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Software for planning loose yards and designing concrete constructions for dairy farms in arid and semi-arid zones

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Abstract

To plan and design dairy housing, several calculations should be made; this requires time and efforts, with the possibility of making mistakes. The objectives of this paper are to develop a tool to assist the designers in planning and designing dairy housing in arid and semi-arid zones, to save time and efforts, and to provide a new design model. Two mathematical models were developed to plan and design corral systems and the required concrete constructions. Subsequently, an electronic spark map (decision tree) was developed for each mathematical model, and then the mathematical models were integrated into the electronic spark maps. Afterwards, C# (C Sharp) programming language was used to develop the software by integrating the electronic spark maps, and making the user interface. The developed software is able to plan and design the housing system (corrals system), specify corrals and house dimensions, and compute the required amounts of construction materials (iron rods, cement, sand, and gravels) to build the required concrete base. Furthermore, it calculates the capital investment and the fixed, variable, and total costs of the construction. Data of 6 dairy farms were used to validate the model, and to evaluate the software. The differences between actual and calculated values were determined, and the standard deviations were calculated. The coefficients of variation (COVs) range between 3% and 7%.

Key words: Arid zones, Dairy farms, Loose yards, Mathematical modeling, Precision livestock farming

Introduction

An open housing system, in hot climates, consists of a yard shaded by a roof. This system allows air to move in the space between the roof and the floor performing natural ventilation which enhances dairy cows' microclimate especially by increasing the cowshed height to 8 m (Hatem et al., 2006). Walthes and Charles (1994) stated that yards or corral systems are used in hot climates and they allow 46 to 56 m^2 per cow; on the other hand, Hatem et al. (2004a,b) and Samer (2004) stated that the standard value is 20 to 25 m^2 per cow. Samer (2010a) investigated and compared three dairy corral designs with 25 m^2 per cow for each design. Samer et al. (2007) developed a dairy farm foundation model. Ahachad et al. (2008) mentioned the most influential parameters on heat stress, which are: ventilation, shape, orientation, number of occupants etc. An important key issue is the area allotted per animal which when increased -up to some limits- the stress decreases. Bartali (1999) stated that reinforced concrete is obtained by adequately mixing in specific proportions aggregates (gravel and sand), cement, and water. Lindley and Whitaker (1996) elucidated that water : cement ratio is 0.53 l/kg and cement : sand : gravel mass ratio is 1:2.2:3.7 for floors, driveways, structural beams, and columns.

In order to accelerate analyses and improve on-farm decision-making, it is necessary to develop computer tools that have the ability to preprocess the data so as to produce value-added information (Lacroix et al., 1998). The common form of an expert system is a computer program, with a set of rules or equations that analyzes information or data supplied by the user, about a specific problem, and recommends one or more courses of user action.

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The expert system may also provide mathematical analysis of the problem (Giarratano and Riley, 2005).

The objective of this study is to develop software to plan and design corral systems and the required concrete constructions, to compute the required amounts of construction materials, and to calculate the costs.

Materials and Methods

The tool is developed by integrating two mathematical models into two electronic spark maps. The mathematical models were developed using the plans, designs, parameters, variables, and constant values of corral systems and the concrete structures available in the references. Subsequently, MS-Excel is used to develop the electronic spark maps of the mathematical models, and to show the results of the input settings automatically.

Afterwards, C# language (C#, 2005), which is an object-oriented programming language, was used to develop the software by integrating the electronic spark maps of the mathematical models to form the back diagram code of the software, and then to develop the user interface. This methodology represents a new approach for developing programs using decision trees and mathematical models for practical implementation.

The software was validated and evaluated using data of 6 Egyptian dairy farms, as examples of dairy farms in arid and semi-arid zones. The relative differences between actual values and calculated values were determined for corral and house dimensions, concrete base dimensions, concrete volume, gravels volume, cement mass, sand volume, and iron rods mass, and then the averages of relative differences were computed. Subsequently, the standard deviations (σ) and the coefficients of variation (COV) were determined.

Design model

The objective of making a design model (DM) is to assist the designers in designing the corrals. The following mathematical model was developed to be the core of the software (for nomenclature see Tables 1 through 4):

Corral dimensions

$$W_C = N_{CC} \times (\frac{1}{N_{CFP}}) \times L_{FB} \quad (1)$$

$$A_C = N_{CC} \times A_{AC} \quad (2)$$

$$L_C = \frac{A_C}{W_C} \quad (3)$$

$$N_{HC} = \frac{N_{CH}}{N_{CC}} \quad (4)$$

where, $4 \le W_C \le 15$ (5)

$$10 \le N_{CC} \le 15 \quad (6)$$

$$1 \le N_{CFP} \le 3 \quad (7)$$

$$0.75 \le L_{FB} \le 0.95 \quad (8)$$

$$20 \le A_{AC} \le 25 \quad (9)$$

The available corral systems are: two sides of corrals, one side of corrals, and one corral where the suitable roof structure for each corral system was presented by Samer et al. (2008, 2008a, 2012). The shade structure should provide 85% shading, i.e. the roof should shade 85% of the corral/yard area (Samer, 2010b,c). If planning several cowsheds in the same farm, it is recommended to consider the farm planning method developed by Samer et al. (2008b), where it is preferred that the sheds have the same orientation (east-west in hot climates) with at least 30 m between any two adjacent sheds. Each corral system has its own mathematical model, but the same general information should be considered for the three systems:

$$0.15 \le W_{RC} \le 0.20 \quad (10)$$

$$0.15 \le W_{BB} \le 0.20 \quad (11)$$

$$W_{LB} = F(\text{feeding system}) \quad (12)$$

$$W_{FP} = F(\text{breed, manure handling system}) \quad (13)$$

The feeding places are parts of the corral. Thus, (W_{FP}) is part of (L_C).

Two sides of corrals

This corral system is suitable for large group size (Figure 1), and it has one concrete base (Figure 2), thus:

$$W_{CB} = W_{LB} + (2 \times W_{FP}) + (2 \times W_{BB}) + (2 \times W_{RC}) \quad (14)$$

$$L_H = \frac{N_{HC} \times W_C}{2} \quad (15)$$

$$W_H = (2 \times L_C) + W_{LB} \quad (16)$$

$$A_H = L_H \times W_H \quad (17)$$

if $L_C > 10$, then $H_C = 8$ (18)

if $5 \le L_C \le 10$, then $H_C = 5$ (19)

if $L_C < 5$, then $H_C = 3.5$ (20)

where, N_{HC} is an even positive number.

One side of corrals

This corral system is suitable for medium group size (Figure 3), and it has one concrete base (Figure 4), thus:

$$W_{CB} = W_{LB} + W_{FP} + W_{BB} + W_{RC} \quad (21)$$

$$L_H = N_{HC} \times W_C \quad (22)$$

$$W_H = L_C + W_{LB} \quad (23)$$

$$A_H = L_H \times W_H \quad (24)$$

if $L_C > 20$, then $H_C = 8$ (25)

if $10 \le L_C \le 20$, then $H_C = 5$ (26)

if $L_C < 10$, then $H_C = 3.5$ (27)

where, N_{HC} is a natural number

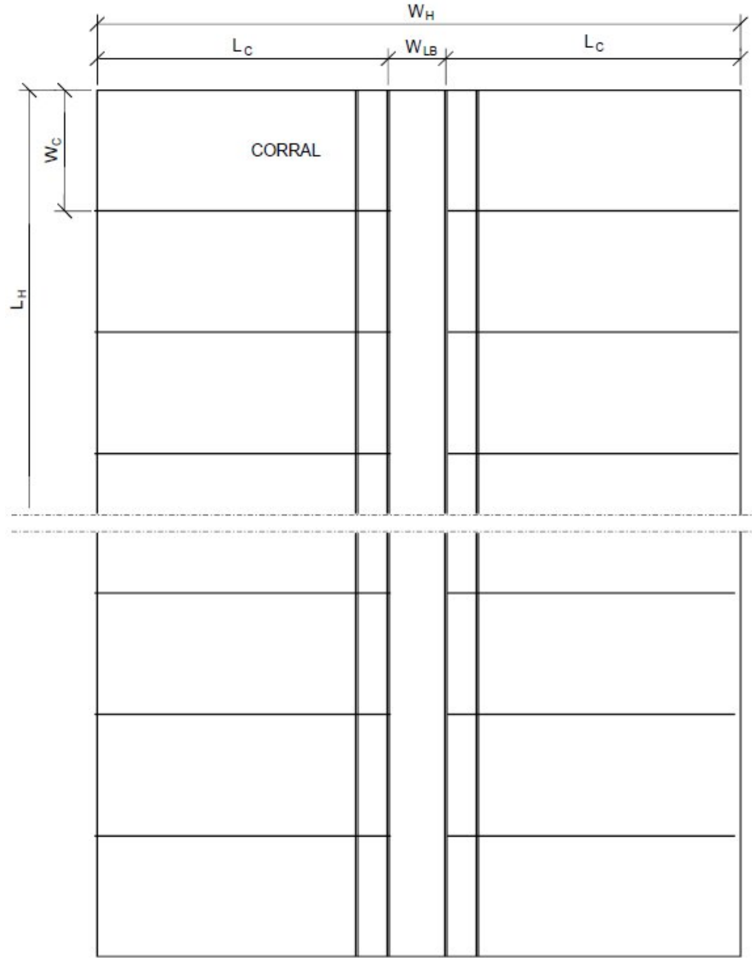


Figure 1. Two sides of corrals.

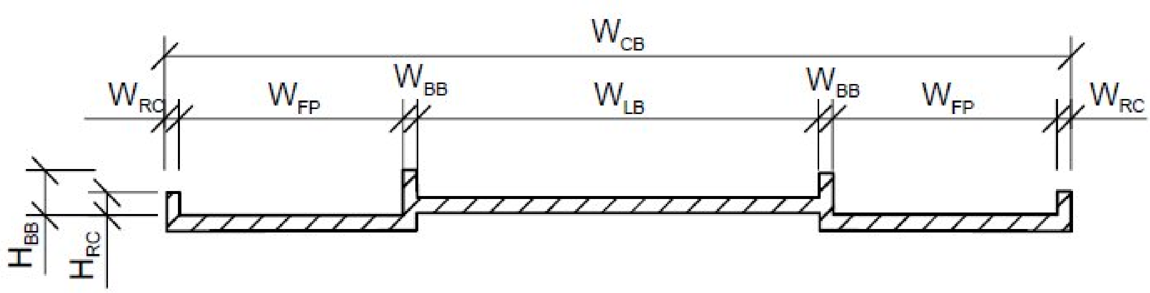


Figure 2. Concrete base for two sides of corrals.

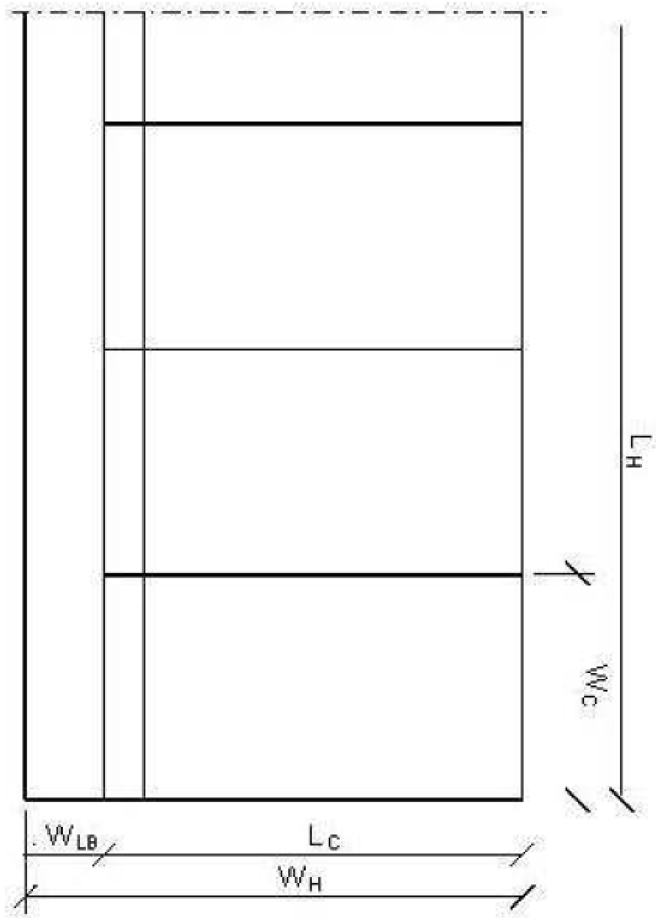


Figure 3. One side of corrals.

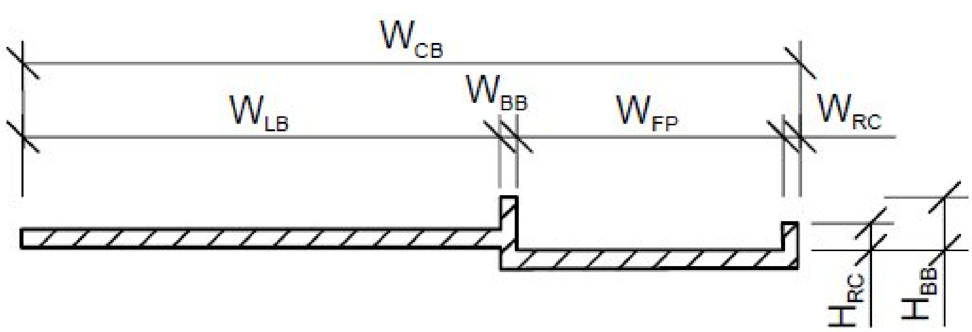


Figure 4. Concrete base for one side of corrals.

One corral

This corral system is suitable for a small group of 10-15 cows (Figure 5), and it has one concrete base (Figure 6), thus:

$$W_{CB} = W_{LB} + W_{FP} + W_{BB} + W_{RC} \quad (28)$$

$$L_H = (N_{HC} \times L_C) + W_{LB} \quad (29)$$

$$W_H = W_C \quad (30)$$

$$A_H = L_H \times W_H \quad (31)$$

if $10 \le W_C$, then $H_C = 5$ (32)

if $W_C < 10$, then $H_C = 3.5$ (33)

where,

$$N_{HC} = 1 \quad (34)$$

$$N_{CH} = N_{CC} \quad (35)$$

$$10 \le N_{CC} \le 15 \quad (36)$$

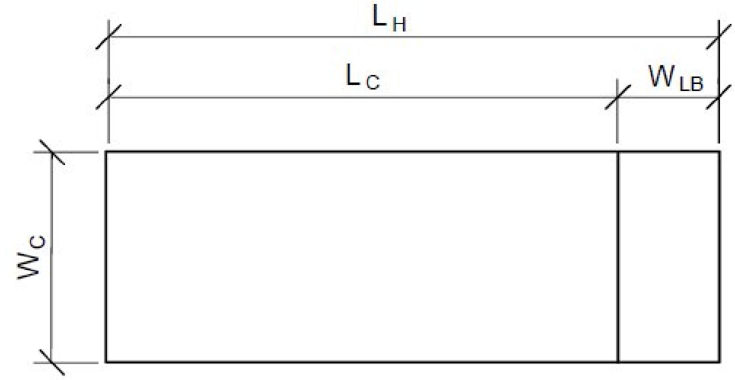


Figure 5. One corral.

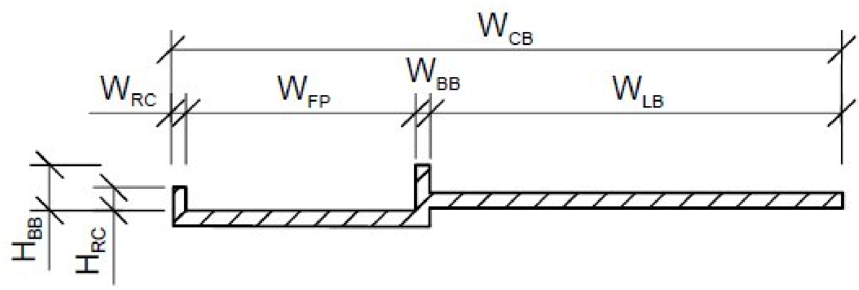


Figure 6. Concrete base for one corral.

Decision making

The designer should gather the climatic data of the location where the dairy farm will be established, such as: precipitation (mm/year), wind speed (m/s), wind direction, mean maximum temperature (^{o}C), relative humidity (%), and sunshine (%). Then, he should make a decision to select one of the following options:

Roof materials

- If Wind Speed < 1.8 m/s and Precipitation < 80 mm/year, then:
Reed Mats, or Straw Mats
- If Wind Speed > 1.8 m/s and Precipitation > 80 mm/year, then:
Polished Aluminum (Reflection 90 - 70%)
or Isolated Aluminum, Burnt-Clay Bricks,
or Concrete (expensive), or Wood (available?)

Construction materials

- Steel Construction (recommended)
- Concrete Construction (expensive)
- Wood Construction (available?)

Orientation

- East-West (recommended in hot climates)
- North-South

Floor materials

- Feeding Place: Concrete
- Laying Place: Sand, or Chopped Straw

Shade calculations

$$A_{FP} = L_{FP} \times W_{FP} \quad (37)$$

$$R_A = \frac{A_{FP}}{A_C} \quad (38)$$

$$A_{SHF} = A_H \times R_A \times \left(\frac{S_F}{100}\right) \quad (39)$$

$$A_{SHL} = A_H \times (1 - R_A) \times \left(\frac{S_L}{100}\right) \quad (40)$$

$$A_{SH} = A_{SHF} + A_{SHL} \quad (41)$$

$$W_{SH} = \frac{A_{SH}}{L_{SH}} \quad (42)$$

where, $L_{SH} = L_H$ (43)

$W_{FP} = F$(breed, manure handling system) (44)

Facilities

$$N_{HF} = \frac{N_{CF}}{N_{CH}} \quad (45)$$

$$A_{tF} = (N_{HF} \times A_H) + A_M + A_{MC} + A_{FS} + A_O \quad (46)$$

Concrete base model

The objective of making such a model is to determine the values of the concrete base dimensions which lead to calculate the concrete base volume, and then the required amount of cement, iron rods, sand, and gravels. The model is also able to calculate the capital investment and the fixed, variable, and total costs.

Concrete base volume

The dimensions of the concrete base have been calculated by DM, but still the thickness and the volume:

Two sides of corrals

$$L_{CB} = L_H \quad (47)$$

$$V_{LB} = L_{CB} \times W_{LB} \times T_{LB} \quad (48)$$

$$V_{BB} = 2 \times L_{CB} \times W_{BB} \times H_{BB} \quad (49)$$

$$V_{FP} = 2 \times L_{CB} \times (W_{FP} + W_{BB} + W_{RC}) \times T_{FP} \quad (50)$$

$$V_{RC} = 2 \times L_{CB} \times W_{RC} \times H_{RC} \quad (51)$$

$$V_{CB} = V_{LB} + V_{BB} + V_{FP} + V_{RC} \quad (52)$$

where, $T_{LB} = F$(feeding system) (53)

$T_{FP} = F$(breed) (54)

$$H_{BB} = 0.50 \quad (55)$$

$$0.20 \le H_{RC} \le 0.25 \quad (56)$$

One side of corrals

$$L_{CB} = L_H \quad (57)$$

$$V_{LB} = L_{CB} \times W_{LB} \times T_{LB} \quad (58)$$

$$V_{BB} = L_{CB} \times W_{BB} \times H_{BB} \quad (59)$$

$$V_{FP} = L_{CB} \times (W_{FP} + W_{BB} + W_{RC}) \times T_{FP} \quad (60)$$

$$V_{RC} = L_{CB} \times W_{RC} \times H_{RC} \quad (61)$$

$$V_{CB} = V_{LB} + V_{BB} + V_{FP} + V_{RC} \quad (62)$$

One corral

$$L_{CB} = W_H \quad (63)$$

$$V_{LB} = L_{CB} \times W_{LB} \times T_{LB} \quad (64)$$

$$V_{BB} = L_{CB} \times W_{BB} \times H_{BB} \quad (65)$$

$$V_{FP} = L_{CB} \times (W_{FP} + W_{BB} + W_{RC}) \times T_{FP} \quad (66)$$

$$V_{RC} = L_{CB} \times W_{RC} \times H_{RC} \quad (67)$$

$$V_{CB} = V_{LB} + V_{BB} + V_{FP} + V_{RC} \quad (68)$$

Building materials

$$M_C = C \times V_{CB} \quad (69)$$

$$V_G = G \times V_{CB} \quad (70)$$

$$V_S = S \times V_{CB} \quad (71)$$

where, $C = 325$ (72)

$$G = 0.8 \quad (73)$$

$$S = 0.4 \quad (74)$$

The different types of iron rods (NØD/m, where N is the number of iron rods per meter length, and D is the diameter of the iron rod) used to make such concrete bases are 6Ø6/m and 6Ø8/m:

$$N_{IL} = [(N_{IML} \times W_{CB}) + 1] \times 1.05 \times L_{CB} \quad (75)$$

$$N_{IW} = [(N_{IML} \times L_{CB}) + 1] \times 1.05 \times W_{CB} \quad (76)$$

$$N_{tIG} = N_{IL} + N_{IW} \quad (77)$$

$$N_{tI} = N_G \times N_{tIG} \quad (78)$$

$$N_{tSI} = \frac{N_{tI}}{L_{SI}} \quad (79)$$

$$M_I = N_{tSI} \times M_{IML} \times L_{SI} \quad (80)$$

where, $L_{SI} = 12$ (81)

if $N\phi D/m = 6\phi 6/m$, then $M_{IML} = 0.666$ (82)

if $N\phi D/m = 6\phi 8/m$, then $M_{IML} = 0.888$ (83)

The factor 1.05 is used to consider the interference between the iron rods. The standard iron rods are cut to shorter iron rods with a length of 1 m, they are then used to build up the concrete base.

Costs calculation

$$P_{tC} = P_C \times M_C \quad (84)$$

$$P_{tG} = P_G \times V_G \quad (85)$$

$$P_{tS} = P_S \times V_S \quad (86)$$

$$P_{tI} = P_I \times M_I \quad (87)$$

$$C_{tEC} = C_{EC} \times V_{CB} \quad (88)$$

$$C_{ICB} = P_{tC} + P_{tG} + P_{tS} + P_{tI} + C_{tEC} \quad (89)$$

$$C_{FCB} = \frac{C_{ICB}}{t_P} \quad (90)$$

$$C_{TCB} = C_{FCB} + C_{VCB} \quad (91)$$

where, $t_P = 20$ (92)

The Feeding Bunk(s) may be covered by a chemical material to prevent cow injuries. This operation may be carried out in a determined time interval. The costs of this operation are considered as part/whole value of C_{VCB}.

Results and Discussion

Spark maps

The spark map of the design model and the spark map of the concrete base model constitute the back diagram code of the software. The spark maps require some input data (Tables 1 and 2); however, the spark maps are empowered by a range of values for each required input data in order to help the designer/user in determining the required values. According to the inserted input data by the designer/user, the spark maps will compute the output data (Tables 3 and 4) using the mathematical models.

Table 1. Input data of the spark map of the design model.

Symbol	Description	Unit
N_{CF}	Number of Cows in Farm	
N_{CH}	Number of Cows in One House	
N_{CC}	Number of Cows in One Corral	
N_{CFP}	Cows per Feeding Place	
L_{FB}	Feeding Bunk Length	m/cow
A_{AC}	Allotted Area per Cow	m^2/cow
	Corrals Distribution (one or two sides of corrals, or one corral)	
W_{LB}	Width of Feeding Line & Feeding Bunk(s)	m
W_{FP}	Width of One Side of Feeding Places	m
W_{BB}	Width of Brisket Board	m
W_{RC}	Width of Rear Curb	m
L_{FP}	Length of One Side of Feeding Places in One Corral	m
W_{FP}	Width of One Side of Feeding Places	m
L_{SH}	Shade Length	m
S_F	Shade for Feeding	%
S_L	Shade for Laying	%
A_O	Office Area	m^2
A_H	Area of One House	m^2
A_{FS}	Forage Storage Area	m^2
A_{MC}	Area of Milking Center	m^2
A_M	Manure Lagoons/Tanks Area	m^2
	Construction Material (Steel or Concrete)	
	Cowshed Orientation (East-West, North-South, or Others)	
	Floor Material (Concrete, Sand, or Chopped Straw)	
	Roof Material (Reed, Straw, Aluminum, or Concrete)	
	Climate Conditions	

Table 2. Input data of the spark map of the concrete base model.

Symbol	Description	Unit
	Corrals Distribution (one or two sides of corrals, or one corral)	
L_{CB}	Concrete Base Length	m
W_{LB}	Width of Feeding Line & Feeding Bunks	m
W_{FP}	Width of One Side of Feeding Places	m
W_{RC}	Width of Rear Curb	m
W_{BB}	Width of Brisket Board	m
T_{LB}	Concrete Base Thickness (Feeding Line & Feeding Bunks)	m
T_{FP}	Concrete Base Thickness (Feeding Places)	m
H_{BB}	Height of Brisket Board	m
H_{RC}	Height of Rear Curb	m
	Type of Iron Rods (NØD/m: 6Ø6/m or 6Ø8/m)	
N_{IML}	Number of Iron Rods per One Meter Length of Concrete	
N_G	Number of Gridirons	
L_{SI}	Length of One Standard Iron Rod	m
M_{IML}	Mass of 1 m Long of Iron Rod	kg/m
P_G	Price of 1 m^3 Gravels	Currency/m^3
P_C	Price of 1 kg Cement	Currency/kg
P_S	Price of 1 m^3 Sand	Currency/m^3
C_{EC}	Employment Costs for 1 m^3 of Concrete	Currency/m^3
P_I	Price of One Ton of Iron Rods	Currency/Ton
t_P	Project Lifetime	Year
C_{VCB}	Variable Costs of Concrete Base	Currency/Year

Table 3. Output data of the spark map of the design model.

Symbol	Description	Unit
L_C	Corral Length	m
W_C	Corral Width	m
A_C	Corral Area	m^2
N_{HC}	Number of Corrals in One House	
W_{CB}	Concrete Base Width	m
A_H	Area of the House	m^2
W_H	House Width	m
L_H	House Length	m
H_C	Cowshed Height	m
A_{FP}	Area of One Side of Feeding Places in One Corral	m^2
R_A	Ratio of Feeding Area to Corral Area	
W_{SH}	Shade Width	m
A_{SHL}	Shade Area for Laying	m^2
A_{SHF}	Shade Area for Feeding	m^2
A_{SH}	Shade Area	m^2
N_{HF}	Number of Houses in Farm	
A_{tF}	Total Area of Farm Facilities	m^2

Table 4. Output data of the spark map of the concrete base model.

Symbol	Description	Unit
W_{CB}	Concrete Base Width	m
V_{FP}	Concrete Volume of the Feeding Places	m^3
V_{RC}	Concrete Volume of the Rear Curbs	m^3
V_{LB}	Concrete Volume of the Feeding Line & the Feeding Bunks	m^3
V_{BB}	Concrete Volume of the Brisket Boards	m^3
V_{CB}	Total Volume of the Concrete Base	m^3
V_G	Gravels Volume	m^3
M_C	Cement Mass	kg
V_S	Sand Volume	m^3
N_{IL}	Number of Iron Rods in Length	
N_{IW}	Number of Iron Rods in Width	
N_{tIG}	Total Number of Iron Rods in One Gridiron	
N_{tI}	Total Number of Iron Rods	
N_{tSI}	Total Number of Standard Iron Rods	
M_I	Iron Mass	Ton
P_{tI}	Total Price of Iron Rods	Currency
P_{tG}	Total Price of Gravels	Currency
P_{tC}	Total Price of Cement	Currency
P_{tS}	Total Price of Sand	Currency
C_{tEC}	Total Employment Costs of Concrete	Currency
C_{ICB}	Capital Investment of Concrete Base	Currency
C_{FCB}	Fixed Costs of Concrete Base	Currency/Year
C_{TCB}	Total Costs of Concrete Base	Currency/Year

Software

The developed software is able to plan and design dairy housing systems (corrals systems), specify corrals and house dimensions, and compute the required amounts of construction materials (iron rods, cement, sand, and gravels) to build the required concrete base. Furthermore, it calculates the capital investment and the fixed, variable, and total costs. However, 2 user interfaces (Figures 7 and 8) were developed in order to be used to insert the input data into the electronic spark maps. The output data of both spark maps will be shown in 2 separated windows (Figures 9 and 10).

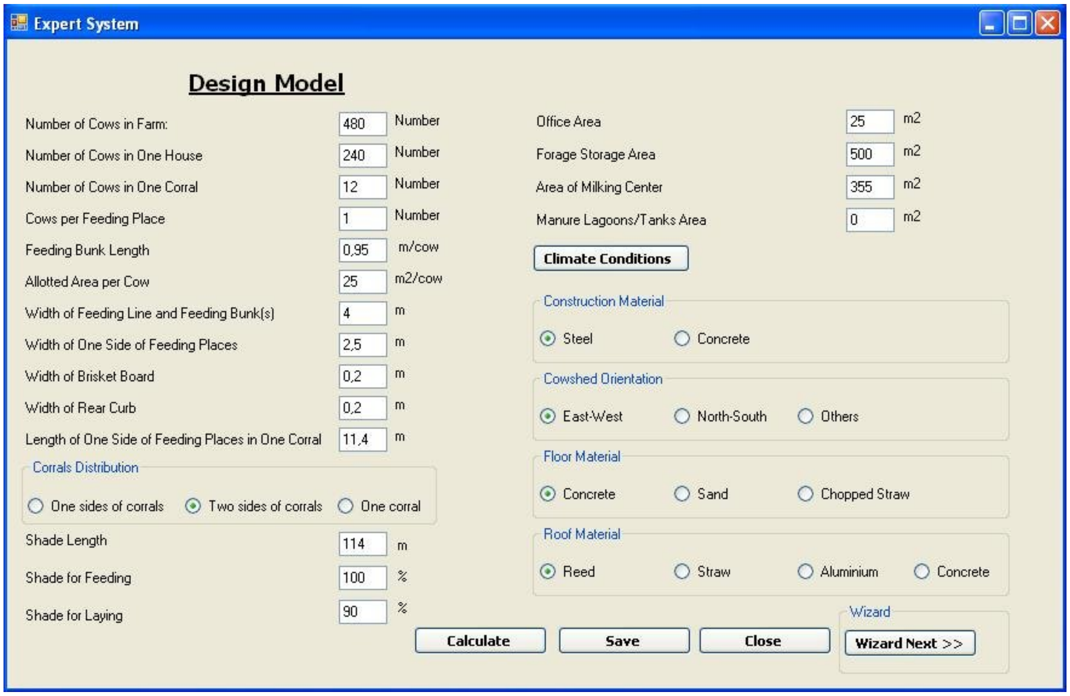


Figure 7. User interface of the input data of the design model.

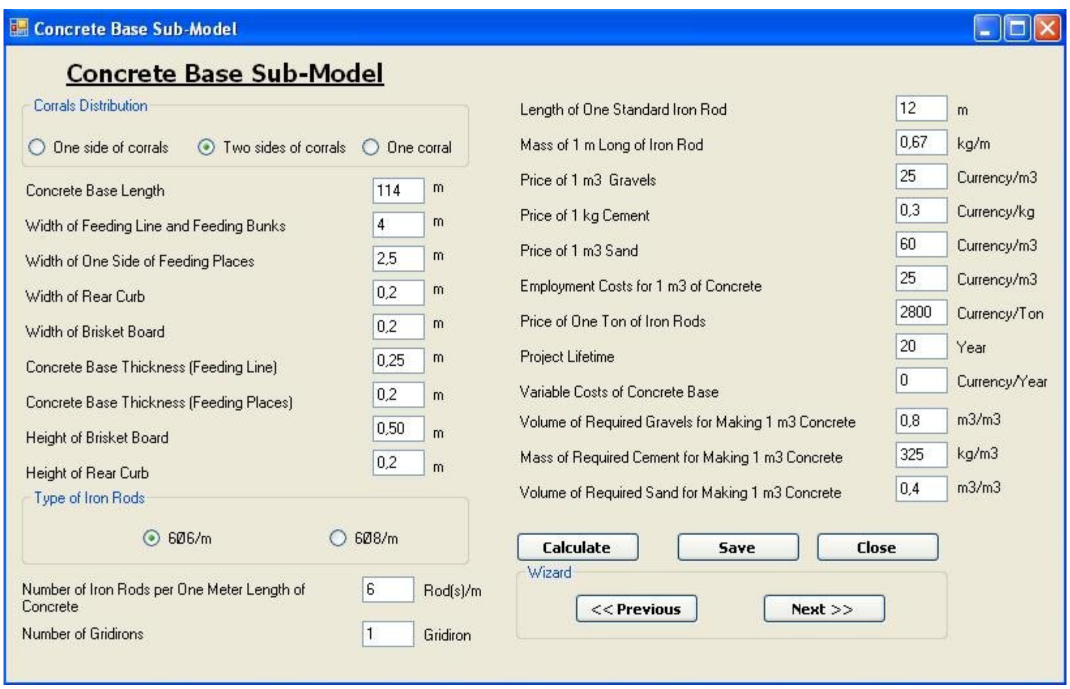
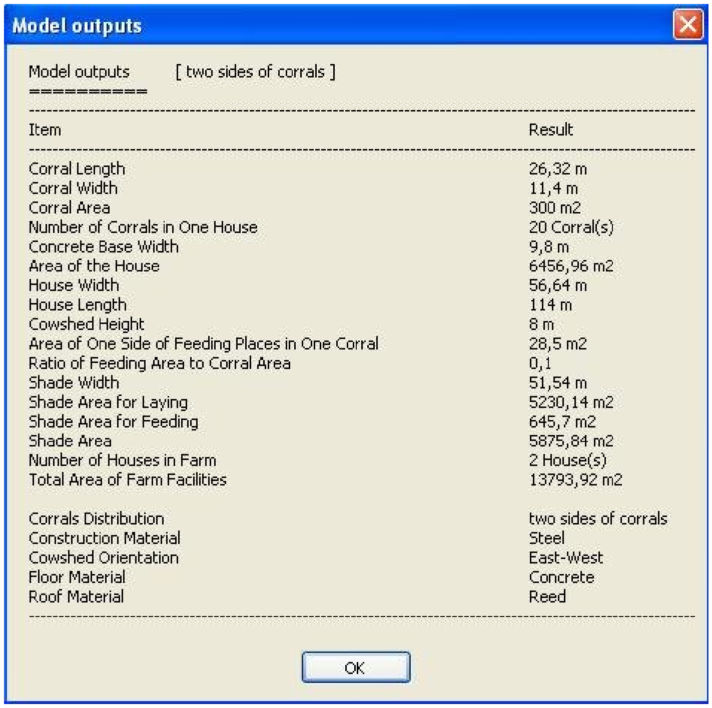


Figure 8. User interface of the input data of the concrete base model.



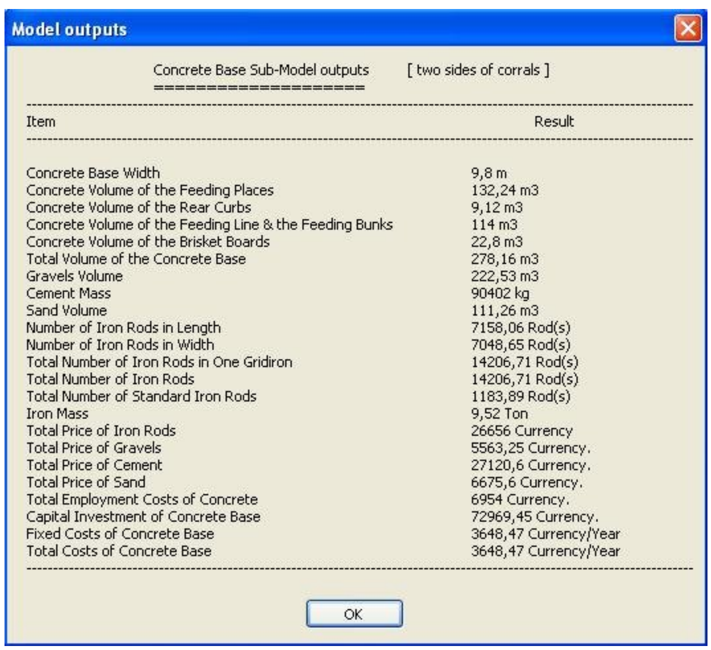
Model outputs

Model outputs [two sides of corrals]

Item	Result
Corral Length	26,32 m
Corral Width	11,4 m
Corral Area	300 m2
Number of Corrals in One House	20 Corral(s)
Concrete Base Width	9,8 m
Area of the House	6456,96 m2
House Width	56,64 m
House Length	114 m
Cowshed Height	8 m
Area of One Side of Feeding Places in One Corral	28,5 m2
Ratio of Feeding Area to Corral Area	0,1
Shade Width	51,54 m
Shade Area for Laying	5230,14 m2
Shade Area for Feeding	645,7 m2
Shade Area	5875,84 m2
Number of Houses in Farm	2 House(s)
Total Area of Farm Facilities	13793,92 m2
Corrals Distribution	two sides of corrals
Construction Material	Steel
Cowshed Orientation	East-West
Floor Material	Concrete
Roof Material	Reed

OK

Figure 9. User interface of the output data of the design model.



Model outputs

Concrete Base Sub-Model outputs [two sides of corrals]

Item	Result
Concrete Base Width	9,8 m
Concrete Volume of the Feeding Places	132,24 m3
Concrete Volume of the Rear Curbs	9,12 m3
Concrete Volume of the Feeding Line & the Feeding Bunks	114 m3
Concrete Volume of the Brisket Boards	22,8 m3
Total Volume of the Concrete Base	278,16 m3
Gravels Volume	222,53 m3
Cement Mass	90402 kg
Sand Volume	111,26 m3
Number of Iron Rods in Length	7158,06 Rod(s)
Number of Iron Rods in Width	7048,65 Rod(s)
Total Number of Iron Rods in One Gridiron	14206,71 Rod(s)
Total Number of Iron Rods	14206,71 Rod(s)
Total Number of Standard Iron Rods	1183,89 Rod(s)
Iron Mass	9,52 Ton
Total Price of Iron Rods	26656 Currency
Total Price of Gravels	5563,25 Currency.
Total Price of Cement	27120,6 Currency.
Total Price of Sand	6675,6 Currency.
Total Employment Costs of Concrete	6954 Currency.
Capital Investment of Concrete Base	72969,45 Currency.
Fixed Costs of Concrete Base	3648,47 Currency/Year
Total Costs of Concrete Base	3648,47 Currency/Year

OK

Figure 10. User interface of the output data of the concrete base model.

Model validation

Data of 6 Egyptian dairy farms were used to perform the model validation and the software evaluation. The farms were: (1) El-Tobgy Farms which housed 480 cows and located in El-Fayoum; (2) Dina Farms -sector 1- which housed 600 cows and located at Cairo-Alexandria desert road; (3) Dina Farms -sector 2- which housed 700 cows and located at Cairo-Alexandria desert road; and three other small dairy farms where their data were acquired from the Cattle Information System of Egypt (CISE). The statistical analysis of the actual and calculated values (Table 5) elucidated that the COVs were 2.90% (σ = 0.01), 5.54% (σ = 0.03), 4.12% (σ = 0.01), 7.31 % (σ = 0.13), and 3.59% (σ = 0.03) for the amounts of concrete, gravels, cement, sand, and iron rods, respectively.

Safety emphasis

Unlike the traditional methods therewith making mistakes is possible, using this software diminishes the possibility of making mistakes and, therefore, improving safety. Further, this paper provides a new tool for planning and designing dairy housing in hot climates, where using a preset tool enhances safety measures. On the other hand, this tool is validated using actual data in order to assure high safety levels and to uproot system errors.

Future developments

For future developments, it would be wise to undertake agro-ecological evaluation of the different housing systems developed in this study with the methodology developed by Albino and Callado (2012). The main objective is to evaluate the environmental impact of these housing systems using the "Emergy Analysis". For this purpose, input data as materials, services, natural renewable/nonrenewable sources are required, where the analysis will be based on energy flows, transforming all inputs and outputs in a common unit.

Conclusions

Two mathematical models were developed to plan and design dairy housing systems (corrals systems) and the required concrete constructions. Subsequently, an electronic spark map (decision tree) was developed for each mathematical model, and then the mathematical models were integrated into the electronic spark maps. Afterwards, C# programming language was used to develop the software by integrating the electronic spark maps into one software program, using the spark maps to form the back diagram code of the software, and making the user interface to ease the use of the program. This method represents a new approach for developing software programs by using the mathematical models for practical implementation. The software is able to plan and design corrals systems, specify corrals and house dimensions, and compute the required amounts of construction materials (iron rods, cement, sand, and gravels) to build the required concrete base. Furthermore, it calculates the capital investment and the fixed, variable, and total costs of the constructions. Data of 6 dairy farms were used to validate the model, and to evaluate the software. The coefficients of variation (COVs) range between 3% and 7%. Further research to be suggested, is to implement similar methodology for developing software for planning and designing several dairy farm facilities (milking parlor, forage storage etc.,). This further research is a part of our project that next step is to develop software for the aforementioned farm facilities.

Table 5. Model validation.

	Parameter	L_C	W_C	N_{HC}	W_{CB}	V_{CB}	V_G	M_C	V_S	M_I
Farm 1	Actual Value	26.15	11.52	20	9.80	282.50	225.98	91415	114.50	9.64
	Calculated Value	26.32	11.40	20	9.80	278.16	222.53	90402	111.26	9.52
Farm 2	Actual Value	22.50	9.00	20	9.60	194.06	155.19	62785	78.50	7.38
	Calculated Value	22.22	9.00	20	9.60	193.05	154.44	62741	77.22	7.32
Farm 3	Actual Value	21.50	20.50	1	4.70	23.52	18.82	7609	9.52	1.06
	Calculated Value	22.00	20.00	1	4.70	23.40	18.72	7605	9.36	1.05
Farm 4	Actual Value	23.50	17.00	1	4.20	24.87	19.91	8049	10.07	1.00
	Calculated Value	23.53	17.00	1	4.20	24.75	19.80	8043	9.90	0.99
Farm 5	Actual Value	35.50	14.20	1	3.65	27.16	21.74	8789	11.03	1.22
	Calculated Value	35.29	14.17	1	3.65	27.03	21.62	8783	10.81	1.21
Farm 6	Actual Value	28.10	9.60	6	6.90	95.97	76.79	31060	38.90	3.41
	Calculated Value	28.13	9.60	6	6.90	95.50	76.40	31037	38.20	3.38

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