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ADVANTAGES OF USING EXPERT SYSTEMS TO PROJECT DAIRY CATTLE FARMS: CASE STUDY OF MENEMEN, TURKEY

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ABSTRACT

This study aimed to asess the advantages of using information technologies in the design of architectural projects of dairy cattle farms. In this context, 3 dairy cattle farms in İzmir – Menemen region, designed with traditional methods and receiving rural development support, were picked as samples and they were examined using an expert system called "Architectural Designing of Dairy Farms" (ADDF). The existing infrastructure in the sample farms and the herd management strategies applicable within the mentioned infrastructure were compared with the herd management applications recommended by ADDF for each farm and the infrastructure facilities required by such strategies. It has been determined that in any of the farms, grouping systems do not meet the expert system's recommendations in terms of both animal density and age groups which causes difficulty access to feed and water, especially for young and special needs cows. In addition, there are design errors in the barns that will adversely affect animal welfare. Pen details and free stall designs caused injury and pollution in the stalls. In this context, it has been emphasized which mistakes can be avoided if expert systems are used and recommended to use the expert systems in the design of architectural projects of dairy cattle farms in order to use the investments effectively and to increase the efficiency in animal production.

Keywords: Dairy cattle housing, Animal welfare, Expert system

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INTRODUCTION

Various investment subsidies are provided for dairy cattle farms, but due to the lack of technical data and the lack of sufficient number of experts, feasible projects in terms of animal welfare and productivity cannot be designed or the suitability of the projects cannot be examined comprehensively in Turkey. Even in modern farms built in recent years and with various supports, there are design errors negatively affecting the yield and limiting the improvement of the herd management plan. This prevents investments and supports from being used effectively (Bakır and Kibar, 2020; Kılıç *et al*., 2020).

Production structures in livestock farms are special structures whose design requires specialist knowledge. Dairy farms consist of many components interacting with each other. The design of each of these components directly or indirectly affects operation performance. It is very difficult and expensive to correct such errors in the architectural design of these structures after the construction is completed. Failing to correct these errors will greatly reduce labor efficiency, productivity and quality, and increase the cost of production (Holmes *et al*., 2013). Due to the increasing number of project criteria, the decrease in the time allocated for projecting, and the lack of sufficient number and quality of experts for each subject, studies in the world have focused on the development of expert systems that will accelerate the analysis and facilitate decision-making in the design and management of agricultural farms (Gartung *et al*., 2006; Karmakar *et al*, 2007; Samer, 2008).

In this respect, Alkan (2017) has developed an expert system program called "Architectural Designing of Dairy Farms" (ADDF) in order to meet the administrative and structural requirements in a dairy farm established under mild climate conditions, and examine whether these requirements are met in an existing business.

In this research, barns on dairy farms, selected from those whose projects were designed using traditional methods and received rural development support, were analyzed in terms of their architecture using an expert system known as ADDF. The study aimed to identify design errors that could potentially impact animal welfare. Additionally, this research highlighted opportunities to leverage information technologies to minimize these errors in existing operations and future design projects.

MATERIALS AND METHODS

The research was carried out in 3 dairy cattle farms, which were built or modernized by receiving rural development support in İzmir – Menemen region. The farms where the research was carried out were selected according to the purposive sampling method (Yurtsever, 1984). It is a type of nonprobability sample, and it's also referred to as a judgmental or expert sample. In this research, while determining the sample farms, it has been taken into account that they have as many structures and facilities as possible in order to represent different business sizes and to be used in comparison with the ADDF. Furthermore, the fact that these farms were subsidized by Izmir Provincial Directorate of Agriculture and Menemen Municipality, Ziraat Bank was also considered as a criterion for selection.

Moreover, in order for the sample farms to be analyzed accurately with the expert system (ADDF), it was taken into consideration that they were enterprises that recorded their data on herd management plan, barn types and architectural details. The data were obtained from the selected farms through a questionnaire form to be evaluated in the expert system (ADDF) and the accuracy of the data was tested through measurement studies. Also, the financial and temporal constraints of the study were also taken into consideration when selecting the sample farms.

The expert system (ADDF), developed by Alkan, (2017) and equipped with expertise for the architectural design of dairy cattle farms, was used to examine the farms. Figure 1 shows the architecture of the sub-models and Figure 2 shows the main menu of the expert system. Expert system has 1. Herd Size and Makeup, 2. Herd Management, 3. Calf and Heifer Pens Designing, 4. Lactating Cows Pens Designing, 5. Special Pens Designing, 6. Barn Systems Designing, 7. Milking System Designing, 8. Manure Storage Designing, 9. Feed Storages Designing and 10. Farmstead lay out modules.

In this study; 2. Herd Management and 5. Lactating and Dry Cows Pens Designing modules were used. The herd flow plan refers to the predicted number of animals for different age and management groups in the herd and varies according to herd size, calving interval, pregnancy rate, culling rate, mortality rate and seasonal or periodic calving patterns. On the other hand, herd management covers all practices ensuring animal welfare and operational efficiency from the birth of the calf to heifer and cow. In this study, herd management plan involves grouping the animals according to their age/live weight and environmental requirements and planning the details of the barns to meet their environmental demands.

In the “herd management” module, young animals are divided into 2 groups according to their age and it is considered that young calves (0-2 months) will be housed in individual calf hutches. It is taken into account that the calves in the transition period (3-5 months) will be housed in the group pens and the number of animals in one pen should be 10 at most. Calves and heifers (6-24 months) are housed in separate pens according to age groups, and the maximum number of animals in a pen should be 60. milking cows will be housed in separate pens in line with their age and live weight. In determining the number of pens planned for milking cows and the size of the milking group calculated according to a milking shift length constitute the basis. However, it is stated that the number of animals housed in a pen should not exceed 100 head. It is foreseen that cows with special needs will be housed in pens planned in line with their age and needs. In expert system, for managing mature cows, group recommendations are as follows; far-off dry cows pen (-60 to 21 days), close-up dry cows pen (-21 to -2 days), maternity pen (-2 to1 days), post-fresh non-saleable milk pen (1to 3 days), post-fresh monitoring (breeding) pen (3 to 21 days), first lactation heifer pen (21 to 305 days), late lactation cows pen (21 to 305 days) and sick cow pens (7 – 10 days commonly).

In the "Lactating and Dry Cows Pens Designing" module, it is projected that the milking cows will be housed in two-row, head-to-head freestall pens. Each pen is designed to include one feed and stall alley, as well as a freestall for every cow. Additionally, a cross alley is planned between each stall block, with a maximum stall block width of 30 meters, to facilitate movement within the pens.

The dry cow pens are also configured as two rows of freestall pens, similar to those for milking cows. However, it is recommended to house a maximum of 30 animals in these dry cow pens and to include two cross-over alleys for ease of access. The stall widths and feed line lengths per animal for these pens are greater than those for lactating cows. Nevertheless, the distance to access food and water is shorter.

ADDF uses the number of mature cows and the milking shift length as inputs and determines an appropriate herd management strategy and the infrastructure facilities required to meet this strategy according to these data. ADDF was run using the current number of milking animals and milking shift lengths in each farm, and the proposed herd management strategy for each farm and the capacity and architectural details of the barn and other service structures to meet these strategies were determined. By comparing the current situation of these farms with the situation proposed by ADDF, structural problems related to animal welfare in the farms were determined and suggestions were made for improvement in accordance with current scientific principles.

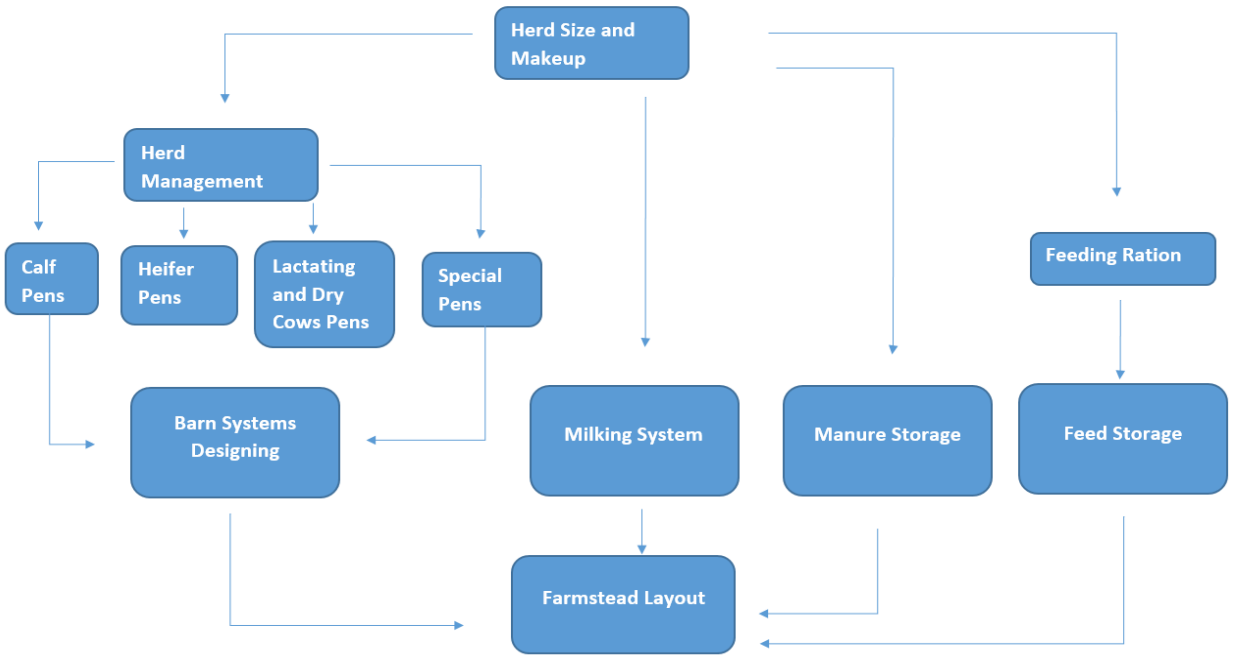


Figure 1. Architecture of the expert system sub-models (Alkan, 2017).

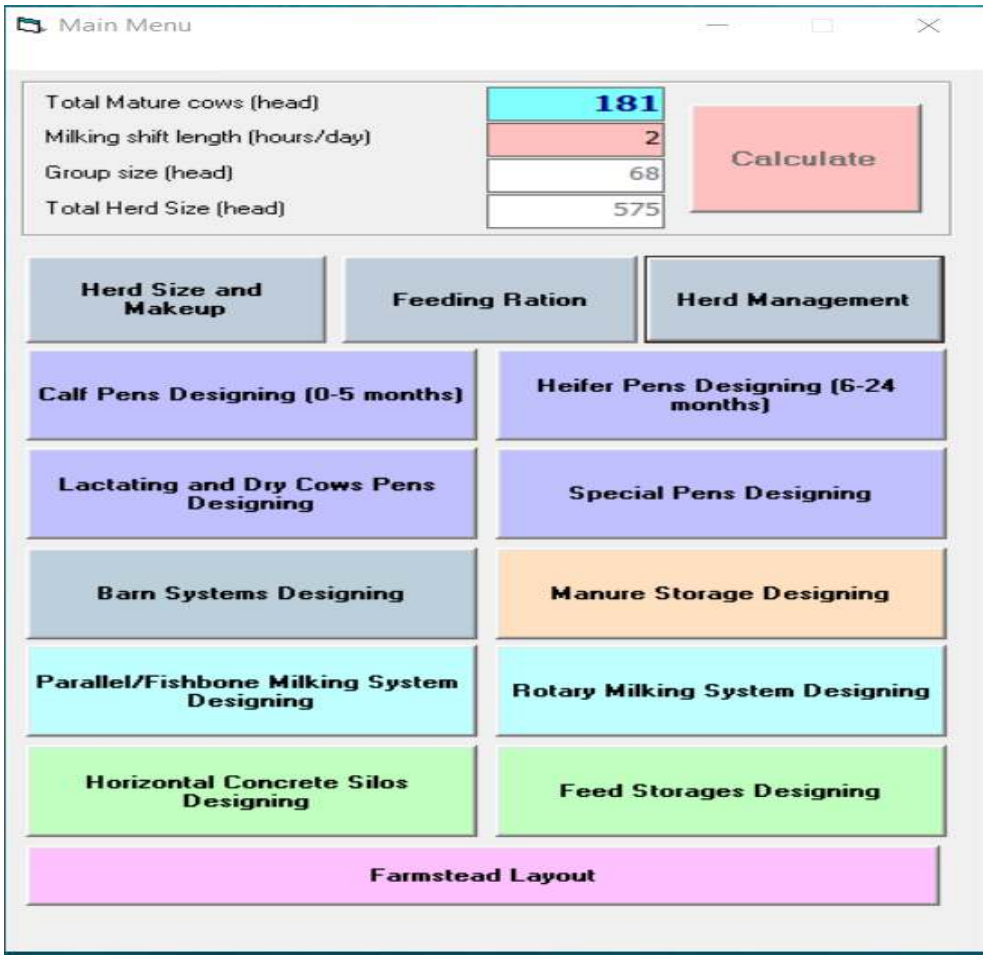


Figure 2. Main menu of the expert system (Alkan, 2017)

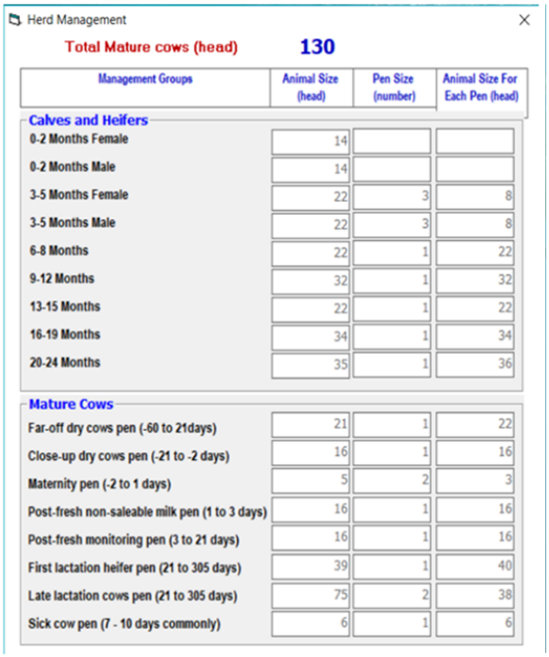
RESULTS

The basic stages of the design process of barns in dairy cattle farms can be listed as follows:

- Determining the herd size and makeup,
- Grouping the animals according to their age, live weight and special needs within the scope of the determined herd size and makeup,
- Determining the number of groups and the herd management plan for each group,
- Identifying of housing systems suitable for this management plan and details of pens and barns equipped to meet the specific needs of each group.

The current state of the farms and the values recommended by ADDF were compared in line with these stages.

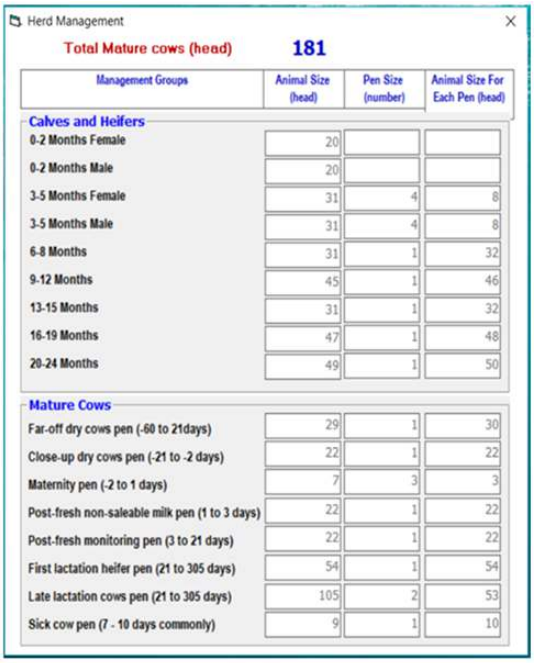
Herd Size and Management: The herd management plans suggested by the expert system according to the number of mature cows for the sample farms and the current group management organizations can be found in Figure 3, Figure 4 and Figure 5 respectively. In the first farm, 0-2 month old calves are housed in adjacent individual pens in the barns. The grouping system planned for the calves in the transition period (3-5 months) does not meet the recommendations of the expert system in terms of the density of the animals in the pen. There are no heifer pens in the farm and these animals are transferred to another farm until the first lactation period. And the mature cows were grouped according to lactation period and there is only one special needs pen, where maternity and dry cows were housed together (Figure 3). In the second farm, 0-2 month old calves are housed in adjacent individual pens in the barns. The grouping system planned for the calves in the transition period (3-5 months) does not meet the recommendations of the expert system in terms of the age difference between the animals in the same pen and the intensity of the animals in the pens. The group management applied for the heifers meets the recommendations of the module in terms of animal density in the pens, but the grouping system does not meet the recommendations of the module, and the age difference between the animals housed in the same pen is more than recommended. In the farm 6-12 months and 18-24 months animals are housed together. In the farm, mature cows were grouped according to their yield values, not their age. The farm has the Far-off dry cows pen (-60 to -21days), Close-up dry Cows pen (-21 to -2 days), Maternity pen and Sick cow pens which supply the animal density but post fresh pens were ignored (Figure 4). In the third farm, 0-2 month old calves are transferred to the group pen from the 15th day. In the group pens 1-7 Month calves, 7-14 Month and 14-17 Month heifers are housed together. This brings a great risk especially in terms of infectious diseases. The grouping system planned for the calves and heifers is far from meeting the recommendations of the expert system in terms of the age difference between the animals in the same pen and the density of the animals in the pens. Milking cows were divided into sections with 60 cows in each section, but age group and body weight were not taken into account. The farm has Close-up Dry Cows pen (-21 to -2 days), maternity pen and sick cow pens but other dry cows (-60 to -21) and 18-24 months heifers were housed together (Figure 5).



Farm 1
Total Mature cows (head) 130

Management Groups	Animal size (head)	Pen size (number)	Max animal size for each pen (head)
Calves and Heifers			
0-2 Months	13	13	1
3-5 Months	13	1	13
6-24 Months	animals are transferred to another farm until the first lactation period		
Mature Cows			
Dry cows + Maternity pen	10	3	4
First lactation heifers	60	1	60
Late lactation cows	60	1	60

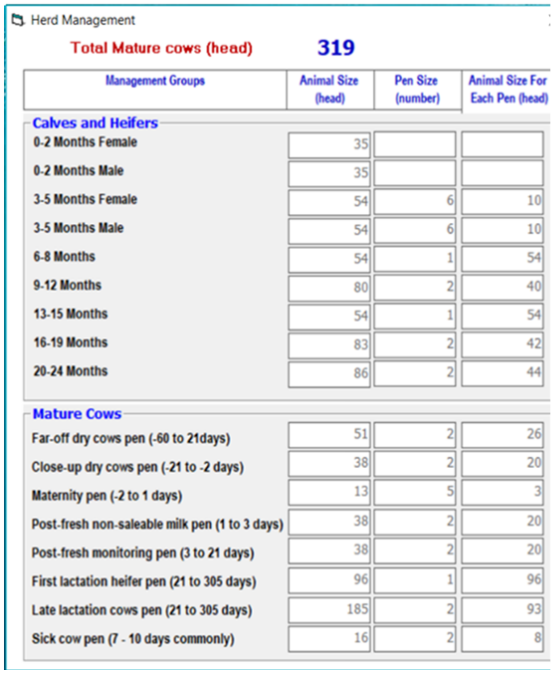
Figure 3. Suggested and current group management organizations for the first farm



Farm 2
Total Mature cows (head) 181

Management Groups	Animal size (head)	Pen size (number)	Max animal size for each pen (head)
Calves and Heifers			
0-2 Months	40	40	1
3-4 Months	20	1	20
5-6 Months	10	1	10
6-12 Months	56	2	28
13-14 Months	21	1	21
14-18 Months	18	1	18
18-24 Months	62	3	21
Mature Cows			
Far-off dry cows (-60 to 21)	10	1	10
Close-up dry cows (-21 to -2)	11	1	11
Maternity pen	5	5	1
Low yield Mature cows	20	1	20
Medium yield Mature cows	55	1	55
High yield Mature cows	60	1	60
Peak yield Mature cows	20	1	20
Sick cows	1	1	1

Figure 4. Suggested and current group management organizations for the second farm



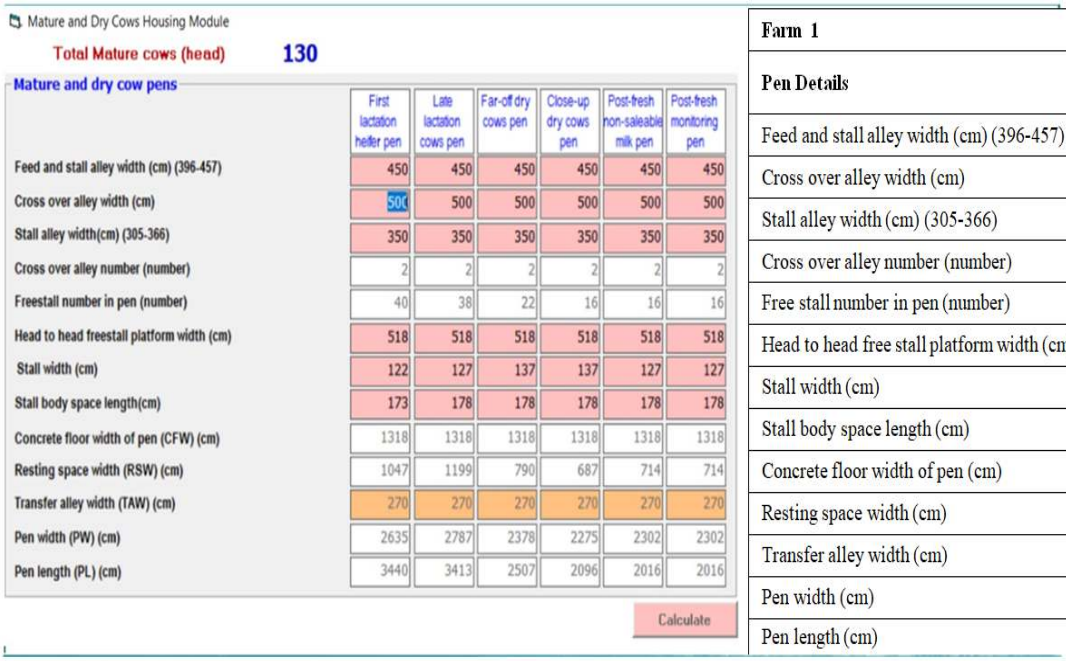
Farm 3
Total Mature cows (head) 319

Management Groups	Animal size (head)	Pen size (number)	Max animal size for each pen (head)
Calves and Heifers			
0-15 Days	62	1	62
1-7 Months	40	1	40
7-14 Months	60	1	60
14-17 Months	70	1	70
Mature Cows			
Dry cows (-60-21) and 18-24 Months	80	1	80
Close-up dry cows (-21 to -2)	0	1	0
Lactation heifers + cows	230	3	80
Maternity pen	6	3	2
Sick cows	3	1	3

Figure 5. Suggested and current group management organizations for the third farm

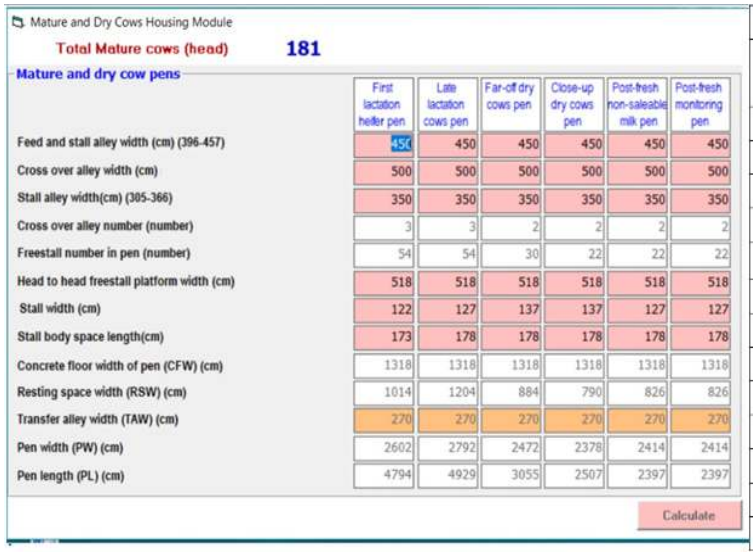
Architectural design of pens: The architectural design of pens suggested by the expert system according to the herd management strategies determined for the sample farms and the current design of the pens can be found in Figure 6, Figure 7, and Figure 8 respectively. In the first farm all lactating cows are housed in two uniform pens. In the pens, alley widths are inadequate. The stall width used for all mature cows is almost the minimum value for the first lactation heifers. Head-to-head free stall platform width is sufficient but because there is no brisket locator in the stalls, stall body space is not limited and the length used by the cows and heifers is far above the recommended maximum length for lactating cows. Resting space not used in any of the pens (Figure 6). In the second farm freestalls not used in dry cow pens. For all other mature cow groups, same alley and free stall

dimensions are used. Feed and stall alleys and cross-over alley widths are inadequate for mature cows. Head-to-head free stall platform width is not sufficient. There is no brisket locator in the stalls and the stall body space is not limited. The cross over alley is placed between 30-stall distances. According to the pen length and resting space width, 525 square meters of resting spaces are used for each mature cow pen and there are 60 free stalls in each pen. Resting space value per animal is adequate (Figure 7). In the third farm, free stalls are not used for 18-24 months heifers and dry cows (-60 to -21). In both close-up dry cow's pen and lactation heifers and cow's pen, alleys and stall widths are below the recommended minimum values. In addition, head to head free stall platform is inadequate for mature cows. There is no brisket locator in the stalls and the stall body space length is not limited. According to the pen length and resting space width, 400 square meters of resting spaces are used for each mature cow pen and there are 60 free stalls in each pen. Resting space value per animal is below the recommended values (Figure 8). Farms are not adequately planned to allow possible changes in the grouping system or animal number and also transfer alleys are ignored in all of the farms.



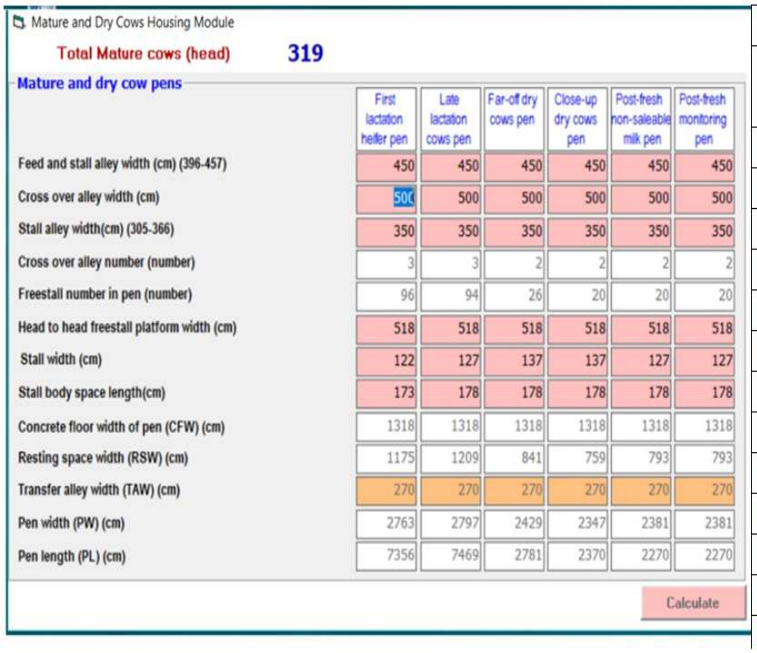
Farm 1	
Pen Details	**Late lactation cows**
Feed and stall alley width (cm) (396-457)	360
Cross over alley width (cm)	110
Stall alley width (cm) (305-366)	300
Cross over alley number (number)	4
Free stall number in pen (number)	115
Head to head free stall platform width (cm)	520
Stall width (cm)	120
Stall body space length (cm)	260
Concrete floor width of pen (cm)	1680
Resting space width (cm)	0
Transfer alley width (cm)	0
Pen width (cm)	1680
Pen length (cm)	5400

Figure 6. Suggested and current designs of the mature and dry cow's pens in the first farm



Farm 2				
Pen Details	Low yield Matu	Mediu m yield Mature	High yield Mature	Peak yield Mature
Feed and stall alley w.	325	325	325	325
Cross over alley width	160	160	160	160
Stall alley width (cm)	325	325	325	325
Cross over alley number	2	2	2	2
Free stall number in pen	60	60	60	60
Head to head free stall	496	496	496	496
Stall width	164	164	164	164
Stall body space length	163	163	163	163
Concrete floor width	1146	1146	1146	1146
Resting space width	1500	1500	1500	1500
Transfer alley width	0	0	0	0
Pen width	2646	2646	2646	2646
Pen length	3500	3500	3500	3500

Figure 7. Suggested and current designs of the mature and dry cow's pens in the second farm



Farm 3		
Pen Details	Close-up dry Cows (-21 to -2)	Lactation heifers and cows
Feed and stall alley width	350	350
Cross over alley width	350	350
Stall alley width	250	250
Cross over alley number	2	2
Free stall number in pen	60	60
Head to head free stall platform	400	400
Stall width (cm)	110	110
Stall body space length(cm)	200	200
Concrete floor width of pen (cm)	1000	1000
Resting space width (cm)	1000	1000
Transfer alley width (cm)	0	0
Pen width(cm)	2000	2000
Pen length (cm)	4000	4000

Figure 8. Suggested and current designs of the mature and dry cow's pens in the third farm

DISCUSSION

In this research, it has been determined that no herd makeup and management plans were prepared prior to the construction of the barns in any of the sample farms. Barns, pens and other service structures were not designed and sized according to a herd makeup plan and management strategy. Animals are not divided into suitable management groups according to their live weight and special needs, while the animal density is high in some pens, there is more space than needed in some pens. The farms also lacked designated special pens, and dry cows were not organized into groups that could cater to their specific requirements; instead, they were randomly placed in available pens. However, there is no suitable infrastructure for herd management strategies that can be developed after the start of production in the farms.

Furthermore, design errors that have a negative impact on animal welfare and productivity were identified, even in relatively modern sample farms that had their projects developed through traditional methods and received rural development support. Notably, none of the farms took into consideration the age groups and live weights of the animals when determining stall dimensions and structural details. They uniformly used the same stall sizes across all pens in the barns. It's worth noting that none of the farms had implemented brisket locators at the freestalls to guide animals into the appropriate position, which resulted in issues such as diagonal lying, injuries, and stall contamination. In the case of the third farm, the stall divider rails were reported to cause severe injuries to the animals, leading to the cancellation of some of these rails for safety reasons.

According to the results of similar research conducted in different regions of Turkey, in the projects implemented in dairy cattle farms, uniform pens are planned according to the total number of animals and not according to a herd management strategy in general. In free-stall barns, stall sizes and the positions of stall elements are not planned according to the management group and live weights of the animals, and stalls with the same dimensions are used in all sections (Bakır, 2002, Bardakçıoğlu ve ark., 2004, Karaman, 2005, Karabacak and Toprak, 2007; Önal ve Özder, 2008, Kaygusuz and Tümer, 2009; Öztürk ve Ünal 2011; Tilki *et al*., 2013). Even in modern farms built in recent years and with various supports, there are design errors that negatively affect the yield and do not allow the improvement of the herd management plan (Bakır and Kibar, 2020; Kılıç *et al*., 2020). In these types of barns, it is challenging to meet the specific needs of the animals. Grouping and breeding are often determined by the limitations of the existing infrastructure (Cook and Nordlund, 2004; Graves *et al*., 2006). Calf hutches, pens for young animals, and other specialized enclosures are typically overlooked, and in cases where they are present, they may not adhere to the technical principles outlined in relevant literature and regulations (Pettersson *et al*., 2001; Nordlund *et al*., 2006; Cook and Nordlund, 2009; Holmes *et al*., 2013; De Rosa *et al*., 2019; Toledo *et al*., 2022). In general, architectural projects for the needs of the sector cannot be produced due to reasons such as not taking into account animal welfare criteria in the planning of barns and other service

structures in farms or lack of sufficient technical knowledge on these issues.

Using an expert system for designing dairy farms is a quick step toward solving these problems. In this way, herd size and makeup plans can be determined and barns can be designed in line with the most appropriate herd management strategy. Thus, barns and other structures (milking unit, manure and feed storages) can be designed to meet both current and future needs of the farm. The infrastructure requirements of all groups in the herd will be met, and the negativities arising from architectural errors in the pens will be prevented. By planning the pen and free stall details separately for each management group, injuries and pollution caused by architectural errors such as diagonal lying at free stalls can be prevented. Especially in young animal barns and special needs pens, preventing competition in food and water access and reducing stress in animals. In addition, it will contribute to the prevention of the spread of infectious disease and the ventilation efficiency. On the other hand, information technologies will enable the production of projects in accordance with scientific principles, the reduction of project preparation / control time and cost, and the prevention of technical or human-induced errors.

Conclusion: By adding quantity-discovery/cost modules to expert systems or different artificial intelligence applications to be developed, alternative designs can be evaluated before they are built. Thus, the approximate cost of the investment can be determined and cost analysis can be made in terms of structural aspects. With the production of ideal projects, the efficiency of the use of investments and supports will be increased, and sustainable and high-efficiency animal production will contribute. In existing farms, it is important in terms of determining the problems arising from structural errors and offering solutions.

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