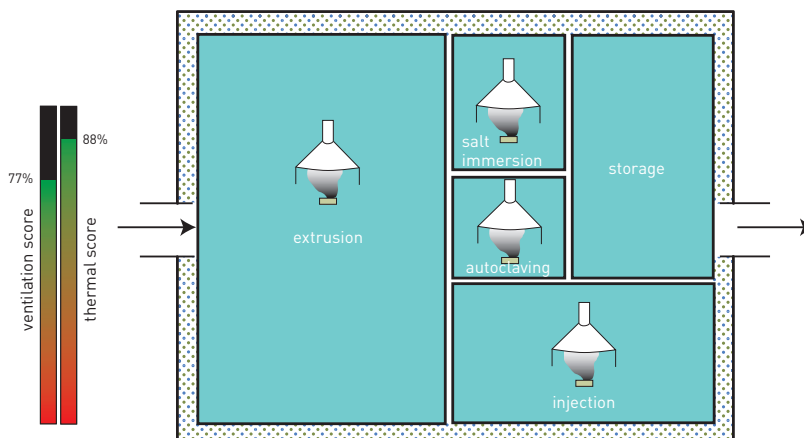
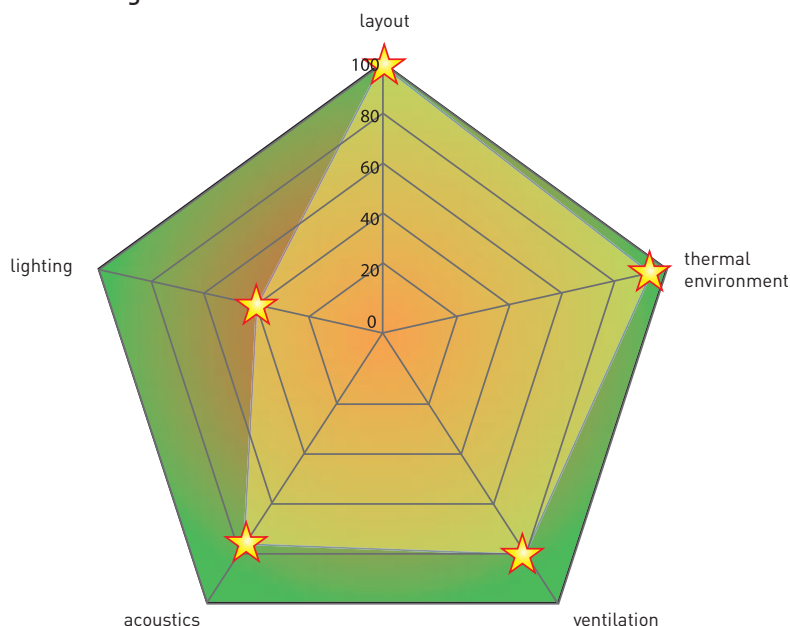


FIGURE 8

Spider's web diagram with five scores



## DISCUSSION

General methodology and the score calculation methods form the MECOLTRA software tool, currently being finalised. On completion, this software programme will be validated in the field in partnership with CRAM (French regional health insurance fund) prevention departments.

The main validation aims are to check whether:

- the score allows solutions complying with prevention principles to be identified,
- the data required to implement the methodology are accessible to the client,
- the information provided by the methodology can be directly used by the client or his assistant for drawing up the programme,
- the method implementation time is compatible with the time normally spent in drafting a programme effectively integrating prevention constraints.

A software valorisation and circulation policy will be defined at the end of this validation phase.

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