

# Innovative Building Design Criteria for the Confectionary Industry

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## ABSTRACT

This is primarily an analysis of the relationship between the activities needed to produce pastries and the environmental, organisational and technological characteristics of the workspace in several sample Italian factories. The study has highlighted their specific requirements and consequently, by means of a metapanning approach, has lead to definitions for the dimensional and relational characteristics necessary for designing new factories.

**Keywords:** Building quality, planning, pastries.

## 1. INTRODUCTION

Achieving ‘quality’ has always been one of the main goals of food processing factories even if this word has had different meanings over time. It was once defined by parameters only related to food safety guaranteed by rigid control of the chemical, physical and microbiological characteristics of the products, with complete disregard for the importance of the building as a part the processes of manufacture and storage.

Today the concept of ‘quality’ is much broader and the result of the interactive and synergistic combination of the components of manufacture, including the building where it takes place (Peri, 1994).

The UNI EN ISO 9000 and UNI EN ISO 14000 regulations outline how to create “management systems for quality” and “space management systems within manufacturing” which in turn establish the prerequisites for the correct management and planning of all the manufacturing processes, without neglecting any aspect necessary to ensure ‘quality’. The aim of these regulations is to improve production processes, safety, company image, market competitiveness, as well as product shelf life.

The regulations define a series of operational principles designed to manage the production processes, the planning and construction processes of the plant, and the supply and post-sales assistance.

Similar concepts are outlined in the 93/43/CEE Directive and from 1<sup>st</sup> January 2006, from the new European Community regulation on food hygiene, and in particular, regulation CE 852/2004, which lays out the need for “correct operational practices” throughout the production phases and is based on national and Community manuals. Most highlighted is the importance of the organization of the buildings and a build quality to ensure hygiene. The

building, therefore, plays an important part equal to any biochemical or mechanical processes (Clerici et al., 2005).

In fact, it is known that buildings influence many factors in production such as flexibility of the system, production costs and in particular maintaining appropriate microclimatic conditions (Cascone et al., 1995; Satake et al., 2003).

The abovementioned themes regard the whole of the food industry. So, even the oven pastries industry should follow suit and aim for quality building manufacture.

In the industrialised countries, and in Italy in particular, there has been progressive growth since the '60s in oven-made products – of diverse qualities and flavours, captivating in their shape and packaging – providing a huge variety of foods on the market sometimes 'continuously' and sometimes in response to competition (ISMEA, 1996, 2001, 2002).

Even in those areas where there is still a strong tradition of 'home-made pastries' the new requirements of consumption, which reflect a change in daily lifestyle (the exponential rise in the domestic and extra-domestic consumption of snacks, moulded sponges, biscuits, crackers etc. at breakfast or in work breaks, the call for ready-made sweet products to save time) have brought about a plethora of reliable highly industrialised products.

Intensive industrial production inevitably overrides traditional production and gives rise to the loss of those techniques and procedures that cannot produce large quantities of product. In mass industrial manufacture, while striving for constant production improvement, there is an inevitable rise in hygiene risks with its consequent impact on 'food safety' (think only of the difficulty of monitoring infestation in a factory which covers hundreds of square metres).

Today, Italian manufacturers of oven confectionery generally use production buildings which, because of the high speed of technological and production innovation, are subject to continuous modification. This impairs the functionality of the building and compromises product quality.

Instead, factories should comply with the specific needs of manufacture, not only as they relate to current production cycles but, above all, to the possible modifications required by production upgrades.

The continual innovation in mechanisation and plant requires great flexibility, and remarkable factory adaptability to allow the manufacturer to keep up with changes in the field (De Montis and Tomaselli, 1999).

Therefore, it is useful to define design criteria that take into account process specificity in order to build factories which guarantee necessary 'performance quality'.

## 2. MATERIALS AND METHODS

To define the *Build Regulations* for planning the buildings that manufacture sweet oven products it is necessary to take into account the specific requirements of the production processes and the different characteristics of the products. So, research was carried out at several of the most nationally important manufacturers in this sector.

The research used questionnaires to acquire the following data:

- *general company information*: location, type of manufactured product, methods of supply and delivery of raw materials and support materials, production capacity, methods of marketing and distributing the finished product;
- *production cycle details*: production process phases and connected activities, the flow and intervention of employees, characteristics of machinery, tools and technical plant;
- *building details*: the characteristics of structural systems, flooring, vertical partitioning, ceilings and fixtures; the environmental conditions of production (temperature, hygiene, lighting, safety); the reciprocal disposition of space and its dimensions.

The questionnaires (non self-administered) included detailed plans and diagrams of product flow in relation to the phases of manufacture.

This work uses the metapanning approach, tried and tested in other studies, which has provided some interesting parameters for planning various manufacturing premises in the agriculture and food industries (Fichera et al., 1994; Chiappini et al., 1994; Fichera et al., 1995; Failla et al., 2001; Tomaselli et al., 2004)). It has been observed that the organisation and quality of environmental space is directly linked to product type and its correlated activities, and by means of a metapanning study, it is possible to provide manual-type support for the various types of activity.

Build metapanning defines useful regulations for the creation of buildings with functions appropriate to the complex requirements of consumers and producers. Thus, it is possible to achieve “build quality” as a *measure of the degree of response of build performance to concept, planning, production and management requirements* (Maggi, 1994).

The methodology proposes new standardised layouts as templates for the design of new confectionery buildings. The process is based on the division of the building system into its environmental, typological and technological sub-systems, defining their characteristics in order to meet the needs of users, in relation to their activities and specific organisational conditions. The environmental and typological sub-systems are determined by means of an analytical process of the aggregation of spaces and functions, articulated by the following phases (fig. 1):

- recognition of *basic employee activities* and of *machine and equipment function*;
- definition of environmental, functional and dimensional needs;
- aggregation of the *basic employee activities* and *machine and equipment function* into *aggregate activities*, intended as a collection of many compatible actions performed in a minimal space, defined as a *spatial unit*;
- definition of *environmental unit*, intended as those spaces in which the activities performed are spatially, temporally and functionally compatible, according to the group utilising the space and according to the models of social behaviour of the users;
- aggregation of *environmental units* defines the layout of the *functional areas*, for confectionery industry building.

Generally, the confectionery industry is organised into the following six functional areas: production, waste management, storage, maintenance of machinery, housing and offices, infrastructures. In this work the definition of layouts is limited to functional production areas.

Referring to a precise industry-business model it is possible to determine the frequency of the moves of the users and the organisational and functional characteristics of the environmental units, so as to stabilise the aggregate criteria that generate the possible layout configurations.

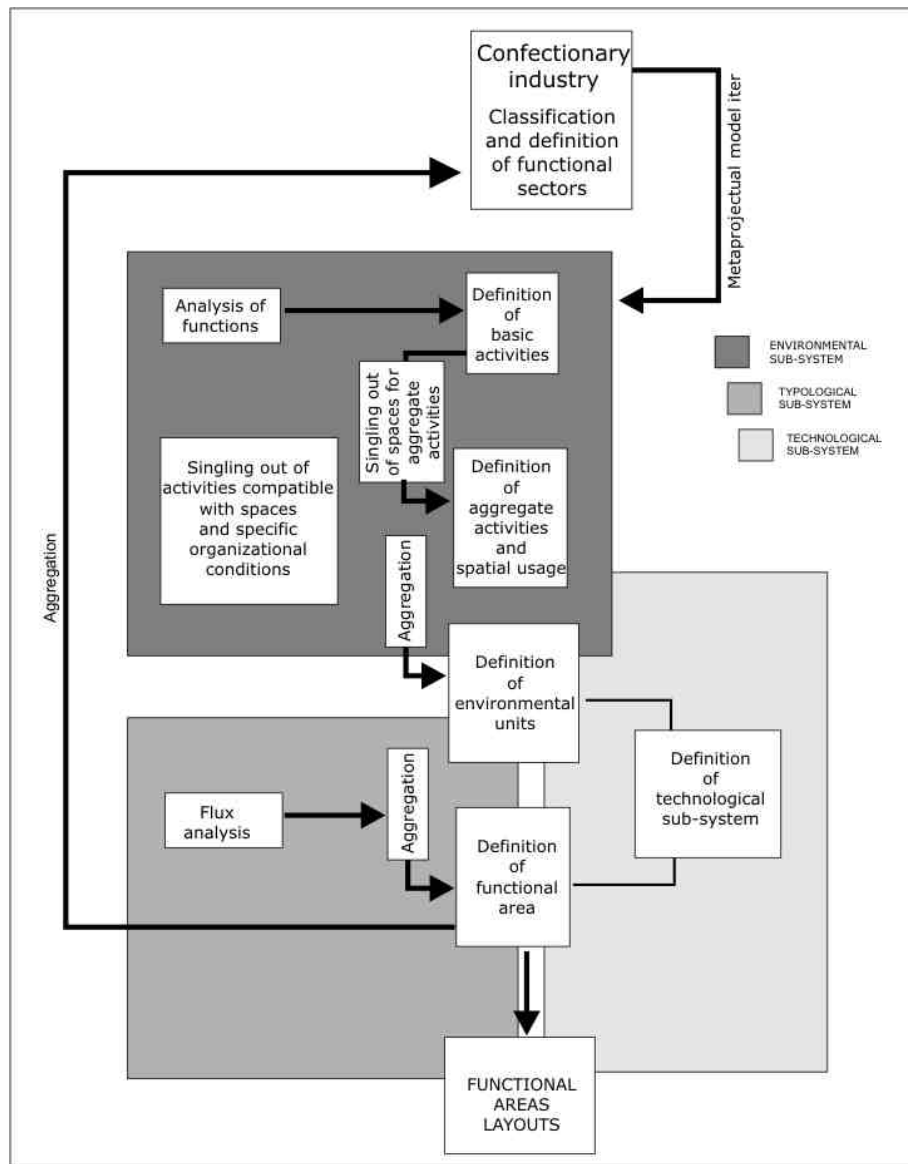


Figure 1. The metaprojectual process

### 3. RESULTS AND DISCUSSION

#### 3.1 Analysis of Current Plant and Identification of Production Requirements

The manufacturing, organization and management, as well as the structural characteristics of thirteen factories which represent the current field in Italy were analysed to represent the regions with the highest concentration of industrial or semi-industrial manufacture of oven confectionary (Veneto, Trentino, Piemonte, Lazio, Campania, Puglia, Sicily). These factories were chosen after consultation with members of AITA (The Italian Association of Food Technology).

For the most part, the factories are made of prefabricated units, which differ in surface area and volume according to function in manufacture or service. These differences are influenced by various factors, but mainly by the type of product, the number of production lines and the level of automation used, the number of employees, the flow management model, and the efficiency and specialisation level.

Generally speaking, in relation to these conditions it is possible to classify the factories as follows:

- 1) *industrial*, with a high level of automation in all production phases, located mainly in northern Italy;
- 2) *semi-industrial*, with some technologically advanced production phases and some manual ones, located throughout Italy;
- 3) *handmade*, being labour-intensive in all the manufacturing phases, also present throughout Italy.

Moreover, it is also possible to classify them according to production technology:

- 1) *confectionery firms using natural fermentation agents*, specialised in the production of “special occasion” products such as Pandoro (Veronese Christmas cake), Panettone (Milanese Christmas cake) and Colomba (Italian Easter cake), or ‘all-year-round’ products such as crackers and croissants;
- 2) *confectionery firms using chemical fermentation agents*, which produce ‘all-year-round’ products, both soft and dry such as sponge cake and biscuits;
- 3) *confectionery firms using both kinds of agents*, natural and chemical, which produce ‘all-year-round’ products and ‘special occasion’ products.

In figure 2, most of the general company data is reported, whereas for the three factory types, in figure 3, are diagrammatic plans with their relative flows.

In figure 4, depending on the type of fermentation, are manufacture process diagrams of various oven-made products.

*Natural fermentation* is obtained by adding ‘the mother’ yeast to the dough, an acidified portion left from the dough of the previous phase. *Pandoro*, *Panettone*, croissants and sweet bread are made by this method.

*Chemical fermentation* is obtained by using chemicals (baking soda or ammonium bicarbonate) to make both soft (sponge cakes) and dry products (biscuits).

For all products the manufacturing process comprises activities ranging from receiving raw materials to obtaining end products. In particular it is possible to define the following phases:

- 1) supply;
- 2) stockpiling raw material;
- 3) automatic or manual weighing of ingredients;
- 4) manufacture and wrapping;
- 5) stockpiling of end product.

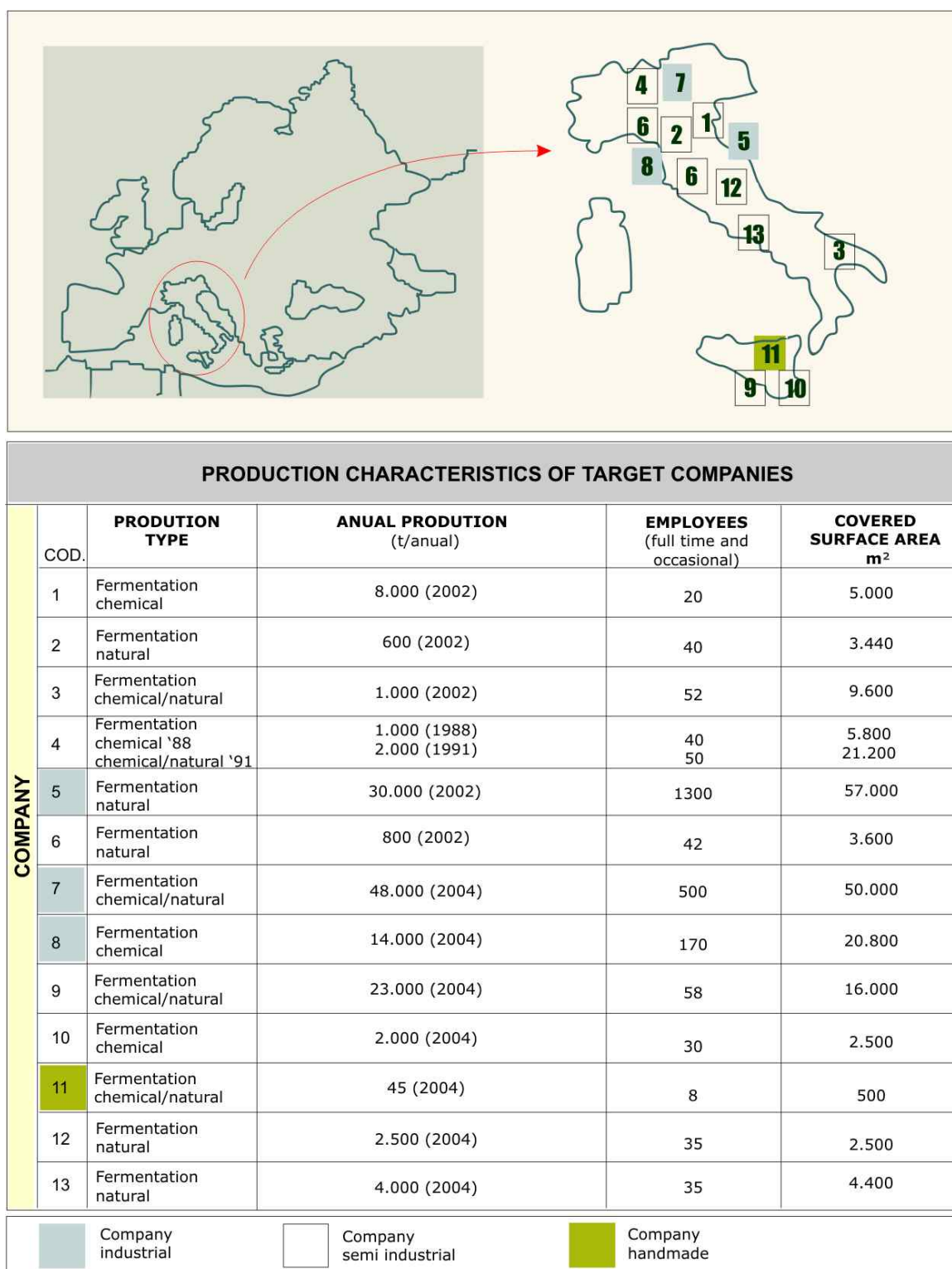


Figure 2. Location & production characteristics of target companies

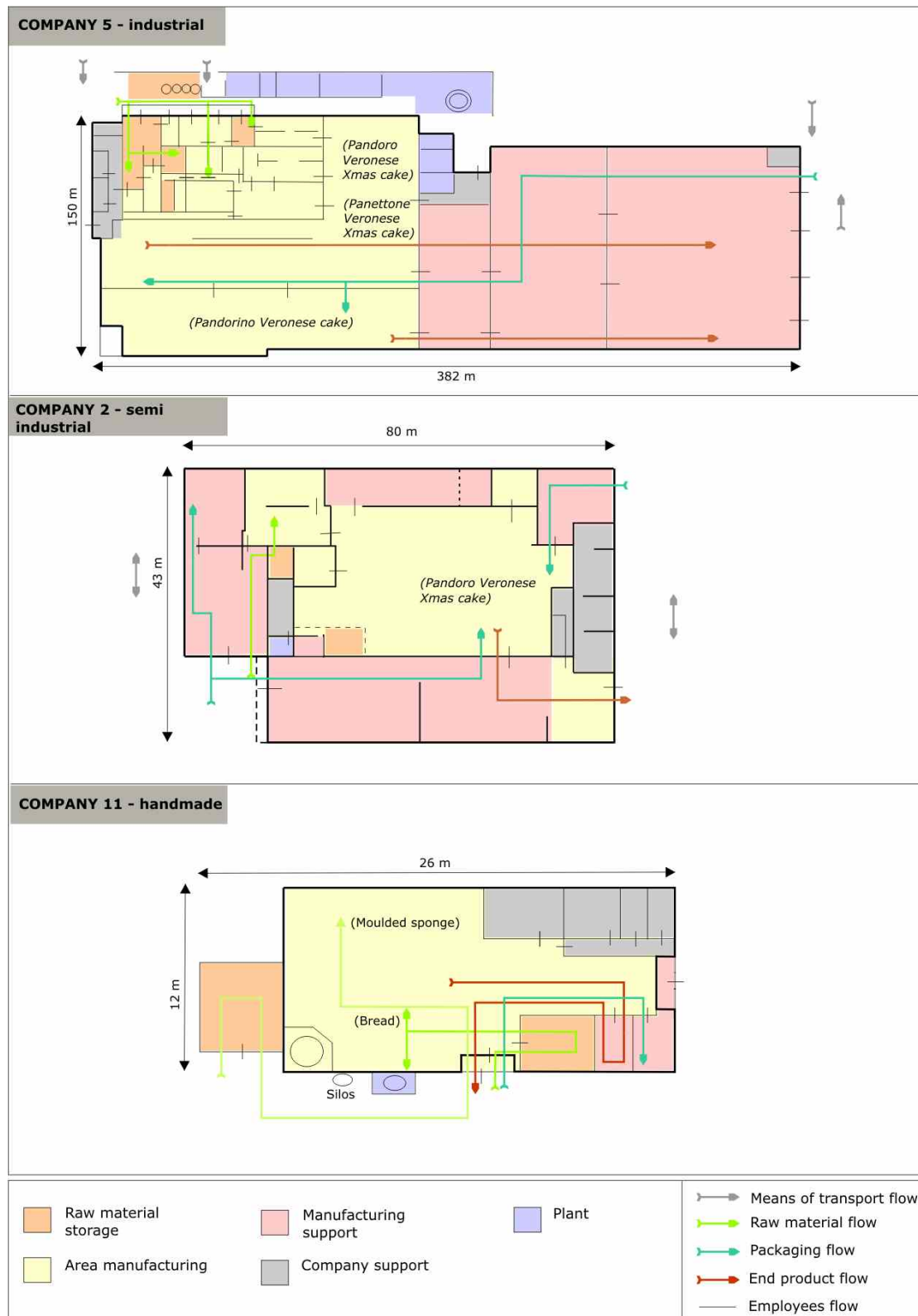


Figure 3. Diagrammatic plans of building types

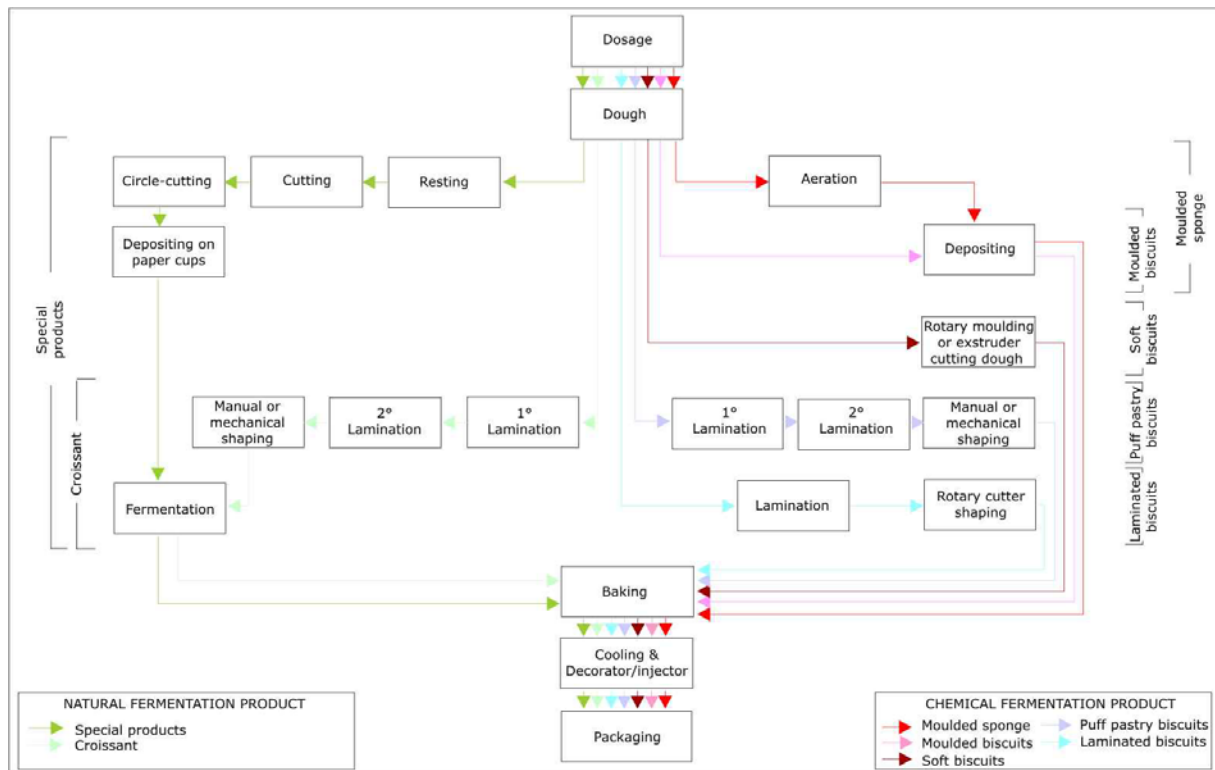


Figure 4. Manufacture flow of the main production lines

Manufacturing phases 1), 2), 3) and 5) are similar for all oven confectioneries, whereas phase 4) represents the patented product.

Furthermore, the data from each manufacturer has been organised and reported using matrices similar to those in figures 5 and 6. These formulations were then summarised.

*Natural leavening products* are made in-house on an industrial or more likely semi-industrial scale.

In this sample, an industrial company manufactures 30,000 tons/year (t/yr) of confectionery, covers an industrial space of 60,000 m<sup>2</sup> and employs 1,300. The semi-industrials produce 2-3,000 t/yr, cover 4,500 m<sup>2</sup> and employ 40.

Generally in-house space is not always used appropriately. Often production phases are not carried out in fully functional premises and/or in inadequate hygienic and environmental conditions.

Since these products contain high water levels they are at risk of microbiological contamination. The risk increases particularly after baking during cooling, such as to be critical for the HACCP (Hazard Analysis and Critical Control Point) and the improvement of security and shelf-life. In the majority of manufacturers, this phase is carried out in the same locale as the baking, hardly the best environment and temperature.

With the exception of some, the tendency is not to separate the production areas, so that packing, boxing, box traffic and transport traffic take place in the same production areas increasing microbiological risk.



Convergence of employee activity, production plants and observed manufacturing areas		Machine and equipment		Activities employees		Presence employees		Presence product	
Company n°9 (2004)									
<b>Manufacturing area</b>									
<b>E</b>	<b>Outside</b>								
ri	delivery								
sp	shipping								
<b>D</b>	<b>Storage</b>								
ca	palleting area	26, 28,	a, b, f						
in	wrapper area	26, 28	a, g						
Mp	raw material (f, z, g, c)	26, 28	a, f						
		26, 28	a, b						
<b>D</b>	<b>Storage</b>								
pf	product end	26, 28	a, g						
<b>D</b>	<b>Refrigerated storage</b>								
Md	perishable material (u, s, m)	3, 7, 9	e, d, b, o						
<b>D</b>	<b>Refrigerated storage</b>								
Md	perishable material (b, m)	26, 9	e, d, b, o						
<b>D</b>	<b>Refrigerated storage</b>								
Md	perishable material (a, l)	7, 9	e, d, b, o						
<b>D</b>	<b>Refrigerated storage</b>								
Md	perishable material (u)	3, 7, 9	e, d, b, o						
<b>D</b>	<b>Refrigerated storage</b>								
Md	material defrosted (u, b)	3, 7, 9	e, d, b, o						
<b>SL</b>	<b>Manufacturing area (tornocini)</b>								
Mp	raw material (m)	26, 28	a, g						
lm	dough (almond)	7, 10, 11	c, h						
cn	packaging	23	m, n, f						
<b>SL</b>	<b>Manufacturing</b>								
lm	dough	7, 10, 11, 12	b, c, e, h						
<b>SL</b>	<b>Manufacturing</b>								
rp	resting	11	c, h						
<b>SL</b>	<b>Manufacturing</b>								
lm	dough (croissant)	7, 9, 10, 11	b, c, e, h						
<b>SL</b>	<b>Manufacturing</b>								
lm	shaping (croissant)	21.1, 21.2, 9	c, h						
<b>C</b>	<b>Room</b>								
lv	fermentation	9	d, o						
<b>SL</b>	<b>Manufacturing</b>								
Sz	shaping (Veronese Xmas cake)	22.1, 22.2, 22.3, 9	h, d, i						
Mp	raw material (z, f)	7, 26	b, e, d						
Cg	sponge shaping	11,	c						
ct	baking	20.2, 20.3, 22.4	o						
Rf	cooling	9, 20.3, 21.4, 22.5	d, o						
Cn	packaging	23	m, n, f						
<b>SL</b>	<b>Manufacturing (Xmas cake)</b>								
cn	packaging	23	l, m, n						
<b>L</b>	<b>Laboratory</b>								
<b>U</b>	<b>Offices</b>								
		29, 7	i, o						

■ Unsuitable work temperatures for employees

C - continuous; S - occasional; G - raw material L - production; N - packaging product;

f - flour; z - sugar; u - eggs; g - glucose; b - butter; m - margarine; c - chocolate; l - milk; o - oil.

Figure 5. Example (a) of analysis form for convergence of employee activity, production plants and observed manufacturing areas referring to one manufacturer (out of 13)

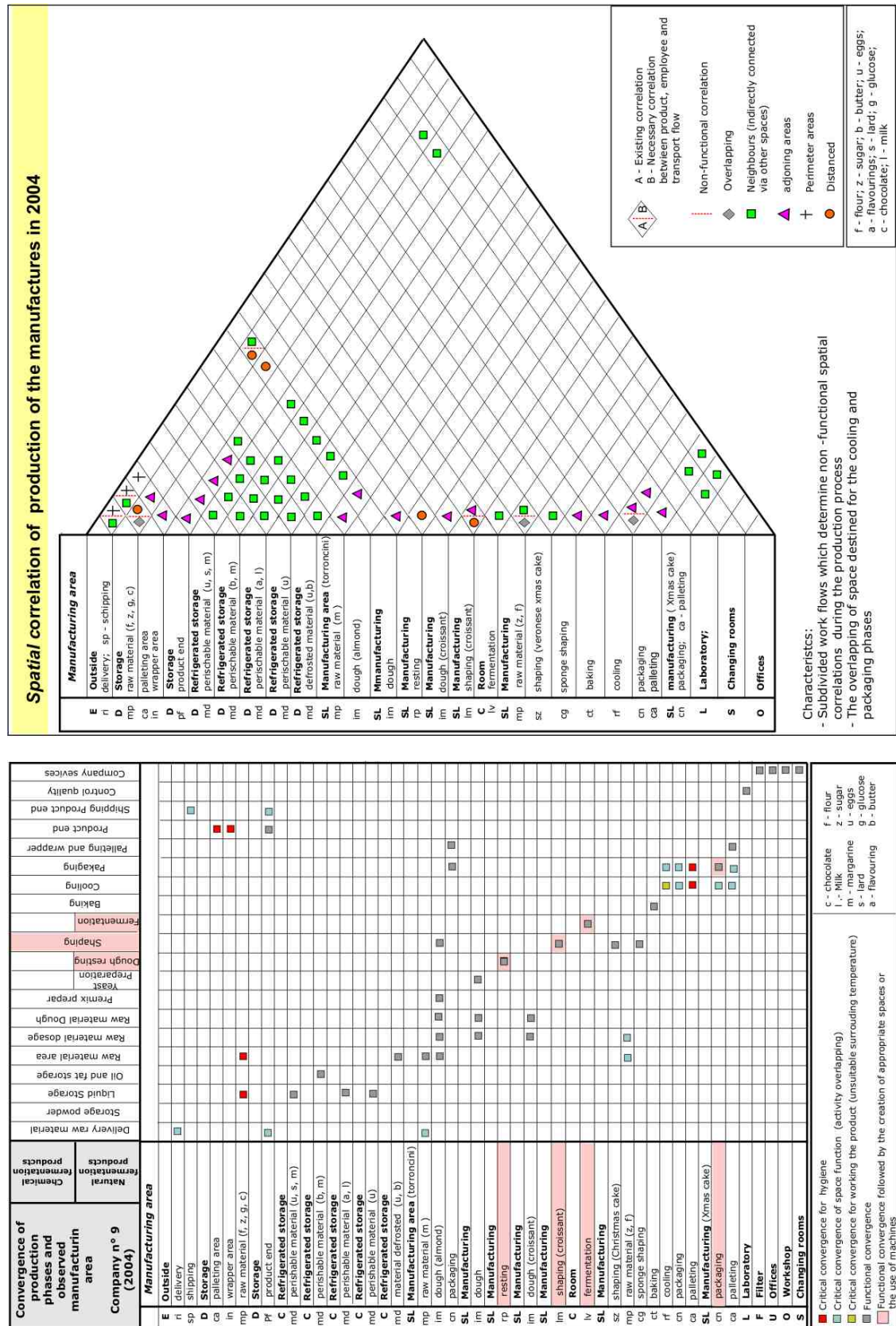


Figure 6. Example (b) of analysis form for convergence of production phases and observed manufacturing areas referring to one manufacturer (out of 13)

Even the finish of the locales for the most part, the floor and wall coverings (the lack of tiles and anti-mildew treatment), are not up to hygiene levels. Furthermore, the poor maintenance of air filters only increases possible contamination.

Even production, worker and transport flow is often impractical.

*The chemical leavening products* in the sample are similarly semi-industrially or industrially produced. The former produce 3,600 t/yr, cover 4,500 m<sup>2</sup> and employ 35; the latter 13 – 14,000 t/yr, 21,000 m<sup>2</sup> and 170 respectively.

Less complex production technology requires fewer diversely equipped locales depending on the phase of production. The larger locales house the linear production lines often preceded by the kneading machines. Often, there is no kneading room since that phase does not require strictly controlled thermohygrometric values.

The organisation of space is not always rational: sometimes the lack of space obliges often incompatible multiple use; in other cases the availability of sufficient space does not benefit the efficiency of the plant because they are used chaotically. Coordinating the production phases becomes difficult generating disorder and time-wasting.

The building characteristics denote above all technical-constructional absences.

*Natural and chemical leavening* is carried out industrially in the sample with average production of about 48,000 t/yr, occupying 50,000 m<sup>2</sup> and employing 500. This production technology is furthermore used by some semi-industrial companies which on average produce about 8,600 t/yr, cover 15,500 m<sup>2</sup> and employ 53.

These companies are more complex because of multiple production lines with diverse organisational and microclimatic characteristics which have varying needs according to what they produce.

Thus, most of the sample companies highlight notable fragmentation of the space meant for collateral operations or for the initial production phases. However, their work space is more compact, packed with machines, raw materials and tools for the production lines making it difficult for the employees.

Furthermore, the movement of raw materials and carton from delivery to the workspace is particularly tortuous.

These problems also distance some production phases.

Even these companies suffer from poor ventilation and air purification, above all during the cooling phase.

In most cases, the companies have modified and adapted their buildings as well as continually readapting how they manage space by building without correct planning.

### **3.2 Planning Invariables and Industry Business-model**

The study of these firms identifies some ‘*invariables*’ and an ‘*industry business-model*’ which can act as references for the development of metapanning aimed at a definition of specific *Build Regulations*. The invariables are:

- physical subdivision of the work spaces in order to differentiate their protection levels and their thermo-hygrometric parameters, according to the various requirements of the product during the phases of manufacture;
- construction of rooms for the storage of perishable and imperishable raw materials with controlled thermo-hygrometric parameters;
- addition of specially equipped spaces for those phases requiring high worker skill levels, or micro-climatic parameters and carefully controlled hygiene levels;
- construction of work areas with straight parallel mechanical production lines;
- location of packing stations away from work areas;
- allowance for properly protected product parking areas;
- construction of end product storage areas according to stay time and equipped with planned handling systems.
- distinguish and highlight the mechanical handling areas to guarantee appropriate safety levels and design solutions and technical devices to maintain environmental hygiene;
- working out of layouts according to EU and national norms and the requirements of HACCP.

The company model has the following characteristics:

- theoretical production capacity (25 m oven) of 800 kg/h (about 2000t/yr).
- natural and chemical confectionery leavening on separate production lines.
- adoption of techniques that require innovative machinery on one or more production lines;
- non-specialised work-force.

### 3.3 Defining the Build Regulations

#### 3.3.1 Environmental Characteristics

The ‘planning invariables’ and the ‘manufacturer model’ were metaplanned and summarised as follows. The requisites of 16 people-based activities and 23 machine and equipment functions were defined. Together, 31 aggregated activities and their associated spaces (Space Usage) were defined (fig 7).

The analysis of the companies and the manufacturing process in each identifies the needs (dimensional, environmental, logistical, security, defence, control and others) in construction terms, diversifying space into departments or Units (U). The design plan of a department (*Unit*) derives from aggregating Space Usage (SU), according to employee roles, the deployment of vehicles, the product itself and any specifically necessary activities (aggregated activities) (Maggi, 1994).

Figure 8 shows the main characteristics of the *Unit* (U) which constitutes the main production centre. Among these, some are common to both cycles (chemical and natural rising), and are carried out singularly or in associated lines; others are only indispensable in those companies

which produce natural rising confectionery. As a result, all the production space is summarised, while Figures 9, 10, 11, 12 & 13 show the Unit layouts.

<b>SPACE USAGE</b> <b>Blending ingredients</b>  <b>AGGREGATE ACTIVITIES</b> <b>Forming the dough</b>	<table border="1"> <tr> <td rowspan="4"><b>Chemical fermentation products</b></td> <td>Laminated</td> <td><input type="radio"/></td> <td rowspan="6"><b>CODE</b>  <b>7</b></td> </tr> <tr> <td>Soft biscuit</td> <td><input type="radio"/></td> </tr> <tr> <td>Moulded biscuit</td> <td><input type="radio"/></td> </tr> <tr> <td>Moulded sponge</td> <td><input type="radio"/></td> </tr> <tr> <td rowspan="2"><b>Natural fermentation products</b></td> <td>Puff pastry</td> <td><input type="radio"/></td> </tr> <tr> <td>Special occasion</td> <td><input type="radio"/></td> </tr> </table>	<b>Chemical fermentation products</b>	Laminated	<input type="radio"/>	<b>CODE</b>  <b>7</b>	Soft biscuit	<input type="radio"/>	Moulded biscuit	<input type="radio"/>	Moulded sponge	<input type="radio"/>	<b>Natural fermentation products</b>	Puff pastry	<input type="radio"/>	Special occasion	<input type="radio"/>
<b>Chemical fermentation products</b>	Laminated		<input type="radio"/>	<b>CODE</b>  <b>7</b>												
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	Moulded biscuit		<input type="radio"/>													
	Moulded sponge	<input type="radio"/>														
<b>Natural fermentation products</b>	Puff pastry	<input type="radio"/>														
	Special occasion	<input type="radio"/>														
<b>DESCRIPTION</b>  Dedicated space for dough-makers, production equipment and employees. Ingredients are piped directly from silos, smaller quantities being hand-fed. Once measured, the ingredients in the dough-maker are mixed to obtain the required dough. Leavened products require various stages of stasis.	<table border="1"> <tr> <td data-bbox="895 524 1078 848"> <b>Basic employee activity</b>   3 - vat moving  5 - ingredient and material moving  8 - work to hand and with equipment  15 - servicing </td> <td data-bbox="1086 524 1278 848"> <b>Machine and equipment functions</b>   1 - liquids and solids piping  6 - dough-making  8 - liquids and solids transports </td> </tr> </table>	<b>Basic employee activity</b>  3 - vat moving 5 - ingredient and material moving 8 - work to hand and with equipment 15 - servicing	<b>Machine and equipment functions</b>  1 - liquids and solids piping 6 - dough-making 8 - liquids and solids transports													
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STANDARD MEASUREMENTS									
Dough-maker vat sizes							Space widths for servicing and parking		Aisle widths
	Vat capacity l	Weight kg	Power kw	H Height m	W Width m	L Length m	E	Ao	Employee aisle 90 - 120 cm
<b>Fixed C vat</b>	100	350-470	2-3,5	1,10-1,80*	0,60-1,10	0,95-1,50	60 cm	Ac	Equipment aisle 160 cm
	200	450-700	3-6						
	300	530-950	6-9						
<b>Inclined vat</b>	200	1800	4,4-5,5	1,40- 2	0,80-1,20	1,10-2,00			
	500	4000	14-22						
<b>Extractable vat</b>	120-300	920-2200	4,5-18	2,50-3,40	0,80 -1,20	1,35-1,80			
	400-800	3150-4300	26-59	3,80- 4,65	1,60-2,00	1,90-2,30			

Dough-maker with extractable vat

Planimetric diagram

Note: - Employee number is proportional to production  
- \* protective grill

Figure 7. Example of a metadesign form for ‘Space Usage’



Code	UNIT	SPACE USAGE	DIMENSIONS REQUIRED	Code	UNIT	SPACE USAGE	DIMENSIONS REQUIRED
1	<b>Powder Storage</b>	1 - Transit route 3 - Raw material storage	Size dictated by silo capacity, machine and employee transit	10	<b>Manufacturing Unit (N)</b>	1 - Transit route 2 - Sinks 9 - Indirect loading of production line 12 - Puff pastry shaping 13 - Special occasion dough shaping 18 - Product fermentation & baking 17 - Product cooling 20 - Tunnel cooling of product 31 - Manufacture support material storage	Size dictated by machines, equipment, the quantities of product and production support materials, sanitary equipment, and the transit of employees and equipment (trolleys, tanks, pans)
2	<b>Perishable Raw Material Storage</b>	1 - Transit route 4 - Raw material parking	Size dictated by product quantity and transit of employees and walkie pallet truck	11	<b>Cooling Unit (N)</b>	1 - Transit route 21 - Trolley cooling 22 - Airborne cooling	Size dictated by equipment (trolleys or transporters) and the transit of employees and trolleys
3	<b>Raw Material Storage</b>	1 - Transit route 4 - Raw material parking	Size dictated by product quantity, packaging and transit of employees and walkie pallet truck	12	<b>Primary Packaging (N)</b>	1 - Transit route 24 - Manual wrapping 25 - Mechanical packaging 31 - Manufacture support material storage	Size dictated by machines, equipment, the quantities of product and production support materials, and the transit of employees and equipment (trolleys)
4	<b>Powder Dosage</b>	1 - Transit route 2 - Sinks 4 - Raw material parking 5 - Dosing and preparation of raw materials 30 - Wash additive storage 31 - Manufacture support material storage	Size dictated by machines, equipment, the quantities of product and production support materials, sanitary equipment, and the transit of employees and equipment (trolleys and buckets)	13	<b>Secondary Packaging</b>	1 - Transit route 26 - Product boxing 28 - Palleting area 31 - Manufacture support material storage	Size dictated by packaging machines (transport units), the transit of walkie pallet truck and the presence of employees
5	<b>Dosage and Premix preparation</b>	1 - Transit route 2 - Sinks 4 - Raw material parking 5 - Dosing and preparation of raw materials 6 - Working with the ingredients 30 - Wash additive storage 31 - Manufacture support material storage	Size dictated by machines, equipment, the quantities of product and production support materials, sanitary equipment, and the transit of employees and equipment (trolleys, buckets & tanks)	8	<b>Equipment Cleaning</b>	1 - Transit route 30 - Wash additive storage 31 - Manufacture support material storage	Size dictated by equipment (pans, tanks, moulds etc) production support materials, and the transit of employees
6	<b>Dough</b>	1 - Transit route 2 - Sinks 7 - Blending ingredients 30 - Wash additive storage 31 - Manufacture support material storage	Size dictated by machines, equipment, the quantities of product and production support materials, sanitary equipment, and the transit of employees and equipment (tanks or trolleys)	15	<b>Cardboard Storage Unit</b>	1 - Transit route 28 - Palleting area	Size dictated by packaging the transit of walkie pallet truck or fork lift trucks and employees
7	<b>Resting (N)</b>	1 - Transit route 8 - Dough resting	Size dictated by encumbrance and by the transit of employees and equipment (tanks or trolleys)	16	<b>Wrapper Storage Unit</b>	29 - Wrapper storage 31 - Manufacture support material storage	Size dictated by packaging production support materials, and the transit of walkie pallet truck and employees
9	<b>Fermentation Unit (N)</b>	1 - Transit route 14 - Product fermentation	Size dictated by encumbrance and by the transit of employees and equipment (tanks or trolleys)	17	<b>Equipment Store</b>	1 - Transit route 31 - Manufacture support material storage	Size dictated by equipment, production support materials, and the transit of employees
10	<b>Manufacturing Unit (C)</b>	1 - Transit route 2 - Sinks 9 - Indirect loading of production line 10 - Direct loading of production line (C4) 11 - Cakes sponge shaping 15 - Laminated biscuit shaping 16 - Soft biscuit shaping 17 - Product baking 19 - Dry product cooling 23 - Airborne cooling 24 - Dry product lining up 25 - Mechanical packaging 31 - Manufacture support material storage	Size dictated by machines, equipment, the quantities of product and production support materials, sanitary equipment, and the transit of employees and equipment (trolleys, tanks, pans)	18	<b>End Product Storage Unit</b>	1 - Transit route 27 - End product area	Size dictated by the encumbrance of pallets, the company's production capacity and commercialisation of the end product
				19	<b>Laboratory</b>		Transverse and longitudinal dimensions beneficial for the transit of walkie pallet truck, equipment, and employees
				14	<b>Filter Unit</b>		
				20	<b>Offices</b>		
				21	<b>Changing rooms</b>		
				22	<b>Canteen</b>		
				23	<b>Workshop</b>		
				24	<b>Electricity centre</b>		
				25	<b>Heating</b>		
				26	<b>Water storage &amp; treatment</b>		
				27	<b>Waste water management</b>		
C - chemical fermentation; N - natural fermentation;			Unit with characteristics similar to those in other research papers				

Figure 8. Summary of Unit Characteristics

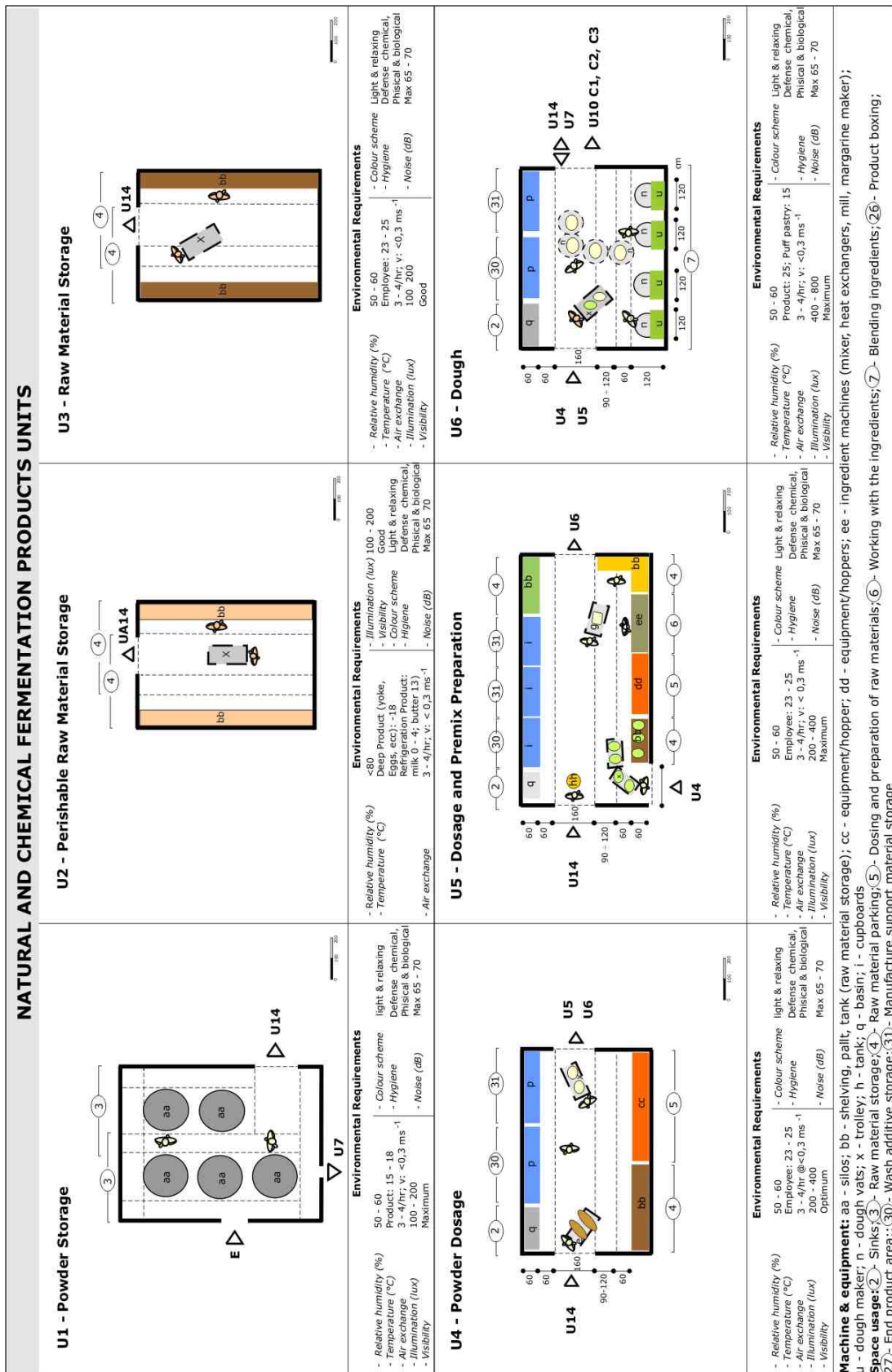


Figure 9. Organizational Layouts of the manufacturing areas for chemical and natural fermentation products

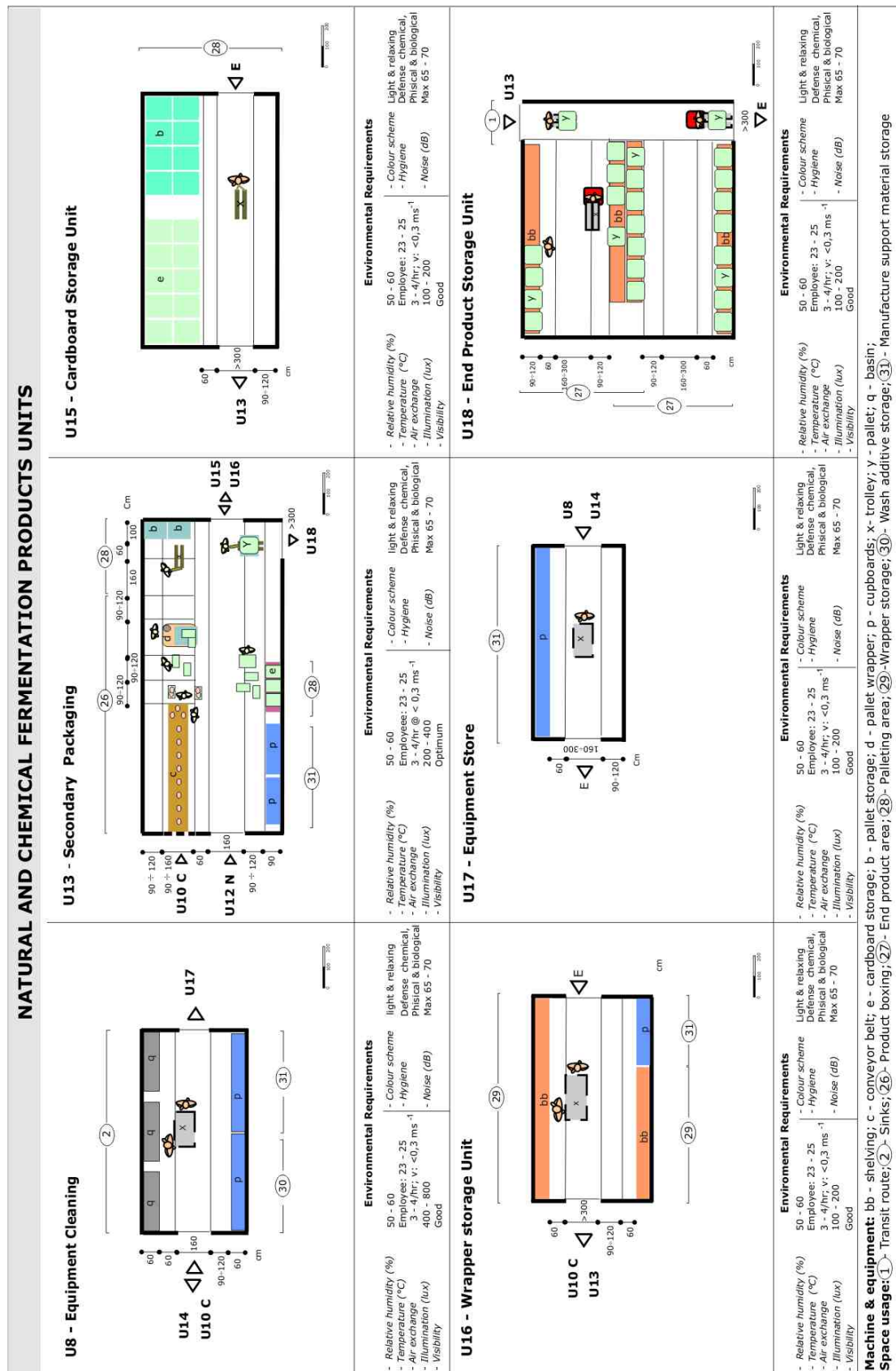


Figure 10. Organizational Layouts of the manufacturing areas for chemical and natural fermentation products



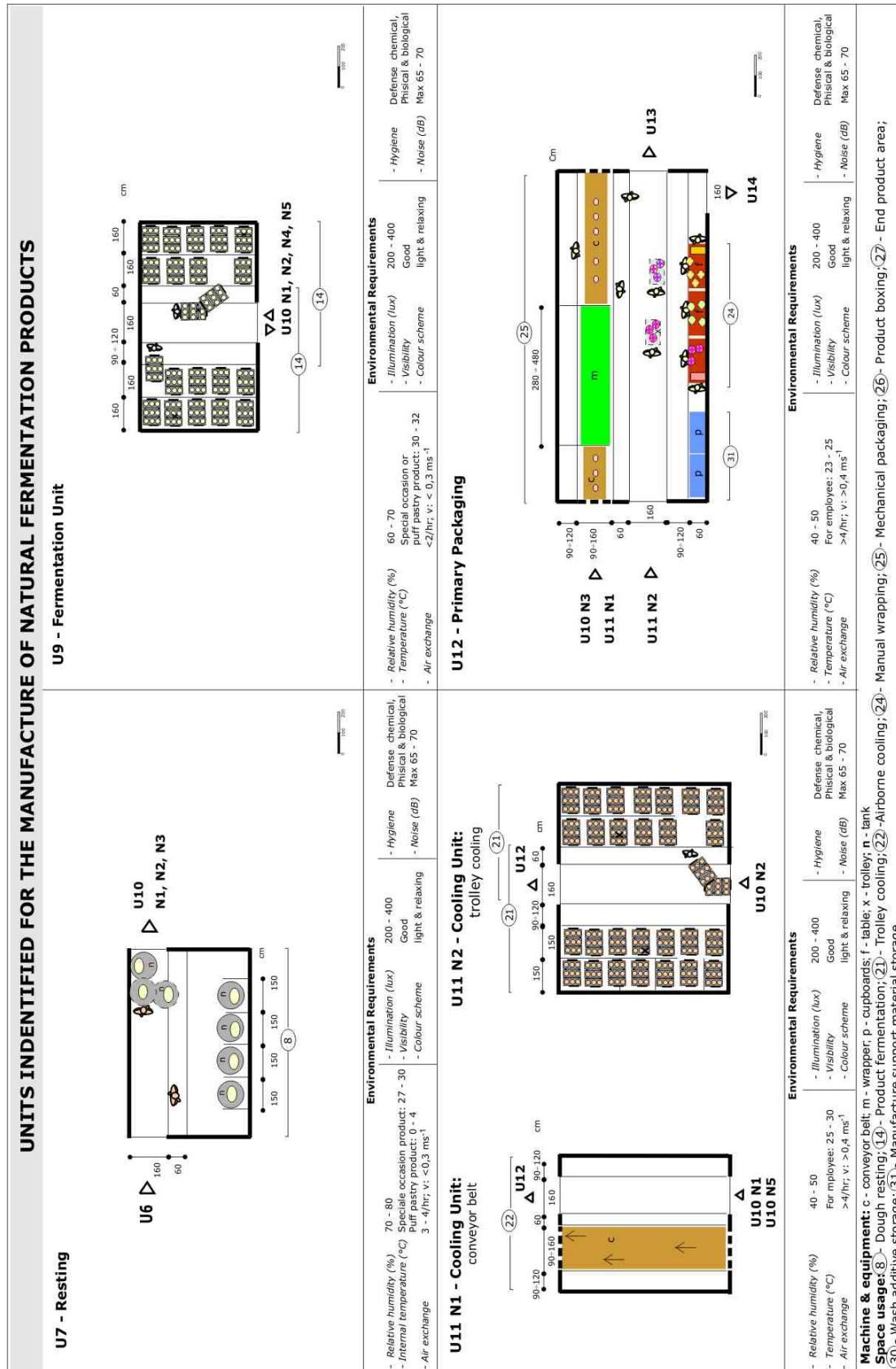
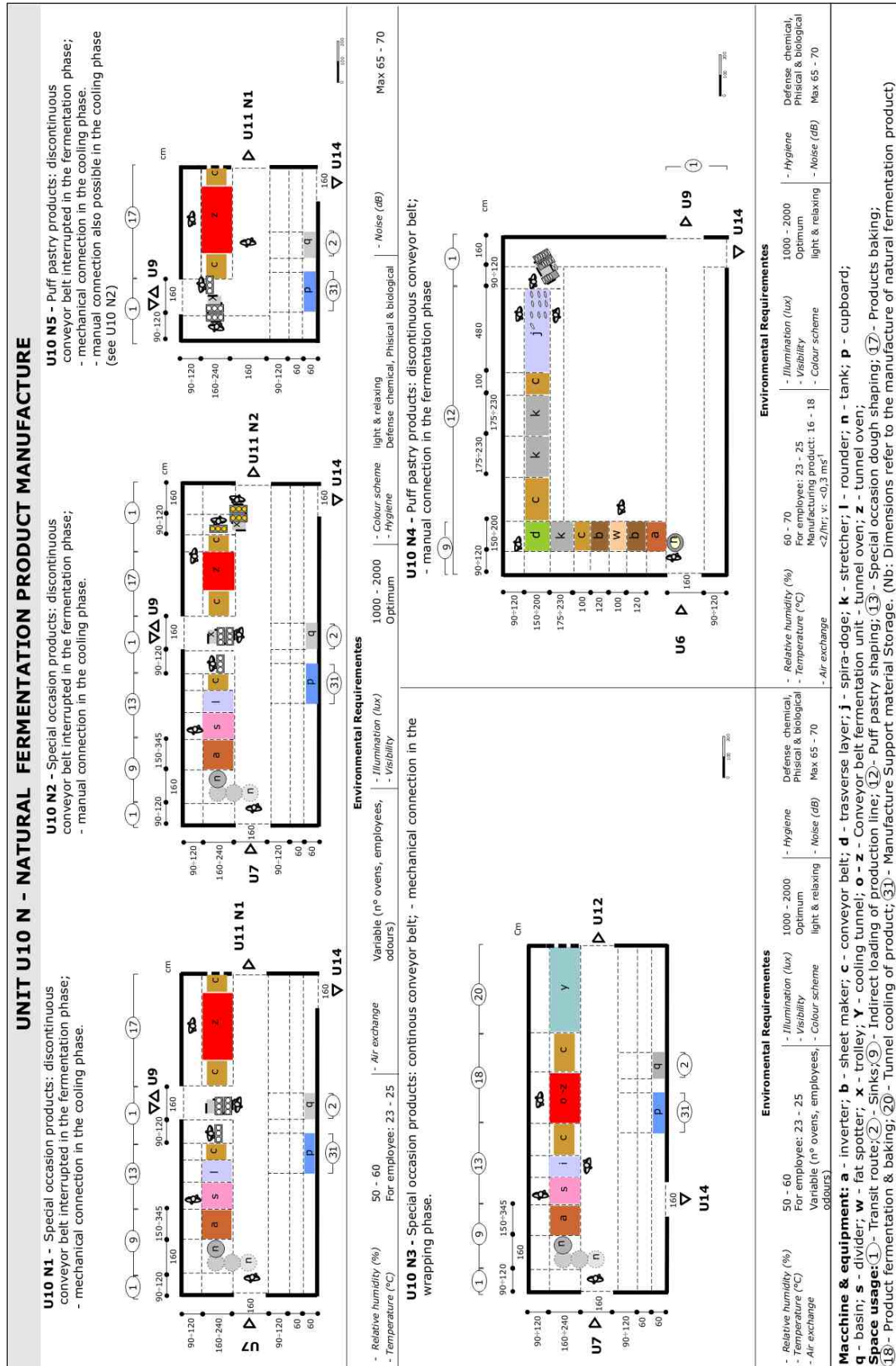


Figure 11. Organizational Layouts of the manufacturing areas for natural fermentation products



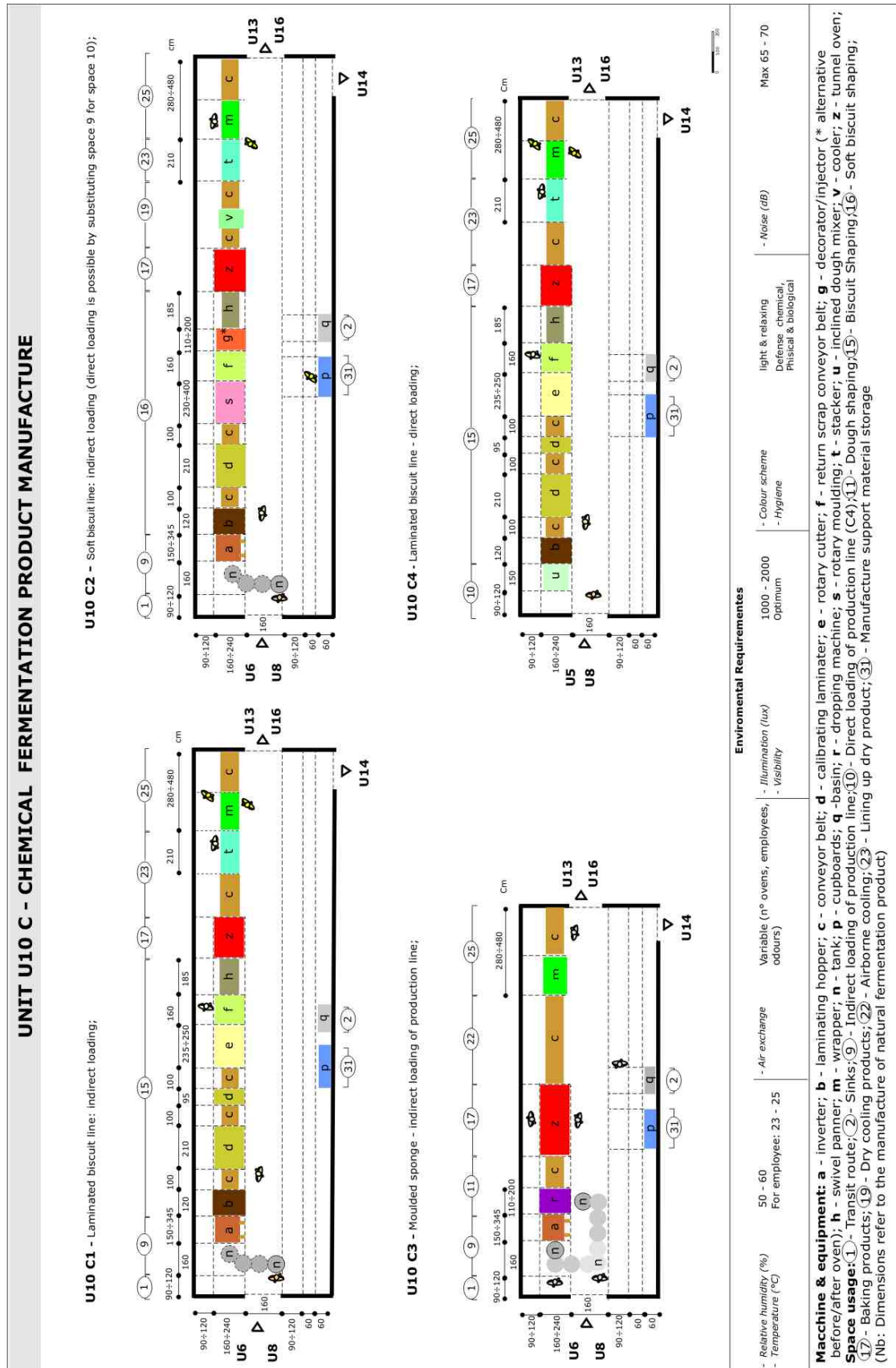


Figure 13. Chemical fermentation product manufacture organisational layouts

### *Unit for the preparation of products with natural or chemical rising*

The preparation of products with natural or chemical rising necessitates Units for the following: the storage of powders, the storage of raw materials, the storage of perishable raw materials, powder dosage, dosage and premix preparation, dough, equipment cleaning, product manufacture, secondary packaging, filters, cardboard storage, wrapper storage, equipment storage and end-product storage (figs. 9 & 10).

The *Powder Storage Unit (U1)*, whether inside or outside the building, is made up of silos to store flour and sugar, powder weighing systems and powder transport systems, tough and easy to clean flooring and if within the building, microclimatic control systems. Therefore, the layout is related to the bulk of the equipment and employee deployment.

In the *Perishable Raw Materials Unit (U2)* the various products (eggs, milk, butter, flavourings, etc.) are kept in special containers. The unit is ventilated and equipped with freezers (-18° C) or refrigeration (0 ÷ 4° C) systems. Its size and organization are related to the volumes stored and the accessibility requirements of the employees. It is important to locate it near the external reception area.

The *Raw Material Storage Unit (U3)* is climate controlled and fitted with platforms and shelves for storing foodstuffs (tins and sacks of cocoa, powdered and UHT milk, starch, salt, additives and flavourings). The layout must allow for hygiene control, protection from external agents (physical and biological) and easy handling, even by small mechanical vehicles. Finally, considering that raw materials are subject to micro-biological contamination, it is advisable to separate the Unit from the manufacturing area, by interposing *Filter Units*.

The *Powder Dosage Unit (U4)* is set up so that the preparation and handling of the ingredients coincides with their ingress and outflow and is furthermore closely choreographed with the Units for *Dosage and Premixes Preparation* and *Dough*.

The Units for *Dosage and Premixes Preparation (U5)* (fat, eggs, egg white, creams, sugar, mixes for the dough, grinding and storage of scrap, preparation of fermentation agents etc.) are related in terms of size to the machinery and equipment needed for manufacture. Moreover, this Unit must closely choreograph with the Units for *Powder Dosage* and *Dough*.

Mixing the silo ingredients, or smaller quantities from the *Powder Dosage Unit* takes place in the *Dough Unit (U6)* either using simple mechanical blenders or those with batchers. The space layout allows the movement of vats and employees, and contains the support equipment (basin, refrigerators for yeast and secondary ingredients). Forced air climate control guarantees the temperatures necessary during specific manufacturing phases (generally about 25° C, and for puff pastry 15° C). The Unit's connectivity requirements depend on the product's manufacturing technology. In some cases the unit can be integrated directly with the *Manufacturing Unit (U10 C4)*.

The cleaning of equipment and baking trays used during production takes place in a special Unit (*U8: Equipment Cleaning*) provided with sinks, where normal hygiene and no standing water must be ensured. In particular, for the preparation of natural fermentation pastry it is advisable that this area, regarded as "humid and dirty", be separated from the manufacturing areas by a *filter*.



How the *Manufacturing Unit (U10)* is organised depends on both the manufacturing methodologies and the specialisation of the lines, which latter characterises the Units and the whole building typology. In this Unit the batter is made, baked and the products are packaged; so it also houses the machinery (ovens, conveyor belt systems, and packaging machines) and equipment of the production lines (figs. 12 & 13).

In the manufacture of the natural fermentation products ('special occasion' and 'puff pastry'), besides the above-mentioned phases, resting, fermentation and cooling phases all require controlled thermo-hygrometric parameters in specific rooms or using advanced tecnology plant. Therefore, the layout of the unit depends on the products and typology of mechanised lines (fig. 12). It is indispensable that space is organised so that product lines with the same environmental requirements are in the same room thus the various operations can be run in sequence, avoiding any process reflux or inter-crossing of activities. The Unit requires fans, efficient hot-air filtering systems, and climate control in order to guarantee air quality and avoid condensation and dispersing contaminants into the environment and product.

In the *Secondary Packaging Unit (U13)*, wrapped products are boxed and assembled on pallets. Its functional layout mainly takes into account the need for conveyor belts, trolleys, pallets, forklifts, platforms, and full and empty boxes. Moreover, it is advisable to rationalise the transit and placement zones of walkie pallet trucks and employees.

The *Filter Units (U14)* are necessary to avoid product contamination and ease worker mobility and the handling of materials and machinery. They are especially useful in separating the damp/dirty areas from dry/clean ones.

The end product wrapping and packaging materials require, according to use or pollution level, a *Cardboard Storage Unit (U15)* and a *Wrapper Storage Unit (U16)*. Space and transit are rationalised for material management by forklift trucks or walkie pallet trucks. Bearing in mind that cardboard is a pollutant, it is advisable to use it in areas which are separate and far from the production areas. It is useful to link them directly with the external area and with the *Primary* and *Secondary Packaging Units*.

In the *Equipment Store (U17)* there are trolleys, dough vats and small tools that are generally not used in the manufacturing cycle. It is indispensable to maintain normal hygiene and physically separate the manufacturing areas.

The size of the *End Product Storage Unit (U18)* is related to product capacity and marketing turnaround. Container types are various and their choice depends on product requirement and available space. In order to ease pallet handling it is necessary to directly link the *Primary* and *Secondary Packaging* areas.

### ***Units necessary only for the manufacture of natural fermentation products***

In the case of natural fermentation there is also a resting space, a fermentation and cooling unit, and a primary packaging department (fig. 11).

The *Resting Unit (U7)* is where the dough is kept during that phase. It should be big enough to park the equipment (trolleys and vats) and accommodate employee transit.

The thermo-hygrometric parameters of the unit should be maintained at the required values (puff pastry  $0 \div 4^{\circ}\text{C}$ ; “special occasion” products about  $30^{\circ}\text{C}$ ). To shorten process time the *Dough Unit* should be connected to the shaping area.

The dough in the *Fermentation Unit* (UA9) is kept for the time and thermo-hygrometric conditions required by the specific manufacturing technology. It is usually necessary to maintain the temperature at  $30 \div 32^{\circ}\text{C}$  and the relative humidity in the range of  $60 \div 70\%$ .

The number and size of fermentation unit is related to manufacturing requirements. Space layout should ease employee transit and equipment handling, and maintain the chronology of product ingress and outflow.

In the case of advanced technology plant, the unit can be replaced by a conveyor belt fermentation unit inserted in the main production line (U10 N3). In this case, all the operations are mechanised and the workers role becomes one of control.

The *Cooling Unit* (U11) contains the oven outflow product. Space layout should accommodate conveyor belts (mechanised lines) and the encumbrance of trolleys and employees (manual manufacture). In any event this Unit should be ventilated and dehumidified. The Unit could be substituted by cooling tunnels within the main production line (U10 N3).

Therefore, unit interconnectivity depends on the type of production line and the system design.

The *Primary Packaging Unit* (U12) has work benches (for gift wrapping), conveyor belts and packaging machines. Employee activity relates to manual wrapping and the assembly of product in the Transport Unit; therefore, space layout should accommodate the machinery and ease employee transit, differentiating between manual and mechanised operations. This Unit, as well as the Cooling Unit groups the most critical production phases to subject to HACCP. Efficient climate and hygiene control should protect the product from possible environmental contamination.

### 3.3.2 Typological Characteristics and Reference Layouts

The project invariables and an analysis of the flow of products and employees give rise to the inter-relational Unit criteria (connection, proximity, distance) and consequently to organisational layouts in Figures 14 & 15.

Seven layouts emerge which reflect the complexity of the production cycles, as well as the flexibility of the processes. The first five (layouts 1, 2, 3, 4 & 5) are basic, each one responsible for a single product. The last two (layouts 6 & 7) are predisposed to include extra production lines – different yet compatible – chosen from those analysed within the systems of units. They are examples of how to develop layouts for alternative products as long as the parameters within the system of units is taken into account. Furthermore, in the project phase, the various units should be located to accommodate expansion of the production lines without interfering with the functioning of the original plant (the Storage and Manufacture Support Units are those most adept at possible transformation.). From this point of view, the manufacturing area is primary and should not be subject to change and if necessary could be reproducible in side by side.

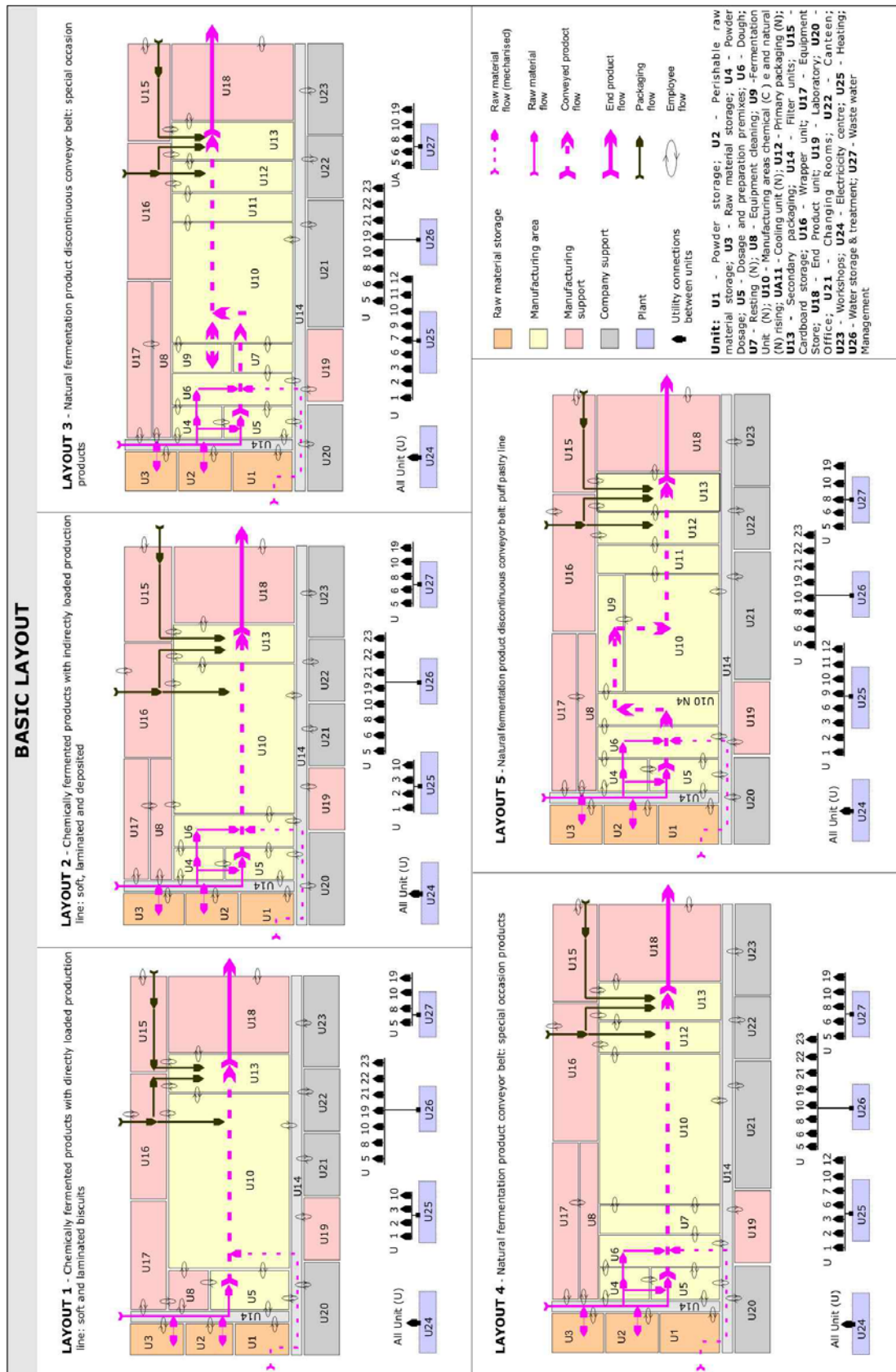


Figure 14. Single Production Line Layouts

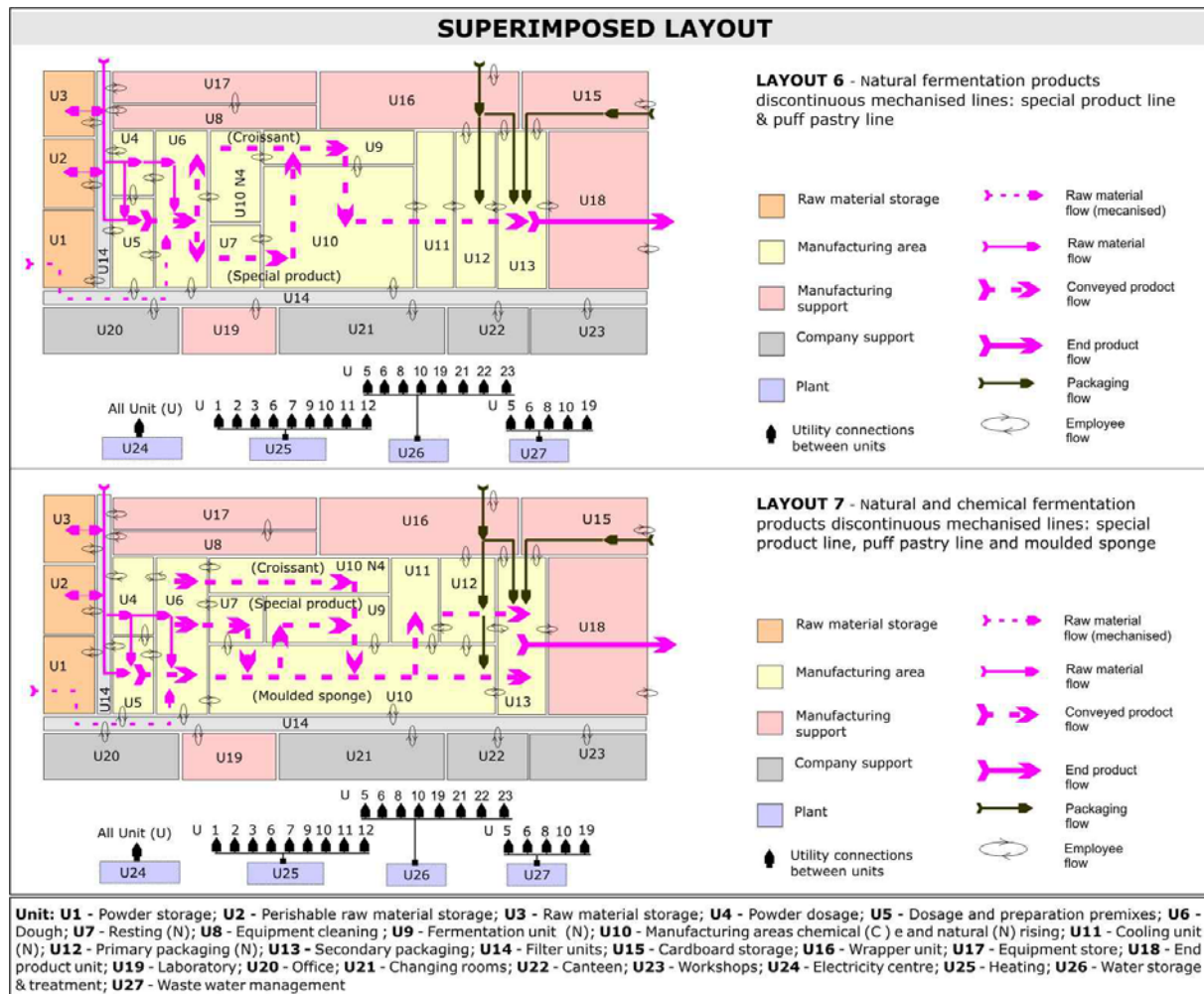


Figure 15. Multiple product line layouts

The proposed layouts take into account the above necessity and contain a basic structure which, irrespective of the size of the company, can be reproduced without altering the original setup.

#### 4. CONCLUSIONS

Analysis of the sample companies has revealed the build characteristics which highlight important functional inadequacies and at the same time identified the principle production and organisational requirements which determine build 'quality'.

The complexity of the production cycles requires variously correlated differentiated spaces.

The matapanning process has provided environmental and typological characteristics for building and in particular has identified the properties of space necessary to ensure the most beneficial conditions for production and allied activities. Particular attention has been paid to the layout of the singular units and their reciprocal correlation. Thus, it has been possible to define five basic layouts and two derivatives that map out the production space. These are principally defined by various flow types and by the need to maintain axial development of the main production line.



The articulation and interconnections proposed are the result of this study and the analyses carried out, and summarise graphically, those that are fundamental for a correct building layout.

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