Methodology for analysis of intensive swine production facility design

Juliano Cesar de Abreu Severo, M.S.

> Federal University of Vicosa, Agricultural Engineering Department, julianosevero@gmail.com

Fernando da Costa Baêta, Ph.D.

> Federal University of Vicosa, Agricultural Engineering Department, baeta@ufv.br

Ilda de Fátima Ferreira Tinôco, Ph.D.

> Federal University of Vicosa, Agricultural Engineering Department, iftinoco@ufv.br

Antonio Cleber Gonçalves Tibiriçá, D.S.

> Federal University of Vicosa, Architecture Department, tibirica@ufv.br

Irene Menegali, M.S.

> Federal University of Vicosa, Agricultural Engineering Department, imenegali@yahoo.com.br

Maria Clara de Carvalho Guimarães, M.S.

> Federal University of Vicosa, Agricultural Engineering Department, mclaracg@yahoo.com.br

Hongwei Xin, Professor

> Iowa State University, Ag. And Biosystems Engineering Department, hxin@iastate.edu

Angela Green, NSF PhD Graduate Fellow

> Iowa State University, Ag. And Biosystems Engineering Department, angelag@iastate.edu

Abstract. *This work was aimed on using Systematic Layout Planning (SLP) methodology to assist in planning of intensive swine production facilities. First, data were collected by local systematic observation. These data were used to make a diagnostic assessment of major existing problems in a swine production system by studying the relationship between production fluxes (of animals, people, feed, equipment and wastes) and the existing layout. Data acquisition, based on the production fluxes, occurred between August and October 2004 in three swine farms of Vale do Piranga region, Minas Gerais State, Brazil, because this region has the state's second largest concentration of swine. After the study of these fluxes, it was possible to verify, by means of SLP, the proximity relations between the buildings. This SLP may be used as a guideline in the planning of new facilities and for diagnostics of problems due to layout in existing facilities.*

Keywords. Design methodology, layout planning, swine facilities.

Introduction

Brazil, the world's 4th largest pork producer, produced 2.6 million tons of pork in 2004. From 1990 to 2003, Brazilian production increased by 158%, while the world production grew 37,1% (USDA, 2004). This increase may be attributed to the development of techniques of swine production, in terms of genetically improved animals and advances in nutrition, management and sanitation.

The intensive swine production system can be defined as a system in which the animals are housed in appropriate indoor facilities, during their entire life (Nicolaiewsky & Wentz, 1998). However, there is still an important lack of knowledge about the types of lodging that are most appropriate to Brazilian weather conditions. Thus, the production process still needs well-designed facilities, in order to furnish the animals with adequate environmental conditions and allow them to reach their maximum productive performance.

Each swine production facility needs specific planning for siting, construction, placement and integration of all components. However, the production facility functionality is affected by many factors, including site topography, distance from market and size of herd. So, facility design is not enough. Optimization of production fluxes, considering both the management and the animals, may lead to a more rational productive process.

The production fluxes can be defined as a set of synchronized and integrated actions from every sector of the production facility needed to meet production goals, such as personnel, infrastructure, animals and technologies management (Correa et al., 2001). Failures on the planning of the facilities are commonly observed, which lead to problems in the production fluxes.

The facilities location itself can affect the production. For example, sectors of the production plant that need constant observation, like pre-gestation, gestation, farrowing and nursery, must be located close to the personnel's most frequently used corridors, the opposite occurring with sectors like growing and finishing, which may be located in more isolated areas, but still respecting the minimum recommended bio-security distances.

Structural details, like corridor ramps, may become obstacles to the workers, when they need to move around with carts or bags, at animals feeding times. Also, badly positioned pillars and others structures may cause many problems during certain activities.

Another important issue to be observed is the production of manure, and its disposal within the production process. An adult swine produces, on average, $0.27 \ m^3$ of liquid manure per month. Thus, in Sao Paulo state, whose swine herd was 1.5 million in 2000, manure production was approximately 13,500 m^3/day (ABCS, 2000).

Other factors, which must also be considered, are related to the animal's welfare, including noise levels and sources, lighting, types of floor, excessive transit of personnel and machinery, etc. These factors can cause stress to the animals, reducing their productivity and violating rules imposed by importing countries. According to Hill (1999), relatively recent tendencies, like the use of deep-bedded floors, can assure benefits to the animals' productivity and welfare, as well as the global environment. However, related field data are controversial and need further investigation.

Also the air quality within the facilities is a factor that influences the animal and worker welfare. According to Klooster (1993), the gases produced within the swine facilities, like ammonia, are responsible for 50% of the occurrence of acid rain. Slotted floors and different manure handling

practices inside the facilities are efficient ways of limiting the gases emissions (Miner, 1995; Hendriks, 1997).

This set of conditioning factors indicates the importance that must be given to the appropriate planning of the production facilities, as well as the analysis of all the production fluxes, in order to maximize the production, while minimizing costs and assuring animal welfare.

The main objective of this work was to use a methodology that allows the diagnosis, the analysis and the design of the components that compose an intensive swine production system. Systematic Layout Planning (SLP) was then used as a tool for the analysis and layout planning. According to Muther (1978), SLP is a structuring of phases, a model of procedures and a series of conventions to identify, evaluate and visualize the elements and areas involved in the layout planning. It is an easy-to-use model, in which procedures are adopted to combine many factors, considerations, elements and objectives, related to a specific project, using techniques of analysis followed by a simplified list of symbols and conventions.

Materials and Methods

The first step was the identification of the main problems present in the swine production system, caused by the facility layout, through the study of fluxes and facilities. The diagnosis was made obtaining information about the rules, parameters and basic concepts of the facilities that compose a full-cycle intensive swine production system. In order to do that, information was collected by means of *in loco* observations, using questionnaires, interviews directed to the workers, photos, flowcharts and spread sheets. Data acquisition was made in three full-cycle standard production facilities, located in Piranga Valley, one of the largest swine production regions of Minas Gerais State, and whose weather, according to Koppen, is Cwa (warm, temperate, rainy, with a dry season in the winter and warm summer).

The visited farms were:

- A: Fazenda Sao Joaquim; with a herd of 900 sows, is located in the City of Urucania, Minas Gerais State (MG) (20°20' S; 42°46' W; 420 m of average altitude);

- B: Sitio Boa Vista; located in the City of Vicosa, MG (20°43' S; 42°52' O; 635 m of average altitude). Its herd is 1200 sows large;

- C: Fazenda da Vargem, located in the City of Jequeri, MG (20°25' S; 42°43' O; 492 m of average altitude), and whose herd is 600 sows large.

All the management practices, as well as facilities deficiencies, problems with the production fluxes and animal level thermal environment were documented and analyzed, furnishing a snapshot of the main problems that affect the swine production in the specified region.

Data acquisition was based on the following production fluxes:

- Animals: the movements in each phase of production were verified: the residence time of the animals within each facility, the execution of these movements (through corridors, machinery, etc.), the characteristics of the circulation areas (dimensions, building materials, location within the system, etc.), among others. These observations were recorded by means of questionnaires, applied to the workers responsible for executing these movements, and also by means of photos and flowcharts. The objective of these registries is to verify whether these movements would negatively affect the animals' welfare or not, and if yes, what can be done to minimize these effects.

- Personnel: the working conditions within the facilities were recorded: the working places and types of work assigned to each worker, as well as the methods employed by the workers to

complete their work. Spread sheets were used to record information such as number of workers per sector, time spent to execute specified activities, protective equipment used, etc. These variables were used to assess the workplaces, in order to propose enhancements in the work conditions.

- Feed: feed transport was observed within the production system, after its arrival to the farm until its distribution to animals. Flowcharts, questionnaires of the responsible workers, and photos were used for recording information of: storage places, amounts and daily frequency of distribution, possible wasted feed and its cause, etc. This information was used to propose enhancements on feed distribution, with minimization of wastes and minimization of production costs.

- Equipment: equipment used in production, their functions, and the way they are used were verified: whether they are stationary or mobile, their daily working time, their location, etc. Spreadsheets and flowcharts were used for recording this information. The analysis of the flux of equipment allows suggestions for reductions in the distances and machinery dimensions, resulting in economy of infra-structure and handling simplification.

- Wastes: currently, the main issue about swine production is related to the amount of manure that is generated by the animals. This has become a problem in various regions of Brazil and worldwide, including the region where this work was done, the Piranga Valley, MG. Thus, due its importance, flowcharts and photos were used to record waste handling parameters: the types of waste produced (whether they are liquid, solid, etc.), the way they are removed from the facilities, the subsequent management and their final disposal.

With the intent of facilitating the layout planning, through the use of SLP, a preferential inter-relations chart was built. This chart is a triangular matrix, in which the type and degree of proximity (or inter-relation) between each facility and the others are represented. In other words, the basic objective of this chart is to show which activities (or facilities, in this case) must be located close to others and which must not.

Figure 1 exemplifies a preferential inter-relations chart, according to Muther (1978). On the horizontal fields on the left are placed the names of each activity or facility. For example, when the descending line from field 1 meets the ascending line from field 3, the resulting cell contains the relationship between these two activities. Thus, there is an intersection cell for each pair of activities.
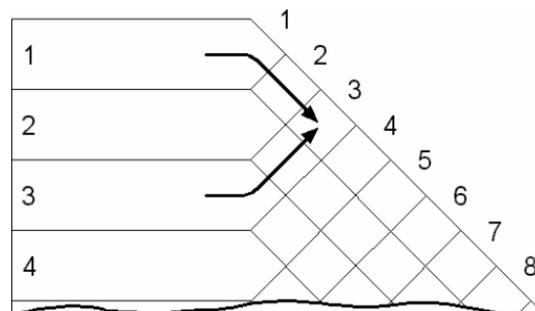

Figure 1. Example of a preferential inter-relations chart (adapted from Muther, 1978).

The main components that constitute the standard full-cycle swine intensive production systems, considered in this work, are shown in Table 1.

Table 1. Facilities that constitute the standard swine production systems

Code	Facility
1	Access
2	Office / dressing room
3	Feed plant
4	Medicine room
5	Artificial insemination lab
6	Pre-gestation and gestation
7	Farrowing
8	Nursery
9	Growing / finishing
10	Loading ramp
11	Decomposition ditch
12	Quarantine
13	Stabilization ponds

In order to classify the degree of inter-relation between the facilities, the SLP methodology uses six letters, which are:

- A – absolutely necessary;
- E – especially important;
- I – important;
- O – ordinary closeness;
- U – unimportant;
- X – undesirable.

The rationale for such inter-relations and the degrees of inter-relation follow. These reasons will depend on the project, and for this work, are shown in Table 2.

Table 2. Reasons for the degrees of inter-relation A, E, I, O, U or X

Code	Reason for the inter-relation
1	Contamination risk
2	Functionality
3	Ease of movement and access
4	Usage frequency
5	Observation / control
6	Noise

Results and Discussion

For the investigation diagnosis of the main problems of the swine production systems, caused by the architectural and constructive designs, as well as to study all the production fluxes, data acquisition was made on the farms previously cited, during the period of August to October 2004.
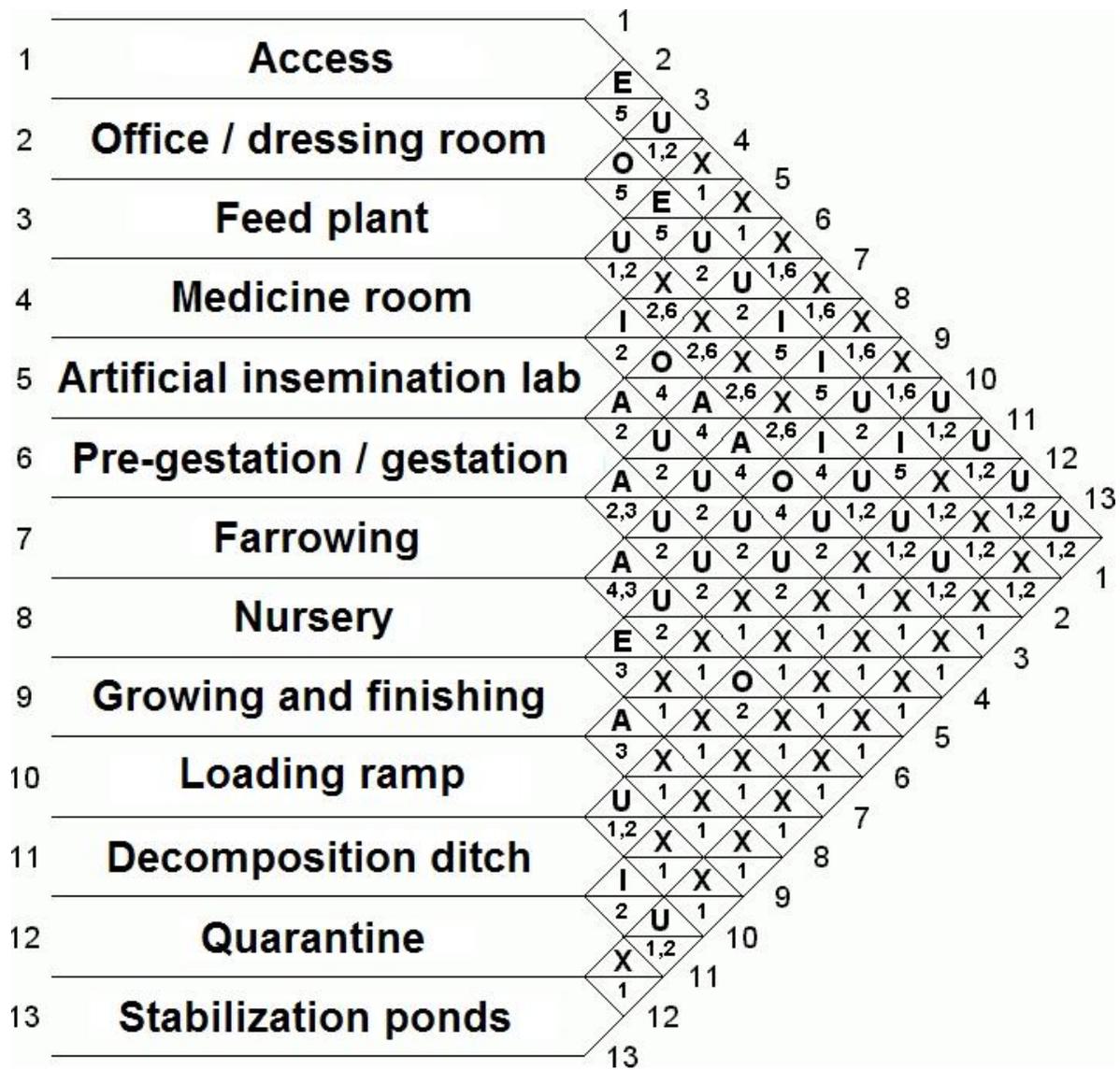
From this data, it was possible to find possible associations between the facilities for each degree of inter-relation. These associations, as well as the explanation for the degrees are displayed in grids, like the Grid 1.

Grid 1 – Possible associations between the facilities that constitute an intensive swine production system, for the degree of inter-relation *absolutely necessary* (A)

	Facilities	Associations					Reason for the proximity relation[1]
1	Access	-	-	-	-	-	
2	Office / dressing room	-	-	-	-	-	
3	Feed plant	-	-	-	-	-	
4	Medicine room	7	8	-	-	-	4
5	Artificial insemination lab	6	-	-	-	-	2
6	Pre-gestation and gestation	5	7	-	-	-	2, 3
7	Farrowing	4	6	8	-	-	4, 3
8	Nursery	4	7	-	-	-	4, 3
9	Growing / finishing	10	-	-	-	-	3
10	Loading ramp	9	-	-	-	-	3
11	Decomposition ditch	-	-	-	-	-	
12	Quarantine	-	-	-	-	-	
13	Stabilization ponds	-	-	-	-	-	

Note: [1] according to Table 2

From the associations, it was possible to build a preferential inter-relations chart (Figure 2), which allows visualizing in an easy way the proximity requirements for the facilities, as well as the reasons that justify these requirements.

1 **Access**
2 **Office / dressing room**
3 **Feed plant**
4 **Medicine room**
5 **Artificial insemination lab**
6 **Pre-gestation / gestation**
7 **Farrowing**
8 **Nursery**
9 **Growing and finishing**
10 **Loading ramp**
11 **Decomposition ditch**
12 **Quarantine**
13 **Stabilization ponds**

Inter-relations degrees		Number of inter-relations		Codes	Reasons for the inter-relation degrees
A	Absolutely necessary	6		1	Contamination risk
E	Especially important	3		2	Functionality
I	Important	6		3	Ease of movement and access
O	Ordinary Closeness	4		4	Usage frequency
U	Unimportant	22		5	Observation / control
X	Undesirable	37		6	Noise
Total = n*(n-1)/2		78			

Figure 2. Preferential inter-relations chart, for an intensive swine production system.

Conclusion

From the data collected in the three swine production plants visited, it was possible to diagnose the main existing problems of the intensive swine production systems, resulting from the facility layouts.

Using the SLP methodology, it was also possible to verify the inter-relations between the facilities that constitute these production systems, synthesizing them into the preferential inter-relations chart (Figure 2). In the case of new projects, one needs to respect all the conditions stated in the preferential inter-relations chart, to optimize the production by means of giving priority to the production fluxes.

This study shows the importance of the layout planning, not only in this case, but in any production system, agro industrial or not, in order to make sure that all actions occur at their correct times, without prejudicing the productivity goals.

References

ABCS. Associação Brasileira dos Criadores de Suínos: Rebanho suíno. Disponível em: <http://www.abcs.com.br/desemp.html>. Acesso em 15 Março 2004.

Corrêa, M. N.; Meincke, W. ; Lucia, T.; Deschamps, J. C. Inseminação artificial em suínos. Pelotas, RS: Márcio Nunes Corrêa, 2001. 181p.

Hendriks, H. J. M. Dutch Policy for Low Emission Housing Systems. In: Ammonia and Odor Control from Animal Production Facilities. Proceedings of the International Symposium, October 6-10, 1997, Vinkeloord, the Netherlands, 1997. p.685-689.

Hill, J. D. Bedding Management for Deep Bed Swine Finishing. South American Deep Bed Swine Production Conference. Santiago, Chile. 1999.

Klooster, C. E.; Voermans, J. A. M. European Perspectives – How Are They Solving Their Problems? Symposium "Meeting The Environmental Challenge". National Pork Producers Council, November 17-18, 1993. Minneapolis, MN.

Miner, J. R. A review of literature on the nature and control of odors from pork production facilities. Prepared For The Odor Subcommittee Of The Environmental Committee Of The National Pork Producers Council, p. 118. 1995.

Muther, R. Planejamento do layout: Sistema SLP. São Paulo, Edgar Blücher. 1978. 215p.

Nicolaiewsky, S.; Wentz, I. Sistema de produção de suínos. In: Suinocultura, Produção, Manejo e Saúde do Rebanho. Concórdia, SC: EMBRAPA-CNPSA. 1998. 388p.

USDA. Livestock and poultry: world markets and trade. Circular Series, November 2004. Washington: United States Department of Agriculture. 2004.