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Livestock Systems Engineering
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**An expert system for planning and designing
dairy farms in hot climates**

Dissertation

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Abbreviations, Units, and Symbols

Symbol	Description
A_{AC}	Allotted Area per Cow (m^2/cow)
A_C	Corral Area (m^2)
A_{CBP}	Area of Concrete Base of Milking Parlor (m^2)
A_{CP}	Area of Cow Platform of Milking Parlor (m^2)
A_{CCY}	Allotted Area per Cow in Collecting Yard of Milking Parlor (m^2/cow)
A_{CY}	Area of collecting Yard of Milking Parlor (m^2)
A_{EA}	Area of Entry Alley of Milking Parlor (m^2)
A_{FEA}	Area of Front Exit Alley of Milking Parlor (m^2)
A_{FP}	Area of One Side of Feeding Places in One Corral (m^2)
A_{FS}	Forage Storage Area (m^2)
A_H	House Area (m^2)
A_M	Manure Lagoons/Tanks Area (m^2)
A_{MC}	Area of Milking Center (m^2)
A_{MPR}	Area of Milking Parlor Rooms (m^2)
A_{MR}	Area of Milk Room (m^2)
A_{MRP}	Area of Machinery Room of Milking Parlor (m^2)
A_{MT}	Manure Tank Area (m^2)
A_O	Office Area (m^2)
A_P	Piles Area (m^2)
A_{PHS}	Area of Concrete Plot of Horizontal Silo (m^2)
A_{PM}	Area of Milking Parlor (m^2)
A_{PR}	Area of Personnel Room of Milking Parlor (m^2)
A_{PS}	Area of Concrete Sides of Milking Parlor (m^2)
A_R	Roof Area (m^2)
A_{RA}	Area of Return Alley of Milking Parlor (m^2)
A_{RM}	Surface Area of One Reed Mat (m^2)
A_{SH}	Shade Area (m^2)
A_{SHF}	Shade Area for Feeding (m^2)
A_{SHL}	Shade Area for Laying (m^2)
A_{SM}	Surface Area of One Straw Mat (m^2)
A_{tCL}	Total Area of Required Concrete Layer for Milking Center (m^2)
A_{tF}	Total Area of Farm Facilities (m^2)
A_{tFA}	Farm Total Area (ha)
A_{tPA}	Total Area of Cow Platforms and Alleys of Milking parlor (m^2)
C	Mass of Required Cement for Making 1 m^3 Concrete (kg/m^3)
CBM	Concrete Base Sub-Model
CBMIS	Computer-Based Management Information System
C_{DPW}	Costs of Depth Perception of a Well (Currency/m)
C_{EC}	Employment Costs for 1 m^3 of Concrete (Currency/ m^3)
C_{ECS}	Employment Costs of Cooling System (Currency)
C_{FAB}	Fixed Costs of All Cow Buildings (Currency/Year)
C_{FAS}	Fixed Costs of Aeration Storage (Currency/Year)
C_{FB}	Fixed Costs of Building (Currency/Year)
C_{FC}	Fixed Costs of Cows (Currency/Year)
C_{FCB}	Fixed Costs of Concrete Base (Currency/Year)
C_{FCC}	Fixed Costs of Milking Center Constructions (Currency/Year)
C_{FCF}	Fixed Costs of Farm Constructions (Currency/Year)
C_{FCH}	Fixed Costs of Concrete Construction of Horizontal Silo (Currency/Year)
C_{FCM}	Fixed Costs of Concrete Constructions of Milking Center (Currency/Year)
C_{FCS}	Fixed Costs of Cooling System (Currency/Year)

C_{FEG}	Fixed Costs of Farm Electricity Consumption from Governmental Supply (Currency/Year)
C_{FF}	Fixed Costs of the Farm (Currency/Year)
C_{FFC}	Fixed Costs of Forage Storage Constructions (Currency/Year)
C_{FFF}	Fixed Costs of Farm Fence (Currency/Year)
C_{FFS}	Fixed Costs of Feeding System (Currency/Year)
C_{FG}	Fixed Costs of One Electric Generator (Currency/Year)
C_{FGS}	Total of fixed costs of the generators (Currency/Year)
C_{FL}	Fixed Costs of Land (Currency/Year)
C_{FLS}	Fixed Costs of Liquid Storage (Currency/Year)
C_{FMC}	Fixed Costs of Manure Handling/Constructions (Currency/Year)
C_{FMH}	Fixed Costs of Manure Handling System (Currency/Year)
C_{FMM}	Fixed Costs of Manure Mechanical System (Currency/Year)
C_{FMS}	Fixed Costs of Milking System (Currency/Year)
C_{FMT}	Fixed Costs of Manure Tank (Currency/Year)
C_{FO}	Other Fixed Costs (Currency/Year)
C_{FOS}	Fixed Costs of Operating Supply Items (Currency/Year)
C_{FS}	Fixed Costs of the Shed (Currency/Year)
C_{FSS}	Fixed Costs of Raw Slurry Storage (Currency/Year)
C_{FT}	Fixed Costs of Technology (Currency/Year)
C_{FTS}	Fixed Costs of Tower Silo (Currency/Year)
C_{FW}	Fixed Costs of Well (Currency/Year)
C_{FWG}	Fixed Costs of Farm Water Consumption from Governmental Supply (Currency/Year)
C_{IAB}	Capital Investment of All Cow Buildings (Currency)
C_{IAS}	Capital Investment of Aeration Storage (Currency)
C_{IB}	Capital Investment of Building (Currency)
C_{IC}	Capital Investment of Cows (Currency)
C_{ICB}	Capital Investment of Concrete Base (Currency)
C_{ICH}	Capital Investment of Concrete Construction of Horizontal Silo (Currency)
C_{ICM}	Capital Investment of Concrete Constructions of Milking Center (Currency)
C_{ICS}	Capital Investment of Cooling System (Currency)
C_{IDW}	Capital investment of Drilling a Well (Currency)
C_{IEG}	Capital Investment of Farm Electricity Consumption from Governmental Supply (Currency)
C_{IF}	Capital Investment of the Farm (Currency)
C_{IFC}	Capital Investment of Forage Storage Constructions (Currency)
C_{IFF}	Capital Investment of Farm Fence (Currency)
C_{IFS}	Capital Investment of Feeding System (Currency)
C_{IGE}	Capital Investment of Farm Electricity Consumption Using Generators (Currency)
C_{IL}	Capital Investment of Land (Currency)
C_{ILS}	Capital Investment of Liquid Storage (Currency)
C_{IM}	Capital Investment of Milking Center Constructions (Currency)
C_{IMC}	Capital Investment of Manure Handling/Constructions (Currency)
C_{IMH}	Capital Investment of Manure Handling System (Currency)
C_{IMM}	Capital Investment of Manure Mechanical System (Currency)
C_{IMS}	Capital Investment of Milking System (Currency)
C_{IMT}	Capital Investment of Manure Tank (Currency)
C_{IO}	Other Capital Investments (Currency)
C_{IOS}	Capital Investment of Operating Supply Items (Currency)
C_{IP}	Interest Payments (Currency/Year)
C_{IPC}	Capital Investment per Cow (Currency/Cow)
C_{IS}	Capital Investment of the Shed (Currency)

C_{ISS}	Capital Investment of Raw Slurry Storage (Currency)
C_{ITS}	Capital Investment of Tower Silo (Currency)
C_{IWG}	Capital Investment of Farm Water Consumption from Governmental Supply (Currency)
CM	Costs Calculation Model
C_{MDW}	Costs of Mechanical Drilling of a well (Currency/m)
C_{OW}	Other Costs of Well (Currency)
C_{OWP}	Operation Costs of Well Pump (Currency/m ³)
CS	Cowshed
CSM	Cooling System Sub-Model
C_{SW}	Salaries of Workers (Currency/Year)
C_T	Taxes (Currency/Year)
C_{TAB}	Total Costs of All Cow Buildings (Currency/Year)
C_{TAS}	Total Costs of Aeration Storage (Currency/Year)
C_{TB}	Total Costs of Building (Currency/Year)
C_{TC}	Total Costs of Cows (Currency/Year)
C_{TCB}	Total Costs of Concrete Base (Currency/Year)
C_{TCC}	Total Costs of Milking Center Constructions (Currency/Year)
C_{TCF}	Total Costs of Farm Constructions (Currency/Year)
C_{TCH}	Total Costs of Concrete Construction of Horizontal Silo (Currency/Year)
C_{TCM}	Total Costs of Concrete Constructions of Milking Center (Currency/Year)
C_{TCS}	Total Costs of Cooling System (Currency/Year)
C_{tEC}	Total Employment Costs of Concrete (Currency)
C_{TEG}	Total Costs of Farm Electricity Consumption from Governmental Supply (Currency/Year)
C_{TF}	Total Costs of the Farm (Currency/Year)
C_{TFC}	Total Costs of Forage Storage Constructions (Currency/Year)
C_{TFF}	Total Costs of Farm Fence (Currency/Year)
C_{TFS}	Total Costs of Feeding System (Currency/Year)
C_{TGS}	Total Costs of the generators (Currency/Year)
C_{TL}	Total Costs of Land (Currency/Year)
C_{TLS}	Total Costs of Liquid Storage (Currency/Year)
C_{TMC}	Total Costs of Manure Handling/Constructions (Currency/Year)
C_{TMH}	Total Costs of Manure Handling System (Currency/Year)
C_{TMM}	Total Costs of Manure Mechanical System (Currency/Year)
C_{TMS}	Total Costs of Milking System (Currency/Year)
C_{TMT}	Total Costs of Manure Tank (Currency/Year)
C_{TO}	Other Total Costs (Currency/Year)
C_{TOS}	Total Costs of Operating Supply Items (Currency/Year)
C_{TPC}	Total Costs per Cow (Currency/Year.Cow)
C_{TS}	Total Costs of the Shed (Currency/Year)
C_{TSS}	Total Costs of Raw Slurry Storage (Currency/Year)
C_{TT}	Total Costs of Technology (Currency/Year)
C_{TTS}	Total Costs of Tower Silo (Currency/Year)
C_{TW}	Total Costs of Well (Currency/Year)
C_{TWG}	Total Costs of Farm Water Consumption from Governmental Supply (Currency/Year)
C_{VAB}	Variable Costs of All Cow Buildings (Currency/Year)
C_{VAS}	Variable Costs of Aeration Storage (Currency/Year)
C_{VB}	Variable Costs of Building (Currency/Year)
C_{VC}	Variable Costs of Cows (Currency/Year)
C_{VCB}	Variable Costs of Concrete Base (Currency/Year)
C_{VCC}	Variable Costs of Milking Center Constructions (Currency/Year)
C_{VCF}	Variable Costs of Farm Constructions (Currency/Year)

C_{VCH}	Variable Costs of Concrete Construction of Horizontal Silo (Currency/Year)
C_{VCM}	Variable Costs of Concrete Constructions of Milking Center (Currency/Year)
C_{VCS}	Variable Costs of Cooling System (Currency/Year)
C_{VEG}	Variable Costs of Farm Electricity Consumption from Governmental Supply (Currency/Year)
C_{VF}	Variable Costs of the Farm (Currency/Year)
C_{VFC}	Variable Costs of Forage Storage Constructions (Currency/Year)
C_{VFF}	Variable Costs of Farm Fence (Currency/Year)
C_{VFS}	Variable Costs of Feeding System (Currency/Year)
C_{VG}	Variable Costs of One Electric Generator (Currency/Year)
C_{VGS}	Total of variable costs of the generators (Currency/Year)
C_{VL}	Variable Costs of Land (Currency/Year)
C_{VLS}	Variable Costs of Liquid Storage (Currency/Year)
C_{VMC}	Variable Costs of Manure Handling/Constructions (Currency/Year)
C_{VMH}	Variable Costs of Manure Handling System (Currency/Year)
C_{VMM}	Variable Costs of Manure Mechanical System (Currency/Year)
C_{VMS}	Variable Costs of Milking System (Currency/Year)
C_{VMT}	Variable Costs of Manure Tank (Currency/Year)
C_{VO}	Other Variable Costs (Currency/Year)
C_{VOC}	Variable Costs of One Cow (Currency/Year)
C_{VOS}	Variable Costs of Operating Supply Items (Currency/Year)
C_{VOW}	Other Variable Costs of Well (Currency/Year)
C_{VS}	Variable Costs of the Shed (Currency/Year)
C_{VSS}	Variable Costs of Raw Slurry Storage (Currency/Year)
C_{VT}	Variable Costs of Technology (Currency/Year)
C_{VTS}	Variable Costs of Tower Silo (Currency/Year)
C_{VW}	Variable Costs of Well (Currency/Year)
C_{VWG}	Variable Costs of Farm Water Consumption from Governmental Supply (Currency/Year)
C_{VWP}	Variable Costs of Well Pump (Currency/Year)
D_{1Xn}	Projection of D_{Xn} in the X-Axis (m)
D_{1Yn}	Projection of D_{Xn} in the Y-Axis (m)
D_{2Xn}	Projection of D_{Yn} in the X-Axis (m)
D_{2Yn}	Projection of D_{Yn} in the Y-Axis (m)
D_A	Duration of Aeration (Day)
D_{CP}	Duration of Composted Product Storage (Month)
d_{CP}	Diameter of Cooling System Pipe Line (mm)
D_{DMS}	Daily Operating Duration of Milking System (h/Day)
D_{DOC}	Daily Operating Duration of Cooling System (h/Day)
D_{DOM}	Daily Operating Duration of Manure Handling system (h/Day)
D_{DS1}	Daily Operating Duration of System 1 (h/Day)
D_{DS2}	Daily Operating Duration of System 2 (h/Day)
D_{DS3}	Daily Operating Duration of System 3 (h/Day)
D_{DS4}	Daily Operating Duration of System 4 (h/Day)
D_{DS5}	Daily Operating Duration of System 5 (h/Day)
D_{DS6}	Daily Operating Duration of System 6 (h/Day)
D_{DS7}	Daily Operating Duration of System 7 (h/Day)
DFD	Dairy Farms Designer Expert System
D_{HM}	Hourly Operating Duration of Microsprinkler (min/h)
DM	Design Model
D_M	Milking Duration (h)
D_{MP}	Duration of Mixing and Pumping (Day)
D_{NL}	Night Lighting Duration (h/Day)
D_P	Depth of Milking Parlor Pit (m)

D_{PXn}	Projection of Building (n) Dimension in the X-Axis (m)
D_{PYn}	Projection of Building (n) Dimension in the Y-Axis (m)
D_{TL}	Duration of Treated Liquid Storage (Month)
D_W	Well Depth (m)
D_{X1}	Dimension of Building (1) in the X-Axis (m)
D_{X2}	Dimension of Building (2) in the X-Axis (m)
D_{X3}	Dimension of Building (3) in the X-Axis (m)
D_{Xn}	Dimension of Building (n) in the X-Axis (m)
d_{X12}	Distance between Buildings (1) and (2) in the X-Axis (m)
d_{X23}	Distance between Buildings (2) and (3) in the X-Axis (m)
d_{X34}	Distance between Buildings (3) and (4) in the X-Axis (m)
d_{XIJ}	Distance between Buildings (I) and (J) in the X-Axis (m)
d_{X1F}	Distance in the X-Axis between Building (1) and the Fence (m)
d_{XnF}	Distance in the X-Axis between Building (n) and the Fence (m)
D_{Y1}	Dimension of Building (1) in the Y-Axis (m)
D_{Y2}	Dimension of Building (2) in the Y-Axis (m)
D_{Y3}	Dimension of Building (3) in the Y-Axis (m)
D_{Yn}	Dimension of Building (n) in the Y-Axis (m)
d_{Y12}	Distance between Buildings (1) and (2) in the Y-Axis (m)
d_{Y23}	Distance between Buildings (2) and (3) in the X-Axis (m)
d_{Y34}	Distance between Buildings (3) and (4) in the Y-Axis (m)
d_{YIJ}	Distance between Buildings (I) and (J) in the Y-Axis (m)
d_{Y1F}	Distance in the Y-Axis between Building (1) and the Fence (m)
d_{YnF}	Distance in the Y-Axis between Building (n) and the Fence (m)
D_{YOC}	Yearly Operating Duration of Cooling System (Months/Year)
E_{CF}	Electricity Consumption of One Cooling Fan (kW)
ECM	Electricity Consumption and Sources Sub-Model
E_{CP}	Electricity Consumption of Cooling System Pump (kW)
E_{CSY}	Cooling System Electricity Consumption per Year (kWh)
E_{FY}	Farm Total Electricity Consumption per Year (kWh)
EG	Electric Generators
E_{GP}	Power of Electric Generator (kW)
E_{HS1}	Electricity Consumption per Hour of System 1 (kWh)
E_{HS2}	Electricity Consumption per Hour of System 2 (kWh)
E_{HS3}	Electricity Consumption per Hour of System 3 (kWh)
E_{HS4}	Electricity Consumption per Hour of System 4 (kWh)
E_{HS5}	Electricity Consumption per Hour of System 5 (kWh)
E_{HS6}	Electricity Consumption per Hour of System 6 (kWh)
E_{HS7}	Electricity Consumption per Hour of System 7 (kWh)
E_L	Electricity Consumption of One Lamp (W)
E_{LSY}	Lighting System Electricity Consumption per Year (kWh)
E_{MHH}	Manure Handling System Electricity Consumption per Hour (kWh)
E_{MHY}	Manure Handling System Electricity Consumption per Year (kWh)
E_{MSH}	Milking System Electricity Consumption per Hour (kWh)
E_{MSY}	Milking System Electricity Consumption per Year (kWh)
E_{YS1}	Electricity Consumption per Year of System 1 (kWh)
E_{YS2}	Electricity Consumption per Year of System 2 (kWh)
E_{YS3}	Electricity Consumption per Year of System 3 (kWh)
E_{YS4}	Electricity Consumption per Year of System 4 (kWh)
E_{YS5}	Electricity Consumption per Year of System 5 (kWh)
E_{YS6}	Electricity Consumption per Year of System 6 (kWh)
E_{YS7}	Electricity Consumption per Year of System 7 (kWh)
FH	Farm House
FSC	Forage Storage Constructions Sub-Model
FSL	Farmstead Layout Sub-Model
G	Volume of Required Gravels for Making 1 m ³ Concrete (m ³ /m ³)

H_C	Cowshed Height (m)
H_{CS}	Height of Cowshed Side (m)
H_{BB}	Height of Brisket Board (m)
H_{IT}	Internal Height of Manure Tank (m)
H_{RC}	Height of Rear Curb (m)
HS	Horizontal Silo
H_S	Shed Height (m)
H_{SS}	Height of the Shed Side (m)
H_{WHS}	Height of Horizontal Silo Wall (m)
L_C	Corral Length (m)
L_{CB}	Concrete Base Length (m)
L_{CL}	Side Length of the supposed square which represents the total area of concrete layer required for milking center (m)
L_{CML}	Length of Cooling System Main Line (m)
L_{CO}	Cooling Line Length (m)
L_{CP}	Length of Cow Platform of Milking Parlor (m)
L_{CSL}	Length of Cooling System Sub-Main Line (m)
L_{EA}	Length of Entry Alley of Milking Parlor (m)
L_{FB}	Feeding Bunk Length (m/cow)
L_{FEA}	Length of Front Exit Alley of Milking Parlor (m)
L_{FP}	Length of One Side of Feeding Places in One Corral (m)
L_H	House Length (m)
L_{HS}	Horizontal Silo Length (m)
L_{MC}	Length of Milking Center (m)
L_{MP}	Length of Milking Parlor Pit (m)
L_P	Pile Length (m)
L_{PA}	Length of Pile Arrow (m)
L_{PC}	Length of Pile Cord (m)
L_{PHS}	Length of Concrete Plot of Horizontal Silo (m)
L_{PM}	Length of Milking Parlor (m)
L_R	Roof Length (m)
L_{RA}	Length of Return Alley of Milking Parlor (m)
L_S	Structure Length (m)
L_{SH}	Shade Length (m)
L_{SI}	Length of One Standard Iron Rod (m)
L_{ICP}	Total Length of Cooling System Pipe Lines (m)
M	Margins (m)
M_{BC}	Mass of one square meter of Burnt-Clay Bricks (kg/m^2)
MC	Milking Center
M_C	Cement Mass (kg)
M_{HM}	Manure Handling/Constructions Sub-Model
M_I	Iron Mass (kg) or (Ton)
M_{IA}	Mass of one square meter of Isolated Aluminum (kg/m^2)
M_{IML}	Mass of 1 m Long of Iron Rod (kg/m)
M_{PC}	Milking Parlor Constructions Sub-Model
M_{PA}	Mass of one square meter of Polished Aluminum (kg/m^2)
M_{RM}	Mass of one Reed Mat (kg/Mat)
MS	Machinery Shop
M_{SM}	Mass of one Straw Mat (kg/Mat)
MT	Manure Tank
M_{tBC}	Total Mass of Burnt-Clay Bricks (kg)
M_{tIA}	Total Mass of Isolated Aluminum (kg)
M_{tPA}	Total Mass of Polished Aluminum (kg)
M_{tRM}	Total Mass of Reed Mats (kg)
M_{tSM}	Total Mass of Straw Mats (kg)
m	Roof Slope (%)

m_{CY}	Slope of Collecting Yard of Milking Parlor (%)
m_{EA}	Slope of Entry Alley of Milking Parlor (%)
m_{FEA}	Slope of Front Exit Alley of Milking Parlor (%)
m_{RA}	Slope of Return Alley of Milking Parlor (%)
N_{BF}	Number of Cow Buildings in Farm
N_{BWC}	Number of Backwater Containers
N_{CC}	Number of Cows in One Corral
N_{CF}	Number of Cows in Farm
N_{CFP}	Cows per Feeding Place
N_{CH}	Number of Cows in One House
N_{CLC}	Number of Cooling Lines for One Cowshed
N_{CPP}	Number of Composted Product Piles
N_{CSF}	Number of Cooling Systems in Farm
N_{CT}	Number of Required Taps for Cooling System
N_{CY}	Number of Cows in Collecting Yard
N_{EG}	Number of Electric Generators
N_G	Number of Gridirons
N_{HC}	Number of Corrals in One House
N_{HF}	Number of Houses in Farm
N_{HSP}	Number of Horizontal Silo Pits
N_{IH}	Number of Iron Rods in Tank Height
N_{IL}	Number of Iron Rods in Length
N_{IML}	Number of Iron Rods per One Meter Length of Concrete
N_{IP}	Number of Iron Rods in Tank Perimeter
N_{IW}	Number of Iron Rods in Width
N_{LC}	Number of Lamps under One Cowshed/House
N_{LO}	Number of Lamps in Other Locations (Alley, Office,...)
N_M	Number of Microsprinklers
N_{MD}	Number of Milking per Day
N_{MHF}	Number of Manure Handling Systems in Farm
N_{MSF}	Number of Milking Systems in the Farm
N_P	Number of posts in one row
N_{Pt}	Total number of posts for one cowshed
N_{RM}	Number of Reed Mats (Mat)
N_{SC}	Number of Years (Seasons) per Cow (Year)
N_{SM}	Number of Straw Mats (Mat)
N_{S1}	Number of Systems 1 in Farm
N_{S2}	Number of Systems 2 in Farm
N_{S3}	Number of Systems 3 in Farm
N_{S4}	Number of Systems 4 in Farm
N_{S5}	Number of Systems 5 in Farm
N_{S6}	Number of Systems 6 in Farm
N_{S7}	Number of Systems 7 in Farm
N_{tCF}	Total Number of Cooling Fans
N_{tI}	Total Number of Iron Rods
N_{tIG}	Total Number of Iron Rods in One Gridiron
N_{tSI}	Total Number of Standard Iron Rods
$N\emptyset D/m$	Type of Iron Rods, where N is the number of iron rods per meter length, and D is the diameter of the iron rod in mm
O/OC	Office/Operation Center
P1	Part One
P2	Part Two
P3	Part Three
P_A	Price of Anemometer (Currency)
P_{BC}	Price of 1 m ² of Burnt-Clay Bricks (Currency/m ²)
P_{BWC}	Price of One Backwater Container (Currency)

P_C	Price of 1 kg Cement (Currency/kg)
P_{CF}	Price of Cooling Fan (Currency)
P_{CML}	Price of 1 m of Cooling System Main Line (Currency/m)
P_{CP}	Price of Cooling System Pump (Currency)
P_{CPL}	Price of 1 m of Cooling System Pipe Line (Currency/m)
P_{CSL}	Price of 1 m of Cooling System Sub-Main Line (Currency/m)
P_{CT}	Price of One Cooling System Tap (Currency/Tap)
P_{DMM}	Percentage of DM in Raw Manure (%)
P_{EG}	Price of 1 kWh of Electricity Governmental Supply (Currency/kWh)
P_F	Farm Perimeter (m)
P_{FC}	Price of Cooling System Filter (Currency)
P_G	Price of 1 m ³ Gravels (Currency/m ³)
P_{ha}	Price of One Hectare (Currency/ha)
P_I	Price of One Ton of Iron Rods (Currency/Ton)
P_{IA}	Price of 1 m ² Isolated Aluminum (Currency/m ²)
P_L	Land Price (Currency)
P_M	Price One Microsprinkler (Currency/Microsprinkler)
P_{MFF}	Price of One Meter of Farm Fence (Currency/m)
P_{MM}	Price of Manure Mixer (Currency)
P_{MP}	Price of Manure Pump (Currency)
P_{MS}	Price of Manure Separator (Currency)
P_{MWS}	Price of Main Watershed (Currency)
P_{OH}	Price of One Heifer (Currency/Cow)
P_{PA}	Price of 1 m ² of Polished Aluminum (Currency/m ²)
P_{PG}	Price of Pressure Gauge (Currency)
P_R	Price of 1 m ³ Rocks (Currency/m ³)
P_{RCM}	Price of Roof Covering Material (Currency)
P_{rCP}	Pressure of Cooling System Pump (kPa)
P_{RM}	Price of One Reed Mat (Currency/Mat)
P_{rMS}	Microsprinkler Pressure (kPa)
P_S	Price of 1 m ³ Sand (Currency/m ³)
P_{SA}	Price of Surface Aerator (Currency)
P_{SM}	Price of One Straw Mat (Currency/Mat)
P_{tBC}	Total Price of Burnt-Clay Bricks (Currency)
P_{tC}	Total Price of Cement (Currency)
P_{tCF}	Total Price of Cooling Fans (Currency)
P_{tCL}	Total Price of Cooling System Main Line (Currency)
P_{tCO}	Total Price of Cows (Currency)
P_{tCP}	Total Price of Cooling System Pipe Lines (Currency)
P_{tCS}	Total Price of Cooling System Sub-Main Line (Currency)
P_{tCT}	Total Price of Cooling System Taps (Currency)
P_{TE}	Price of Turning Equipment (Currency)
P_{tFF}	Total Price of Farm Fence (Currency)
P_{tG}	Total Price of Gravels (Currency)
P_{tI}	Total Price of Iron Rods (Currency)
P_{tIA}	Total Price of Isolated Aluminum (Currency)
P_{tM}	Total Price of Microsprinklers (Currency)
P_{tMP}	Total Price of Manure Pumps (Currency)
P_{tPA}	Total Price of Polished Aluminum (Currency)
P_{tR}	Total Price of Rocks (Currency)
P_{tRM}	Total Price of Reed Mats (Currency)
P_{tS}	Total Price of Sand (Currency)
P_{tSC}	Total Price of the Steel Construction (Currency) incl. Concrete Piers and Rails (railed corrals)
P_{tVF}	Total Price of Valves and Fittings (Currency)
P_{tWC}	Total Price of Backwater Containers (Currency)

P_{WF}	Price of Well Filter (Currency)
P_{WG}	Price of 1 m ³ of Water Governmental Supply (Currency/m ³)
P_{WP}	Price of Well Pump (Currency)
Q_{CP}	Discharge of Cooling System Pump (m ³ /h)
Q_{MS}	Microsprinkler Discharge (l/min)
Q_{WP}	Well Pump Discharge (m ³ /h)
R	Constant depends on roof type
R_A	Ratio of Feeding Area to Corral Area
R_E	Elimination Rate (%)
R_{ET}	External Radius of Manure Tank (m)
R_{IT}	Internal Radius of Manure Tank (m)
RSM	Roof Material and Structure Sub-Model
S	Volume of Required Sand for Making 1 m ³ Concrete (m ³ /m ³)
S_{CF}	Span or Distance between 2 Cooling Fans (m)
S_M	Span or Distance between 2 Microsprinklers (m)
S_p	Span or Distance between Geometric Centers of 2 Posts (m)
S_F	Shade for Feeding (%)
S_L	Shade for Laying (%)
t_{AS}	Aeration Storage Lifetime (Year)
t_B	Building Lifetime (Year)
T_{CL}	Thickness of Concrete Layer of Milking Center (m)
t_{CS}	Cooling System Lifetime (Year)
t_{EG}	Lifetime of Electric Generator (Year)
t_{FF}	Lifetime of Farm Fence (Year)
T_{FP}	Concrete Base Thickness of Feeding Places (m)
t_{GC}	Lifetime of Governmental Supply Circuit (Year)
t_{GW}	Lifetime of Governmental Supply Watershed (Year)
T_{LB}	Concrete Base Thickness of Feeding line & Feeding Bunks (m)
t_{LS}	Liquid Storage Lifetime (Year)
t_{MM}	Manure Mechanical System Lifetime (Year)
t_P	Project Lifetime (Year)
TS	Tower Silo
t_S	Lifetime of the Shed (Year)
T_{SB}	Thickness of Horizontal Silo Base (m)
t_{SS}	Raw Slurry Storage Lifetime (Year)
T_{SW}	Thickness of Horizontal Silo Walls (m)
T_{TB}	Base Thickness of Manure Tank (m)
T_{TW}	Wall Thickness of Manure Tank (m)
t_W	Well Lifetime (Year)
V_A	Aeration Storage Volume (m ³)
V_{BB}	Concrete Volume of Brisket Boards (m ³)
V_{BHS}	Concrete Volume of Horizontal Silo Base (m ³)
V_{BW}	Backwater Volume (m ³)
V_{CB}	Total Volume of Concrete Base (m ³)
V_{CC}	Capacity of Backwater Container (m ³)
V_{CCP}	Required Concrete Volume for Constructions of Milking Center (m ³)
V_{CHS}	Required Concrete Volume for Horizontal Silo (m ³)
V_{CP}	Composted Product Volume (m ³)
V_{CT}	Concrete Volume of Manure Tank (m ³)
V_{ET}	External Volume of Manure Tank (m ³)
V_{FP}	Concrete Volume of Feeding Places (m ³)
V_{FSC}	Volume of Forage Storage per Cow and Year (m ³ /Cow.Year)
V_G	Gravels Volume (m ³)
V_{GC}	Volume of Grain Storage per Cow and Year (m ³ /Cow.Year)
V_{HC}	Volume of Hay Storage per Cow and Year (m ³ /Cow.Year)
V_{IT}	Internal Volume of Manure Tank (m ³)

V_{LB}	Concrete Volume of Feeding Line and Feeding Bunks (m^3)
V_M	Volume of the Materials Stored in the Tank (m^3)
V_{MCM}	Manure Storage Volume per Cow and Month ($m^3/\text{Animal} \cdot \text{Month}$)
V_{PC}	Volume of Potatoes Storage per Cow and Year ($m^3/\text{Cow} \cdot \text{Year}$)
V_{PR}	Volume of Milking Parlor Construction Rocks (m^3)
V_{RC}	Concrete Volume of Rear Curbs (m^3)
V_{RS}	Raw Slurry Storage Volume (m^3)
V_S	Sand Volume (m^3)
V_{SC}	Volume of Silage Storage per Cow and Year ($m^3/\text{Cow} \cdot \text{Year}$)
V_{STC}	Volume of Straw Storage per Cow and Year ($m^3/\text{Cow} \cdot \text{Year}$)
V_{IFS}	Total Volume of Forage Storage per Year (m^3/Year)
V_{IGS}	Total Volume of Grain Storage per Year (m^3/Year)
V_{tHF}	Total Volume of Stored Forage in Horizontal Silo per Year (m^3/Year)
V_{tHS}	Total Volume of Hay Storage per Year (m^3/Year)
V_{TL}	Treated Liquid Storage Volume (m^3)
V_{tMD}	Total Manure Storage Volume per Day (m^3/Day)
V_{tMM}	Total Manure Storage Volume per month (m^3/Month)
V_{IPS}	Total Volume of Potatoes Storage per Year (m^3/Year)
V_{ISF}	Total Volume of Stored Forage under Shed per Year (m^3/Year)
V_{ISS}	Total Volume of Silage Storage per Year (m^3/Year)
V_{IST}	Total Volume of Straw Storage per Year (m^3/Year)
V_{WHS}	Concrete Volume of Horizontal Silo Walls (m^3)
W_{BB}	Width of Brisket Board (m)
W_C	Corral Width (m)
W_{CB}	Concrete Base Width (m)
WCM	Water Consumption and Sources Sub-Model
W_{CP}	Width of Cow Platform of Milking Parlor (m)
W_{CSY}	Cooling System Water Consumption per Year (m^3/Year)
W_{EA}	Width of Entry Alley of Milking Parlor (m)
W_{FEA}	Width of Front Exit Alley of Milking Parlor (m)
W_{FP}	Width of One Side of Feeding Places (m)
W_{FY}	Farm Total Water Consumption per Year (m^3/Year)
W_H	House Width (m)
W_{HSP}	Width of Horizontal Silo Pit (m)
W_{HS1}	Water Consumption per Hour of System 1 (l/h)
W_{HS2}	Water Consumption per Hour of System 2 (l/h)
W_{HS3}	Water Consumption per Hour of System 3 (l/h)
W_{HS4}	Water Consumption per Hour of System 4 (l/h)
W_{HS5}	Water Consumption per Hour of System 5 (l/h)
W_{HS6}	Water Consumption per Hour of System 6 (l/h)
W_{HS7}	Water Consumption per Hour of System 7 (l/h)
W_{LB}	Width of Feeding Line and Feeding Bunk(s) (m)
W_{LR}	Leeward Roof Width (m)
W_{LS}	Leeward Structure Width (m)
W_M	Water Consumption of One Microsprinkler (l/min)
W_{MC}	Width of Milking Center (m)
W_{MHD}	Manure Handling System Water Consumption per Day (m^3/Day)
W_{MHY}	Manure Handling System Water Consumption per Year (m^3/Year)
W_{MR}	Main Roof Width (m)
W_{MS}	Main Structure Width (m)
W_{MSH}	Milking System Water Consumption per Hour (l/h)
W_{MSY}	Milking System Water Consumption per Year (m^3/Year)
W_{OR}	Opened Ridge Width (m)
W_P	Width of Milking Parlor Pit (m)
W_{PHS}	Width of Concrete Plot of Horizontal Silo (m)
W_{PM}	Width of Milking Parlor (m)

W_R	Roof Width (m)
W_{RA}	Width of Return Alley of Milking Parlor (m)
W_{RC}	Width of Rear Curb (m)
W_S	Structure Width (m)
W_{SH}	Shade Width (m)
WT	Water Tanks
W_{WR}	Windward Roof Width (m)
W_{WS}	Windward Structure Width (m)
W_{YRC}	Yearly Water Requirements of the Cows (m^3/Year)
W_{YS1}	Water Consumption per Year of System 1 (m^3/Year)
W_{YS2}	Water Consumption per Year of System 2 (m^3/Year)
W_{YS3}	Water Consumption per Year of System 3 (m^3/Year)
W_{YS4}	Water Consumption per Year of System 4 (m^3/Year)
W_{YS5}	Water Consumption per Year of System 5 (m^3/Year)
W_{YS6}	Water Consumption per Year of System 6 (m^3/Year)
W_{YS7}	Water Consumption per Year of System 7 (m^3/Year)
X_1	Milk Production of One Cow (kg/Day)
X_2	Dry Matter Content of Forages (%)
X_F	Farm Dimension in the X-Axis (m)
Y	Water Requirements for One Cow (kg/Day \approx l/Day)
Y_F	Farm Dimension in the Y-Axis (m)
YS	Youngstock
α	Roof Slope Angle (degree)
β	Angle between Building-Axis and X-Axis (degree)
Ψ	Ratio of gathered waste from manure canals to total waste

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1 INTRODUCTION

A dairy farm consists of several facilities, such as: housing system, milking parlor, forage storage, and manure tank(s). Hence developing a simulation model, which is a quantitative system, for each facility is required; and then integrating the developed simulation models into an expert system, which is a rule-based qualitative system, will combine the advantages of both systems in a hybrid system.

The coupling of symbolic (qualitative) and numerical (quantitative) reasoning has received a great deal of attention from those working in artificial intelligence and other disciplines. There are two primary reasons for the interest in coupling. First, there is a need to assist those using complex numerical algorithms and programs. The second reason for the recent interest in coupled systems is the need to deal with problems involving ambiguous, contradictory, and imprecise data. For these cases, a problem solving environment that is more robust than traditional environments is needed (ENGEL et al., 1990).

Expert system development has been accelerated with the increasing availability of special programming languages and expert-system shells. These tools are able to speed the time-consuming development of expert systems. Existing expert-system programs range from the very complex to those which are very task-specific and narrowly defined. Extremely complex systems represent those being developed by artificial-intelligence theorists who are attempting to emulate the thought process of the human brain. The tasks performed by expert systems are numerous; the functional categories for expert-system applications are interpretation, prediction, diagnosis, monitoring, debugging, repair, instruction, control, design, and planning (DOLUSCHITZ, 1990).

The common form of an expert system is a computer program, with a set of rules or equations that analyses information or data supplied by the user, about a specific problem, and recommends one or more courses of user action. The expert system may also provide mathematical analysis of the problem (GIARRATANO & RILEY, 2005).

1.1 Problem

Planning and designing dairy farm facilities is a sophisticated work where a multitude of procedures should be carried out which requires time and efforts; moreover, making mistakes is also possible. Therefore, it is necessary to develop computer tools that have the ability to pre-process the data so as to produce value-added information, in order to accelerate analyses and to improve decision-making (LACROIX et al., 1998).

1.2 Objectives

This dissertation aims to develop an expert system, for planning and designing dairy farms in hot climates, which is able to:

- plan and design several dairy farm facilities, such as: corrals system, cowshed, cooling system, milking parlor, forage storage, and manure tank(s);
- compute the required amounts of construction materials;
- plan the farmstead layout;
- implement technologies, machines, and equipments;
- study the water and electricity requirements versus the available sources on farm;
- calculate the capital investment and the fixed, variable, and total costs.

2 LITERATURE REVIEW

2.1 Housing System

MARTIN (1998) mentioned that housing systems are open housing system (open accommodation), semi-confinement system, and total confinement system. BLOWEY (1994) stated that open housing system is used in hotter climates, with varying systems of protection from heat stress, depending on the ambient temperature. 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 (HATEM et al., 2004a; HATEM et al., 2004b; HATEM et al., 2006). GEORGES et al. (2005) stated that selecting suitable roof materials and implementing cooling systems minimize the negative effects of heat stress in arid and semi-arid zones.

SCHMIDT et al. (1988) noted that, regardless of the type of housing used, each system should (1) provide comfort to cows; (2) minimize injuries; (3) minimize exposure of cows to disease and stress; (4) have a feeding system that enables cows to obtain sufficient quantities of feed to meet their nutrient requirements; (5) provide for production of good-quality milk; (6) provide a comfortable environment for people caring for the cows; (7) result in high labor efficiency; (8) be economically feasible. He added that, the major components of the housing system are the milking center, protection from weather, the feeding center, and facilities for manure collection, removal, and disposal.

2.1.1 Housing Design

JUNGBLUTH (1995) developed the "Searching Method" which convenes the requirements of housing system success (animal welfare, environmental impact, and proper function) by finding the optimum solution/design, among several suggested designs in the framework of the pre-design phase, for each special case with a justifiable amount of work searching for the solution by economic criteria.

SCHMIDT et al. (1988) cited that the types of housing arrangements are stall barns as tie stalls or stanchion barns, loose housing as either bedded pack or free-stall barns, and open-lot housing.

According to BLOWEY (1994) loose yards allow cows lie where they wish; also they are encouraged to lie on a clean, bedded area. Apart from hotter climates, where sand is used in open yards, straw is the prime bedding material.

LINDLEY and WHITAKER (1996) stated that yards or corral systems are best suited to dry, hot climate zones. Variations include unpaved yards with 45 m² per cow which are dry scraped twice a year, semi-paved yards with 33 m² per cow and weekly scraping or complete paving with 12 m² or less per cow and daily scraping. Rectangular corrals for herds of up to 400 cows have at least four basic arrangements (Figure 2.1).

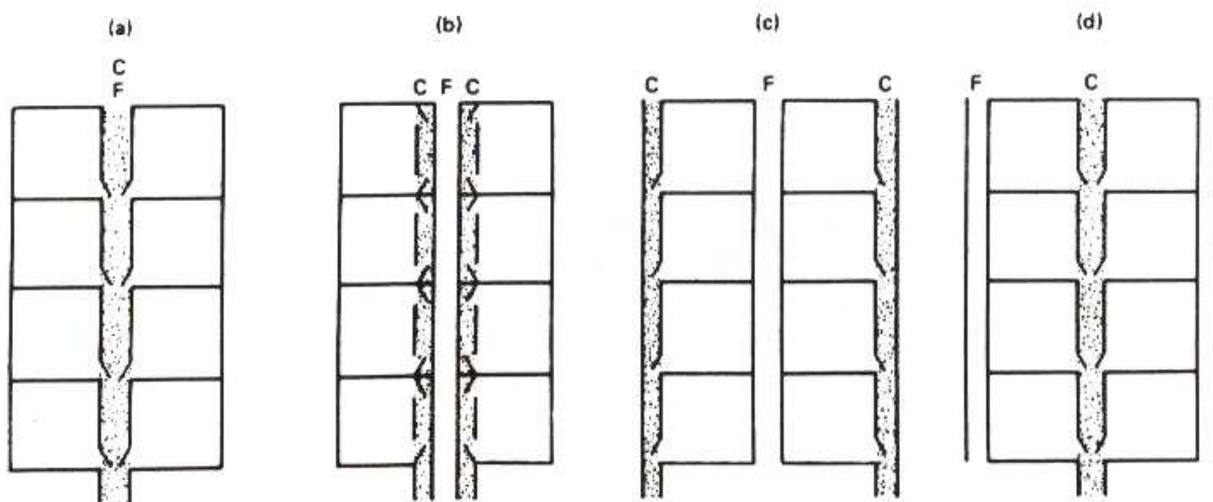


Figure 2.1: Rectangular corrals (LINDLEY and WHITAKER, 1996)

- type (a) uses the center lane for feeding and moving cows
- type (b) uses center lane for feeding and adjacent lanes for moving cows
- type (c) uses the center lane for feeding and the outside lanes for moving cows
- type (d) uses the center lane for cows and the outside lanes for feeding

Furthermore, pie-shaped corrals (Figure 2.2) are suitable for herds of 250 to 500 cows divided into groups of 40 to 60 cows.

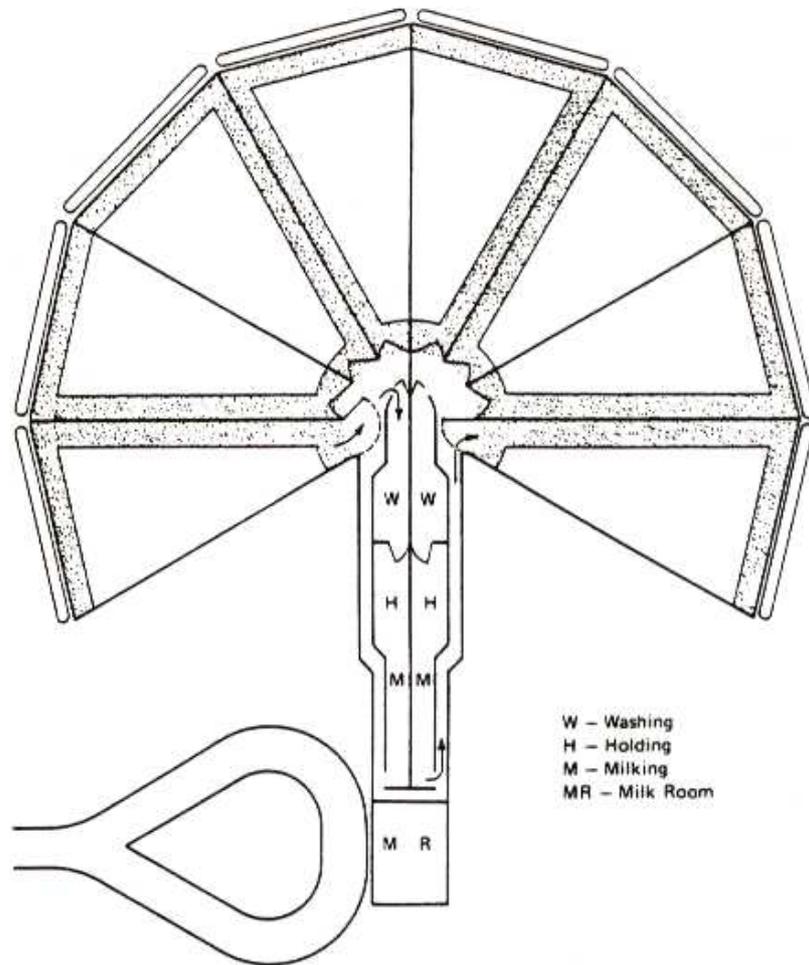


Figure 2.2: Pie-shaped corrals (LINDLEY and WHITAKER, 1996)

2.1.2 Concrete Constructions

BARTALI (1999) stated that reinforced concrete is obtained by adequately mixing in specific proportions aggregates (gravel and sand), cement, and water. Plain or reinforced concrete is used in livestock housing for structures, foundations, floors, and walls. It is a durable material that can resist attack by water, animal manure, chemicals, and fire. High-quality concrete is recommended for milk-, silage-, or manure-containing structures. 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 concrete floors, driveways, structural beams, and columns. STEINER et al. (2007) recommended a refurbishment method involving solid concrete floor surfaces.

2.1.3 Roof Materials and Structures

BARTALI (1999) stated that the common construction materials are concrete, steel, wood, plastics, reed, and burnt-clay bricks. Besides, the best suited roof materials for arid and semi-arid zones are reed and straw mats which are economically feasible (HATEM et al., 2004a; HATEM et al., 2004b; HATEM et al., 2006). However, HATEM (1993) mentioned that when the wind speed exceeds 1.8 m/s and the precipitation rate exceeds 80 mm/year the best suited roof materials are polished aluminum, isolated aluminum, and burnt-clay bricks. GEORG (2007) studied green roofing which decreased the inside temperature by 5 °C, compared to cement roofing.

HOUSE et al. (2000) mentioned that the buildings commonly are constructed on two types of foundation systems. The first foundation system is on grade, having the steel frames anchored directly to a concrete floor provides the best support for the structure. The horizontal forces generated when the roof members are loaded and carried by the concrete floor. The second foundation system is on posts, these structures are constructed on a short post-frame wall. This provides more usable height along the wall and keeps animals away from the covering material and more sustainable structure (Figure 2.3).

HATEM et al. (2004a) presented a new shade structure design suitable for arid and semi-arid zones. The roof type was designed exploiting the concept of thermal buoyancy, and then the contaminated air can be exhausted through the open ridges with assistance of external air thrust (Figure 2.4). HATEM et al. (2004b) reported that shade structures -in hot climates- should be 8 m high to enhance animal microclimate, and oriented east–west to minimize sun intrusion and maximize air flow rate. The relationship between roof type (open-ridge, semi-monitor, and mono-slope), roof slope angle (16.7°, and 18.4°), and wind direction and air movement inside and outside the house were investigated by IKEGUCHI and OKUSHIMA (2001), it was predicted that the mono-slope type might decrease contaminant and create a high concentration area near the leeward side of the building. When the open side of the semi-monitor type ridge faced windward, contaminants are dispersed more readily than when the ridge face the leeward. In addition, a small difference in slope angle made a large difference in air movement and contaminant diffusion of open-ridge houses (Figure 2.5).

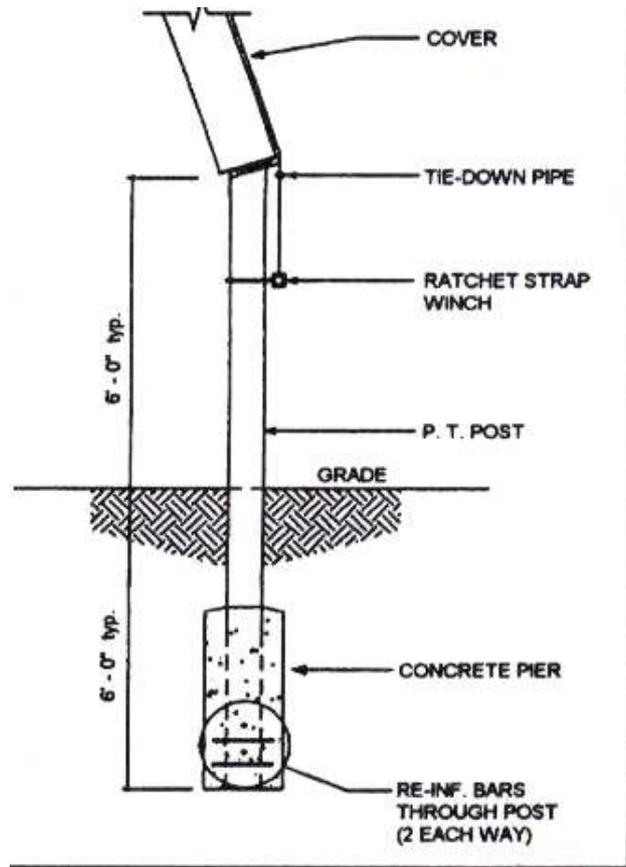


Figure 2.3: Typical foundation detail (HOUSE et al., 2000)

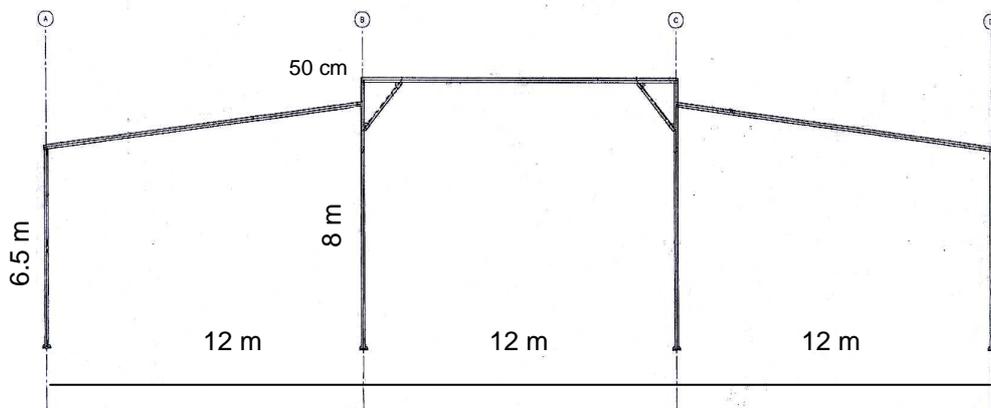


Figure 2.4: Shade structure (HATEM et al., 2004a)

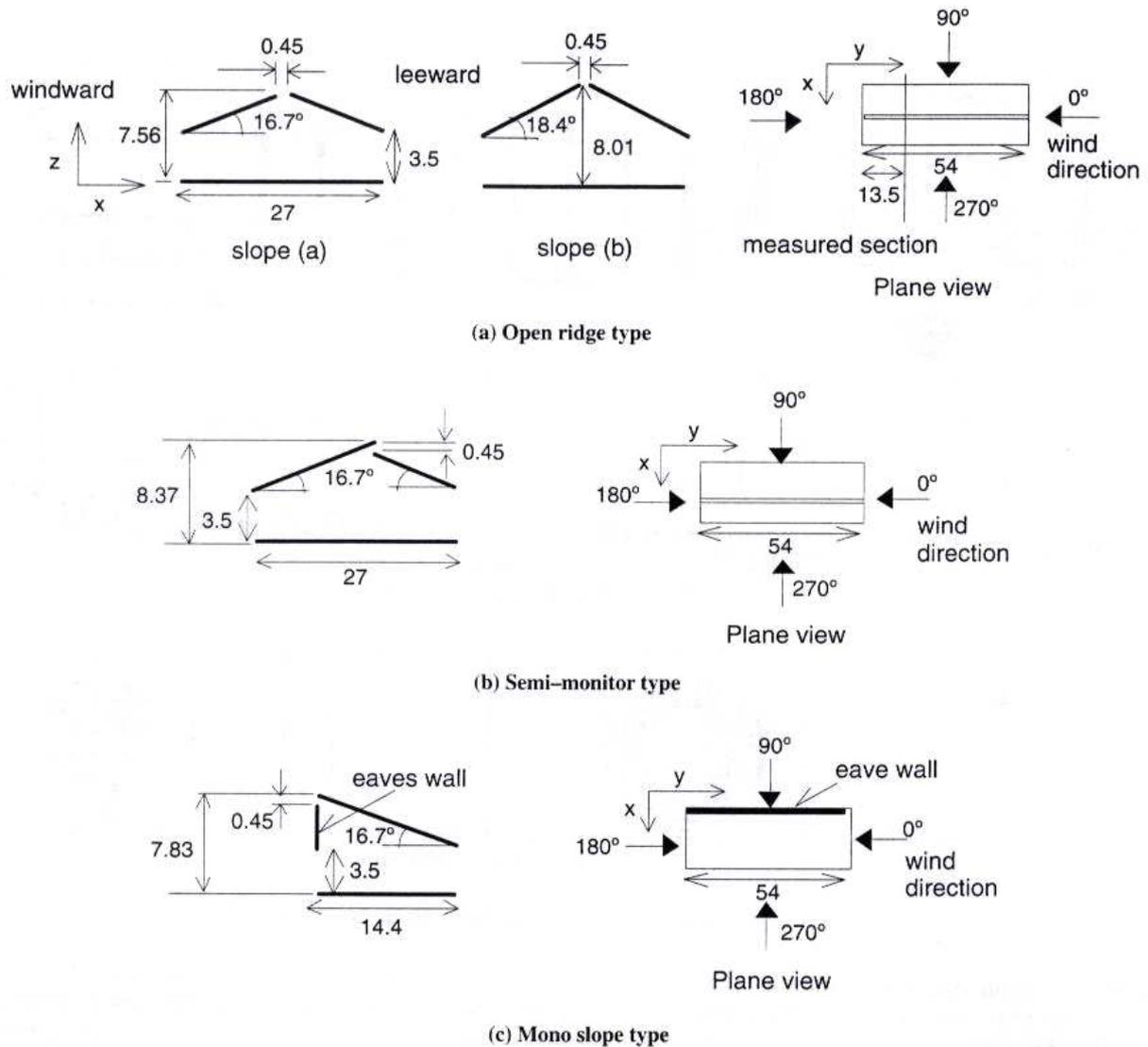


Figure 2.5: The relationship between roof types and roof slope angle (IKEGUCHI and OKUSHIMA, 2001)

2.2 Dairy Farm Facilities

2.2.1 Cooling System

SCHMIDT et al. (1988) reported that comfort range for dairy cows is between 4.5 and 21 °C. Cows are usually not adversely affected by the cold until the temperature drops to -15 °C; below this temperature a drop in milk production occurs. KEOWN and GRANT (1999) stated that heat stress in dairy cattle is one of the leading causes of decreased production. Thus, dairy cattle need mechanical means to reduce heat

stress. When temperature is between 5 and 15 °C the cows are most productive, and when the temperature is between 15 and 25 °C a small degree loss in production occurs, when the temperature exceed the upper critical temperature (25 °C) a great degree loss in production occurs. If the body temperature increases from 38.8 °C to 39.9 °C a drop of 2.2 kg/day in milk production occurs. The way to estimate heat stress is computing the temperature humidity index (THI):

$$\text{THI} = (0.81 \times \text{dry bulb temp. } ^\circ\text{C}) + [\text{RH}\% \times (\text{dry bulb temp. } ^\circ\text{C} - 14.4)] + 46$$

If THI less than 72 there is no stress, between 73 and 77 there is a mild stress, between 78 and 88 there is a significant stress, between 89 and 99 there is a severe stress, if THI exceed 99 a possible death occurs.

HATEM et al. (2006) cited that skin and rectal temperature and respiration rate increase with the increasing of the temperature. For these reasons the installation of an efficient cooling system is required. They added that cooling system efficiency increases by increasing cowshed height.

The sprinklers create droplets that wet the cows' hair coat to the skin. Fans are then used to force air over the cows' body (Figure 2.6), causing evaporative cooling to take place on the skin and hair coat. Heat from the cows' body causes the moisture to evaporate (TURNER et al., 1997; MEYER et al., 2002).

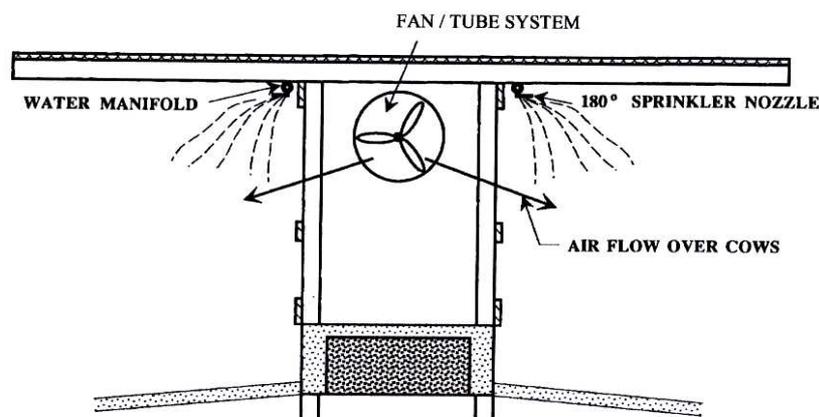


Figure 2.6: Sprinklers and fans cooling system (TURNER et al., 1997)

There are some general design guidelines must be followed in locating the system, selecting the nozzles and fans, and ensuring water supply (TURNER et al., 1997).

For best results system should be located under shade. A shaded feed bunk (Figure 2.6) or the holding pens (Figure 2.7) are the two locations currently recommended. Because of some concern over possible mastitis problems, location of a sprinkler system in a freestall barn may not be desirable, particularly if straw, sawdust or other absorbent bedding is used (TURNER et al., 1997).

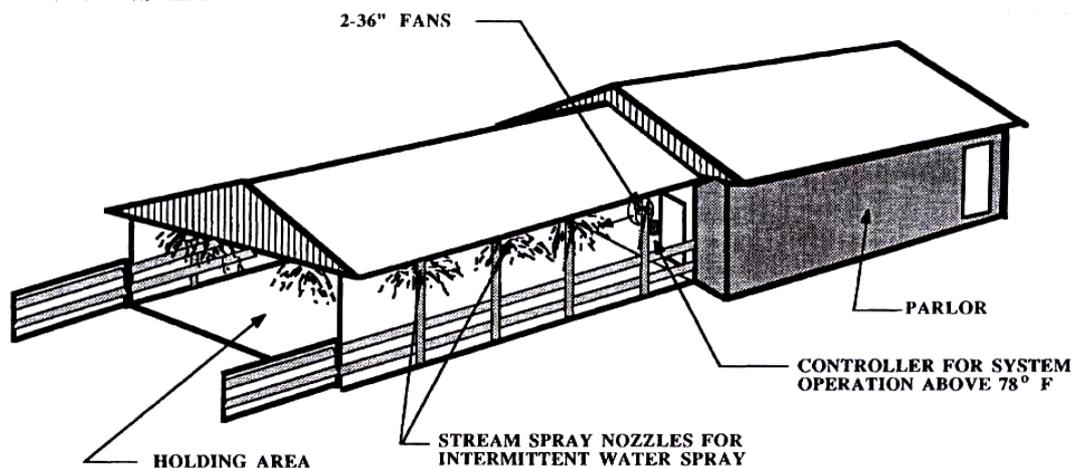
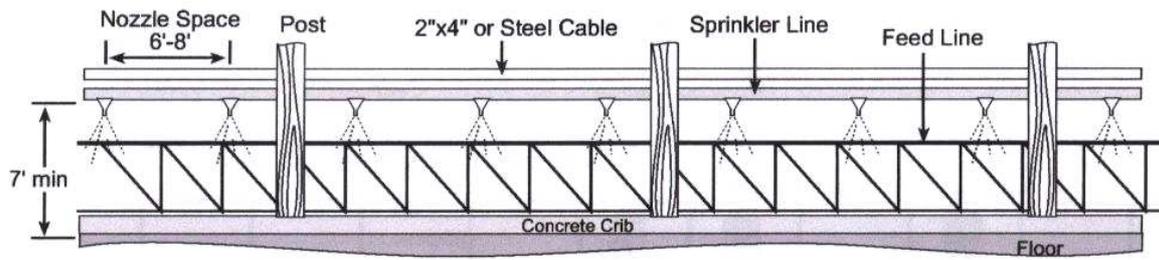


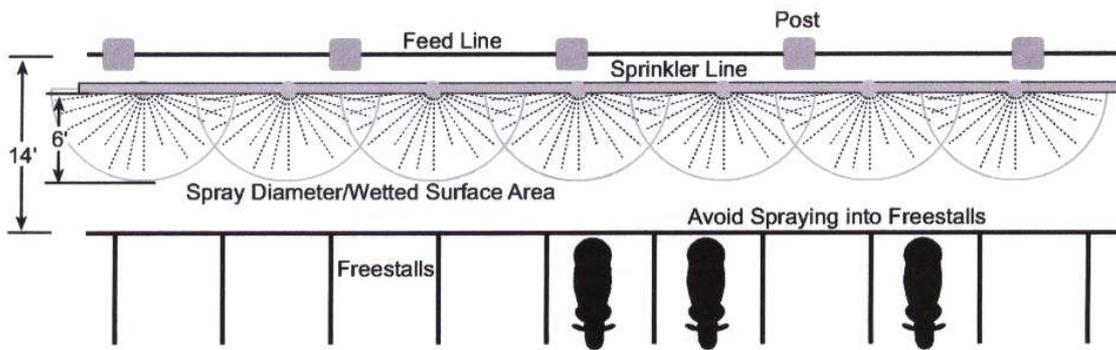
Figure 2.7: The holding pen (TURNER et al., 1997)

A size range of 0.45 to 1.89 liter/min per nozzle is preferred to conserve water, reduce the total required flow rate and avoid runoff problems. Either 180° (half-circle) or 360° (full-circle) nozzles may be used. The 180° nozzles work well mounted next to a feed bunk, spraying away from the feed to help avoid wetting it (Figure 2.8). The 360° nozzles work well in a holding area, sprinklers system needs to be suspended 1.5 m behind the feed line and spray diameter limited to 2.4 m (TURNER et al. 1997; HARNER et al., 1999).

The recommended nozzle pressure for most spray jets and microsprinklers is 138 to 172 kPa. If the operating pressure is too high, the droplet size will be reduced and the resulting mist will drift. Also, the smaller droplet will not penetrate through the animal's hair coat to the skin, and much less cooling will occur. Thus, pressure regulator should be installed to limit the required nozzle pressure to these recommended values (TURNER et al., 1997).



(a): Side view



(b): Top view

Figure 2.8: Typical sprinkler located over feed line (HARNER et al., 1999)

A thermostat should be set to turn the sprinkler on when the air temperature exceeds 21 to 24 °C. The thermostat will control a valve or solenoid located prior to the first nozzle, the solenoid valve controls the water flow through the pipe (HARNER et al., 1999). Figure 2.9 shows the cooling system components.

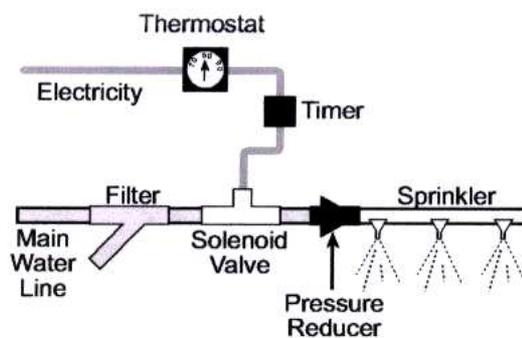


Figure 2.9: Cooling system components (HARNER et al., 1999)

Air movement in the velocity range of 1 to 2 m/s across the cows is needed. Fan/tube systems have been successfully used; they should be sized to provide 255 to 425 m³/h of air flow per cow. For tubes mounted high above the cows, a flow rate of 680 m³/h may be needed per cow. Another type of fan is often used, particularly in holding pens or other areas with higher eave heights, is ½ hp 91.5 cm fans. Such fans will blow about 16990 to 18689 m³/h with a “throw” distance of about 9.2 m. A 1 hp 122 cm fan will provide 35679 m³/h with an effective throw distance of 12.2 m. These fans should be mounted out of reach of the cows and angled downward slightly. Overhead paddle fans can also be used to provide airflow, but they offer limited air movement unless cows are directly under a fan. The paddle fans do have much higher efficiencies of operation, with range of 170 m³/h per Watt of power input (TURNER et al., 1997).

2.2.2 Manure Handling System

The aerated lagoon/tank is a simple low-cost system for aerobic slurry treatment (BURTON and TURNER, 2003). The overall scheme of manure handling operation is summarized in Figure 2.10. A storage tank(s) should be built for each phase of the manure handling operation. Moreover, a mechanical manure handling system should be implemented.

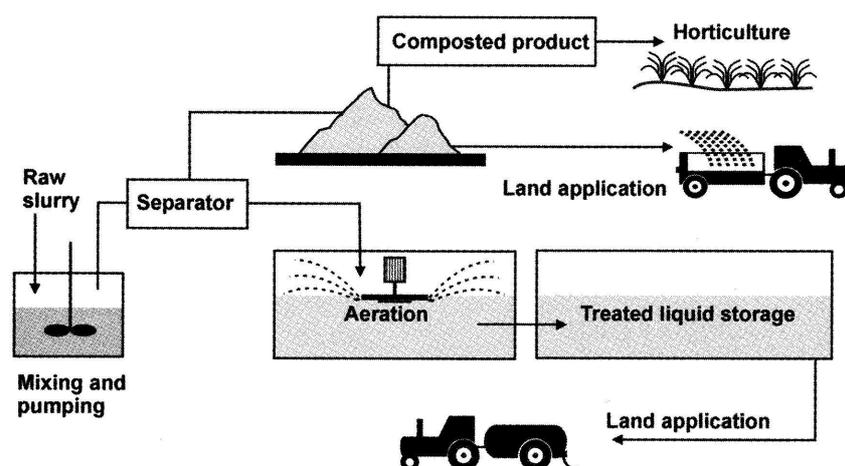


Figure 2.10: Treatment scheme for animal manure based on aeration (BICUDO, 2001)

GODBOUT et al. (2003) mentioned that cylindrical cast-in-place concrete tanks are commonly used for storing liquid manure during long periods. A serviceable tank should be watertight to prevent corrosion of the reinforcing rods and groundwater pollution. Therefore, these tanks should be designed to withstand different design loads. Codes and design recommendations require that the effects of liquid, soil, and vehicle loads, and temperature should all be considered in the design. They added that liquid manure is often stored in large cylindrical concrete tanks, which are partially below ground. The dimensions of these tanks vary from 18 to 33 m in diameter with heights from 2.4 to 4.9 m and a uniform wall thickness varying from 150 to 200 mm. Generally, the designer assumes the base of the tank wall to be fixed or hinged. The liquid level varies during winter as a function of time. Generally, manure is added from the top by successive batches. The number of days between each batch varies from one to ten. The tank capacity is designed, in most cases, for 200 to 300 days of storage.

2.2.3 Milking Parlor

For planning a milking centre, it is important to calculate the space needed for work, animals, personal, and milk storage in the planned building. Parlor performance is mostly affected by building design. Efficiency of cow entry and exit is affected by parlor and collecting yard design, and floor materials (ALFA LAVAL AGRI, 1996; BRAMLEY et al., 1992). When planning a milking parlor, managers need to be aware of how cow entrance will affect labor efficiency and milking parlor performance. Management can minimize those affects, and training teams of skilled milkers will be essential. Milking facilities need to be sized to allow the use of a full pre-milking hygiene when needed to maintain udder health (SMITH et al., 1998).

Concerning parallel layouts, the basic dimensions depend on the guidelines of the corporation which will carry out the parlor construction. However, pit width varies between 2.4 m and 2.6 m, pit depth is usually 1 m but for adjustable pit floor is 1.24 m, and minimum distance to ceiling is between 2.2 m and 2.4 m. Regarding herringbone layouts, pit width varies between 2 m (low line) and 2.3 m (recorder), pit depth is usually 0.85 m but for adjustable pit floor is 1.07 m, and minimum distance to ceiling is between 2.45 m and 3.4 m. On the other hand, pit length depends on the

parlor size, parlor layout, and corporation's guidelines. On the other hand, the factors that decide the size of a collecting yard (waiting area) are: breed (Holstein: 1.6 m²/cow, Jersey: 1.3 m²/cow), group size, parlor size, number of milkers, parlor size contra group size, installations, and plans for the future (ALFA LAVAL AGRI, 1996).

SIMON (2006) compared the investment costs and the functions of different milking house arrangements regarding the dairy cow house. The study shows that the costs of the different arrangements were alike and independent on number of cows.

2.2.4 Forage Storage

LINDLEY and WHITAKER (1996) stated that horizontal silos are built of concrete, provide storage at considerably lower costs, and are adaptable to self feeding. MILLER and MARTER (2003) stated that the engineering design for proper feed-off rate, gives the highest quality feed, lowest losses, and the lowest operational costs. Furthermore, bunker silos (Figure 2.11) have three key elements: site preparation, walls systems, and floors. ZHANG and BRITTON (2003) have developed a model for predicting dynamic pressures during discharge in bulk solids storage bins.

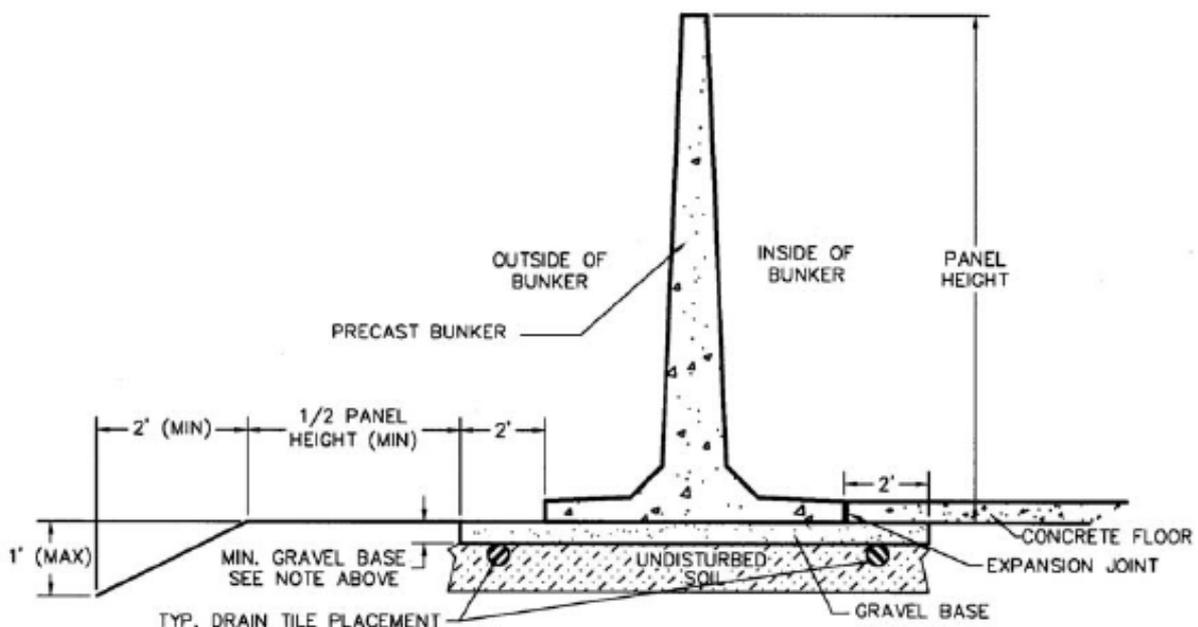


Figure 2.11: Bunker silo design (MILLER and MARTER, 2003)

2.3 Farmstead Layout

JUNGBLUTH (1995) stated that a lot of agricultural buildings have to be fitted into a group of existing buildings, i.e. of an existing farm, or have to be placed in relation to silos or other production units. Hence, the use of space and the simulation of vehicle movement should be accomplished and optimized in order to reach the minimum working time requirements with the maximum efficiency of the farm operations.

HATEM (1993) defined that farmstead layout is a two dimensional distribution of the farm buildings. On the other hand, the purposes of planning a dairy farmstead layout are: reaching optimum efficiency in handling materials and using labor, controlling the environment more precisely, attaining highest production, and sustaining best product quality.

TYSON (2000) recorded that layout of a dairy operation has a direct effect on the operation and overall efficiency of the farm. Dairy farmstead layout develops and designs the interaction and traffic flow between the components and integrates them into one coherent operation. In Figure 2.12 the “webbing” between the components represents that relationship between components and traffic flow around the farm.

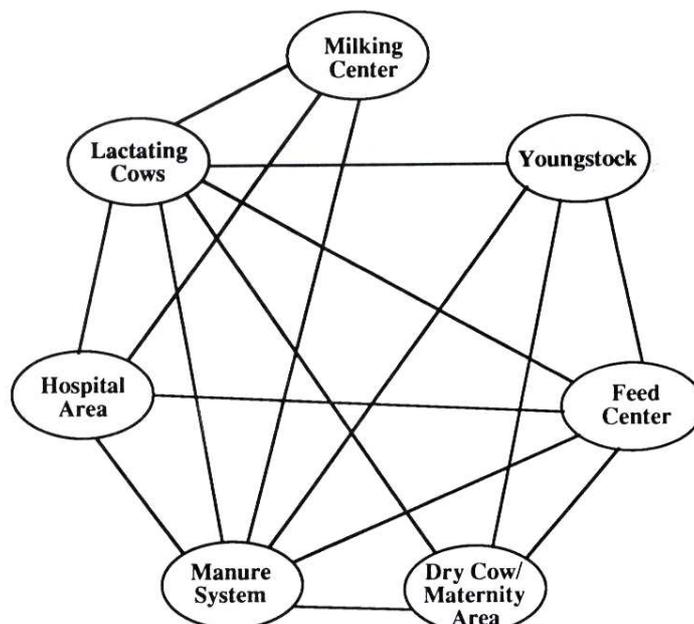


Figure 2.12: Dairy design web (TYSON, 2000)

LINDLEY and WHITAKER (1996) stated that interaction between the system and the building affects labor and investment. The arrangement of facilities for maximum efficiency of operation should be prime concern in farmstead planning. Proper arrangement increases efficiency by reducing walking distances to a minimum and providing adequate driveways and turnarounds. They added, distance between farm buildings should be between 15 and 30 m; and drives that will be carrying large equipment should be a minimum of 5 m wide, but branch drives may be as little as 2.5 m. However, when planning a farmstead layout, some factors should be taken into consideration, such as: farmstead location in relation to field, well-drained soil, ability of handling manure without serious problems, building and cowshed orientation (in hot climates) perpendicular to prevailing summer wind, future expansions, and contour lines.

The planning process for construction sites is similar to that for agricultural settings in that it must have clearly defined values for the critical elements, including a performance criterion on which to judge success, and an associated recurrence interval and duration of the period of interest (YODER et al., 2007).

ELDER et al. (2001) stated the procedures that should be followed in order to eliminate problems and create solutions for any dairy expansion or remodeling plan to succeed:

- determine the operator's goals and wants
- investigate the site and all existing facilities located on the dairy
- determine how each facility is used in the overall management of the dairy
- determine the role of each facility in the future dairy operation
- review all of the information gathered
- compare efficiencies and operational costs in new facilities vs. old to develop a weighted score for decision making

-
- create a staged plan that is obtainable, workable while the dairy is operating, and allows for future changes to be met
 - design all new facilities to be as efficient, cost effective, energy efficient and functional as possible
 - review and revise the expansion or remodeling plan and all of the new facility designs until everyone involved is satisfied
 - implement the plan and stay with it

Proper planning and information gathering ensures all expansion or remodeling projects can be completed to the satisfaction of everyone involved. A good plan for expanding or remodeling old dairies into new efficient modern dairies will result in larger profits for many years into the future (ELDER et al., 2001).

2.4 Operating Supply Items

HATEM (1993) mentioned that operating supply items, for a dairy farm, are electricity and water. Furthermore, electricity supply is either governmental supply or electric generators. On the other hand, water supply is either governmental supply or a well. However, making decision to select a supply mode depends on farm location.

KRAATZ and BERG (2007) stated that the amounts of electricity used to perform a farming procedure vary with the size and kind of equipment used, as well as the level of farm management.

The investigations of JÄKEL (2003) include the electrical energy consumption for the whole farm. The mean for all investigated farms was 9 kWh/100 kg milk. The share of the electrical energy consumption of the separate sections of the production procedure is shown in Figure 2.13. Most of the electrical energy consumption on the dairy farm is used for the section milking. That is about 6.2 kWh/100 kg milk.

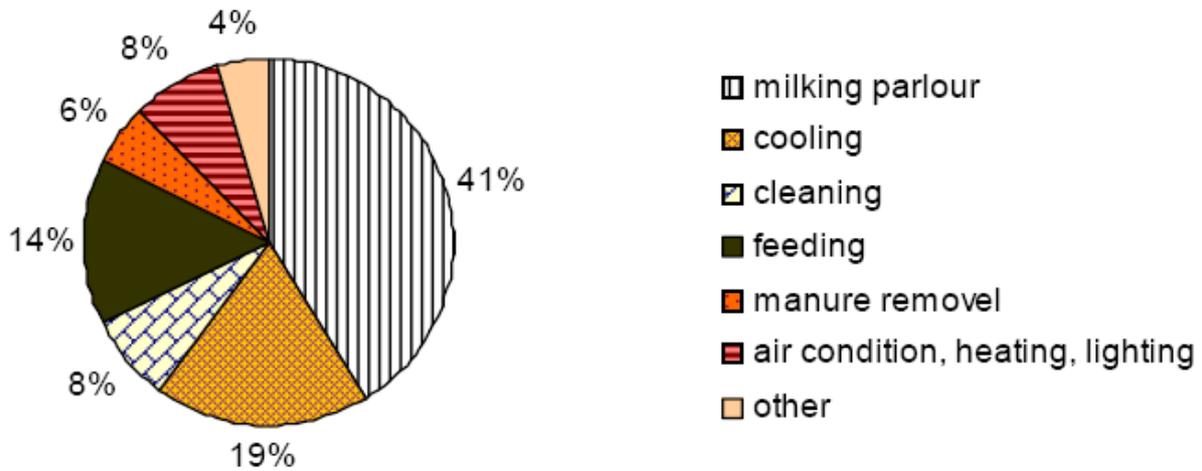


Figure 2.13: Consumption of electrical energy in the sections of the procedure milk production (JÄKEL, 2003)

BRUGGER and DORSEY (2006) showed that the average annual water use on a modern dairy farm was >100 liter/cow.day for all purposes with a direct correlation between temperature and water consumption.

TILLIE (1999) elucidated a method to calculate the drinking water requirements of dairy cows. He added that the quantities of water absorbed depend on various factors: production, dry-matter content of the feed, stage of lactation, and ambient temperature. The following equation predicts the required drinking water for one cow:

$$y = 2.53x_1 + 0.45x_2 - 15.3 (\pm 8.31)$$

Where,

y = water requirement (kg/d)

x_1 = milk production (kg/d)

x_2 = dry matter content of feed (%).

2.5 Expert System

GREER et al. (1994) explains that decision support systems (DSS) are computer programs, which encode expert knowledge that assists users in making management decisions. Expert knowledge is collected from many sources, including human experts in the domain, research results, and government policies. The expert knowledge is then embodied in simulation models, expert systems, hybrid systems,

databases, or spreadsheets as so-called "decision support". Unfortunately, many of these decision support systems do not adequately explain and justify their recommendations. Agricultural decision support systems must be able to make recommendations that the user can easily understand, trust, and apply to his or her particular situation.

DOLUSCHITZ and SCHMISSEUR (1988) define "expert system" as an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution.

SPANGLER et al. (1989) stated that an expert system is a computer program that manipulates symbolic descriptions of facts and heuristics in an attempt to emulate the reasoning processes of an expert. Heuristics are rules of thumb which enable the human expert to make educated guesses about potential problem approaches and to deal effectively with incomplete or inconsistent data. Expert systems try to model these heuristics as exemplified by metaphors, analogies, and gestalts while conventional programs usually try to model algorithms as exemplified by logic and mathematics. The fundamental task of the knowledge engineer is to capture these heuristics or patterns of thought used by experts in the performance of complex problem solving tasks.

According to GIARRATANO and RILEY (2005), an intelligent and advanced expert system may have the following characteristics and constituents:

1. a stand-alone system that can be easily used via CD-ROM
2. an accuracy that should be computed
3. a determined number of rules
4. an inference process which mimics the way of thinking of the experts
5. a database module, a knowledge base, a reasoning machine, a case elicitation tool, an explanation subsystem, and a user interface

A computer simulation, a computer model or a computational model is a computer program, or network of computers, that attempts to simulate an abstract model of a particular system. Computer simulations have become a useful part of mathematical modeling of many natural systems. Traditionally, the formal modeling, or modelling, of systems has been via a mathematical model, which attempts to find analytical solutions to problems which enable the prediction of the behavior of the system from a set of parameters and initial conditions. However, a mathematical model is an abstract model that uses mathematical language to describe a system, it is also defined as a representation of the essential aspects of an existing system (or a system to be constructed) which presents knowledge of that system in usable form. While computer simulations might use some algorithms from purely mathematical models, computers can combine simulations with reality of actual events, such as generating input responses, to simulate test subjects who are no longer present. Whereas the missing test subjects are being modeled/simulated, the system they use could be the actual equipment, revealing performance limits or defects in long-term use by the simulated users (GIARRATANO and RILEY, 2005).

GREER et al. (1994) stated that overall expert system architecture consists of user interface, simulation model, explanation module, and user model; whereas:

- the user interface has three responsibilities: querying the user for suitable inputs to the simulation (i.e. assisting the user in formulating a question to be answered), acquiring knowledge about the individual user to inform the user model, and presenting output to the user
- the simulation model carries out an analysis of the user's question and generates a table of numeric values as output
- the explanation module interprets the output of the simulation and generates explanations, taking into account information in the user model
- the user model determines general and specific attributes of the user and provides modification rules to the explanation module, which are used to individualize the explanation

3 MATERIALS AND METHODS

3.1 General Procedures

The expert system was prototyped to contain two main models and nine sub-models, which are a total of eleven simulation models for planning and designing dairy farm facilities. The two main models are: (1) Design Model in form of electronic spark map which designs the housing system (corrals system), and (2) Costs Calculation Model which calculates the capital investment and the fixed, variable and total costs of the constructions, technologies, land, and cows. Figure 3.1 shows the architecture of the expert system and the reciprocal interactions between the main models and sub-models on one side, and the user-interface on the other side.

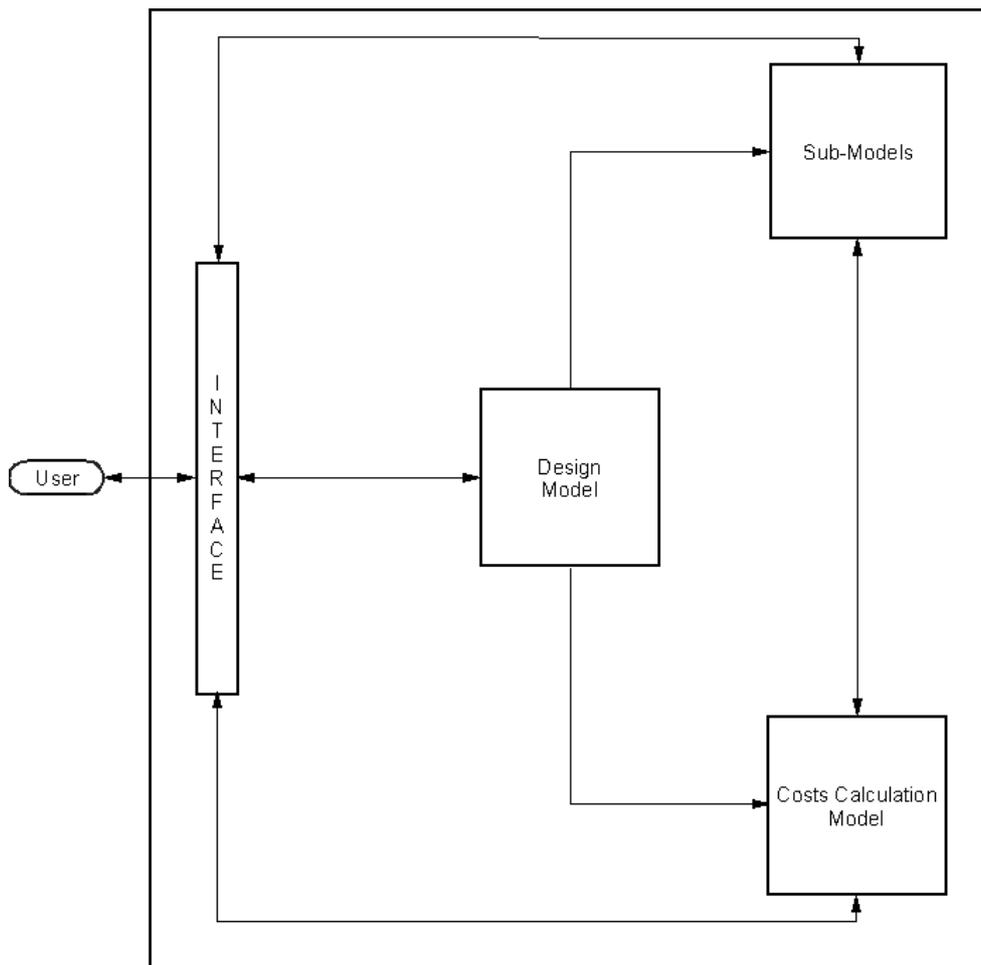


Figure 3.1: Architecture of the expert system (SAMER et al., 2008d)

The sub-models, simulation models integrated into electronic spark maps, are in input/output exchange relation to each other and to the Design Model which is the mentor of the sub-models. The sub-models are: (1) Concrete Base Sub-Model which is responsible of designing the concrete base of the feeding line and feeding bunks; (2) Roof Materials and Structure Sub-Model which specifies the appropriate roof material according to the climate conditions, and then it configures the suitable roof type; (3) Manure Handling/Constructions Sub-Model designs the required manure tanks and the handling system; (4) Milking Parlor Constructions Sub-Model is able to plan and design the milking centre inclusive milking parlor, collecting yard, and parlor rooms; (5) Forage Storage Constructions Sub-Model determines the specifications of the horizontal silo and the storage shed; (6) Farmstead Layout Sub-Model which plans the dairy farm and distributes its different facilities over a two-dimensional layout; (7) Cooling System Sub-Model configures the cooling system, which is highly required in hot climates, and specifies its components; (8) Water Sub-Model determines the water requirements/consumption of the dairy farm versus the available sources as governmental supply and/or drilling a well; (9) Electricity Sub-Model determines the energy requirements/consumption of the dairy farm versus the available sources as governmental supply and/or using generators.

Furthermore, some sub-models perform two or three operations such sub-models are divided into several parts accordingly. Some sub-models require data from other sub-models; Figure 3.2 shows the interactions between the different sub-models taking into consideration their dependence on the Design Model.

3.2 Knowledge Acquisition

The simulation models were developed using the plans, designs, parameters, variables, and constant values of the dairy farm facilities and their concrete structures available in the references, mainly in LINDLEY and WHITAKER (1996) and in BARTALI (1999).

Furthermore, contacts were made with the experts of the Cattle Information System of Egypt (CISE) in order to emulate their expertise thought and using it in developing the structured induction of the expert system.

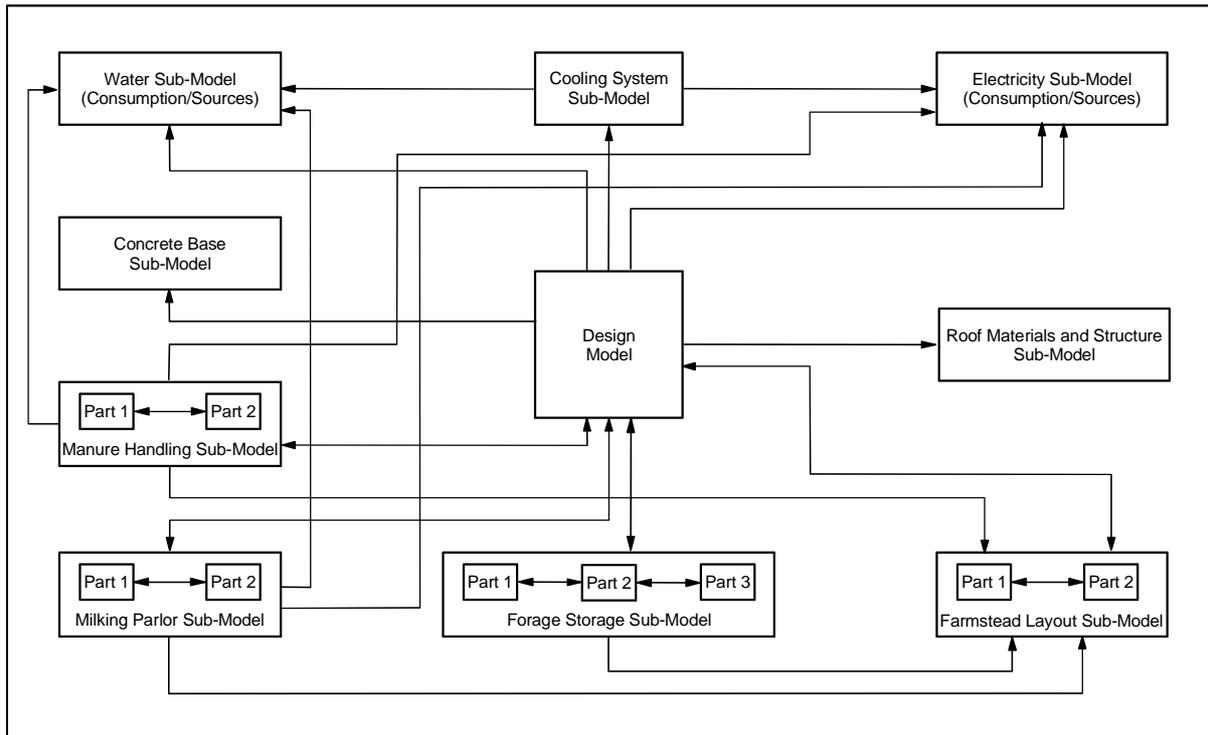


Figure 3.2: Architecture of the expert system sub-models (SAMER et al., 2008d)

3.3 Mathematical Modeling

3.3.1 Housing Design

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 expert system.

3.3.1.1 Corral Specifications

The specifications of the different rectangular corral systems can be expressed as:

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

$$A_C = N_{CC} \times A_{AC} \tag{2}$$

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

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

where,

$$4 \leq W_C \leq 15 \quad (5)$$

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

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

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

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

The available corral systems are: two sides of corrals, one side of corrals, and one corral. Each has its own mathematical model, but the same general information should be considered for the three corral systems:

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

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

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

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

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

Two Sides of Corrals

This corral system is suitable for large group size (Figure 3.3), and it has one concrete base (Figure 3.4). Thus,

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

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

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

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

with the following conditions:

$$\text{if } L_C > 10, \text{ then } H_C = 8 \quad (18)$$

$$\text{if } 5 \leq L_C \leq 10, \text{ then } H_C = 5 \quad (19)$$

$$\text{if } L_C < 5, \text{ then } H_C = 3.5 \quad (20)$$

where N_{HC} is an even positive number, thus:

$$N_{HC} = \{0, 2, 4, 6, 8 \dots\} \quad (21)$$

One Side of Corrals

This corral system is suitable for intermediate group size (Figure 3.5), and it has one concrete base (Figure 3.6). Thus,

$$W_{CB} = W_{LB} + W_{FP} + W_{BB} + W_{RC} \quad (22)$$

$$L_H = N_{HC} \times W_C \quad (23)$$

$$W_H = L_C + W_{LB} \quad (24)$$

$$A_H = L_H \times W_H \quad (25)$$

with the following conditions:

$$\text{if } L_C > 20, \text{ then } H_C = 8 \quad (26)$$

$$\text{if } 10 \leq L_C \leq 20, \text{ then } H_C = 5 \quad (27)$$

$$\text{if } L_C < 10, \text{ then } H_C = 3.5 \quad (28)$$

where N_{HC} is a natural number, thus:

$$N_{HC} = \{0, 1, 2, 3, 4 \dots\} \quad (29)$$

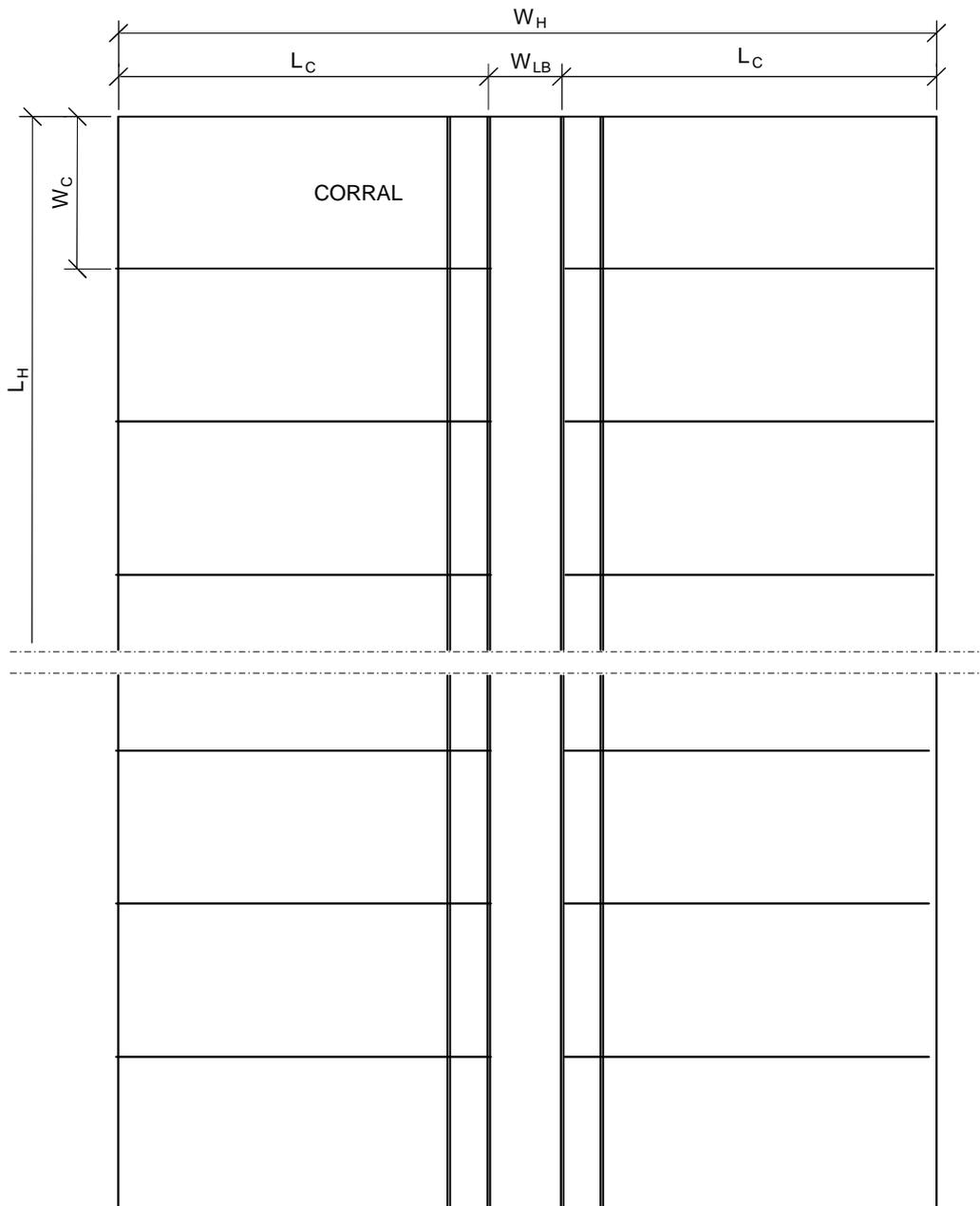


Figure 3.3: Two sides of corrals (SAMER et al., 2008b)

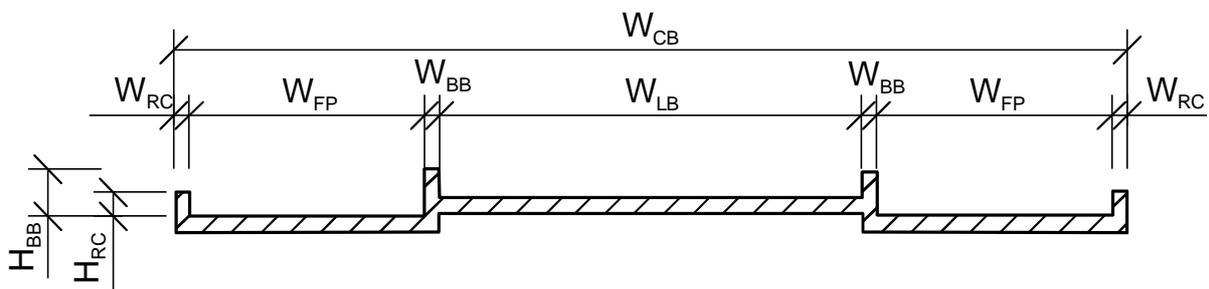


Figure 3.4: Concrete base for two sides of corrals (SAMER et al., 2008b)

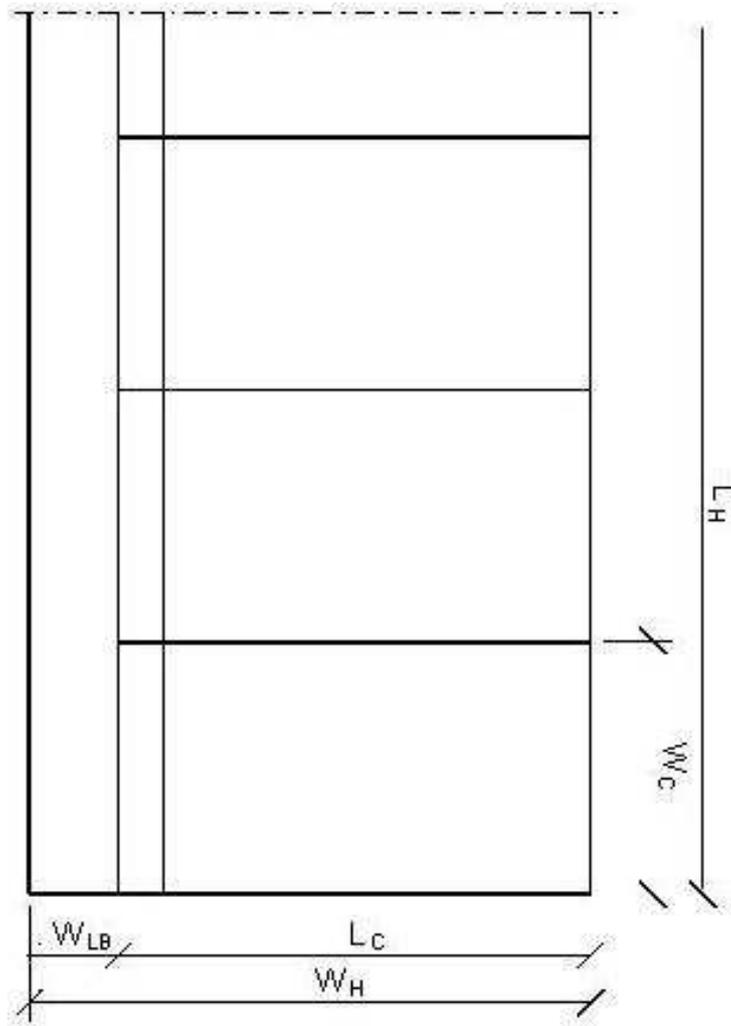


Figure 3.5: One side of corrals (SAMER et al., 2008b)

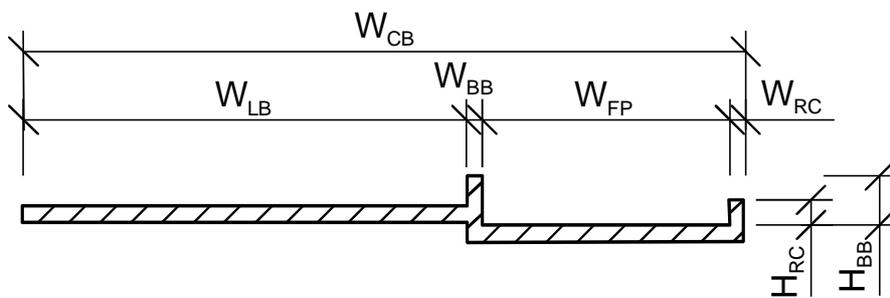


Figure 3.6: Concrete base for one side of corrals (SAMER et al., 2008b)

One Corral

This corral system is suitable for a small group of 10-15 cows (Figure 3.7), and it has one concrete base (Figure 3.8). Thus,

$$W_{CB} = W_{LB} + W_{FP} + W_{BB} + W_{RC} \quad (30)$$

$$L_H = (N_{HC} \times L_C) + W_{LB} \quad (31)$$

$$W_H = W_C \quad (32)$$

$$A_H = L_H \times W_H \quad (33)$$

with the following conditions:

$$\text{if } 10 \leq W_C, \text{ then } H_C = 5 \quad (34)$$

$$\text{if } W_C < 10, \text{ then } H_C = 3.5 \quad (35)$$

where,

$$N_{HC} = 1 \quad (36)$$

$$N_{CH} = N_{CC} \quad (37)$$

$$10 \leq N_{CC} \leq 15 \quad (38)$$

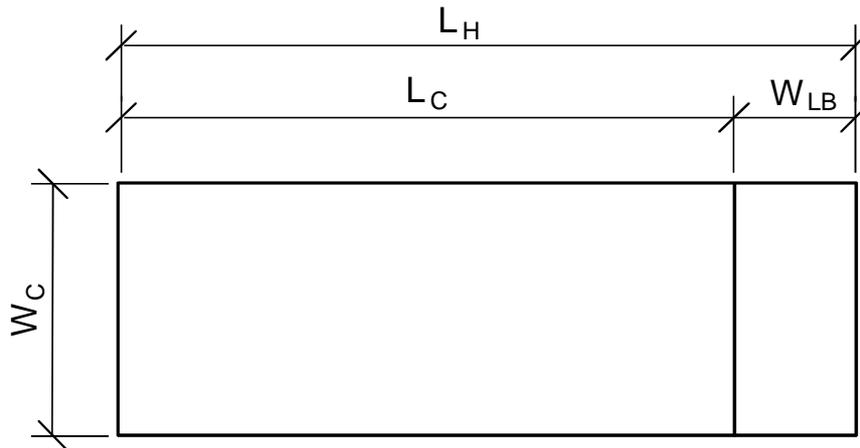


Figure 3.7: One corral (SAMER et al., 2008b)

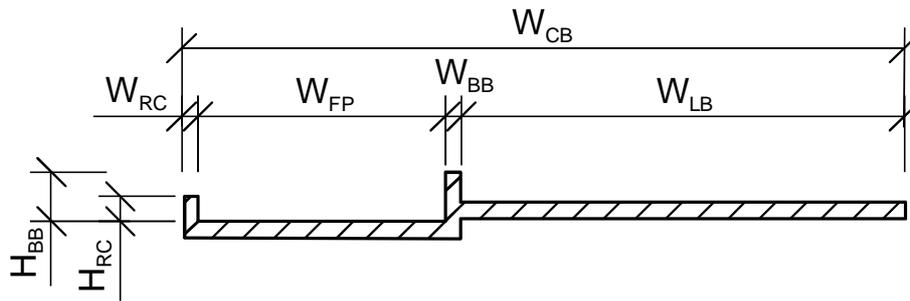


Figure 3.8: Concrete base for one corral (SAMER et al., 2008b)

3.3.1.2 Decision Making

The designer should gather some climate information about the location where the dairy farm will be established, such as: precipitation (mm/year), wind speed (m/s), wind direction, mean maximum temperature ($^{\circ}\text{C}$), 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 roof material is:
Reed Mats, or Straw Mats
- If Wind Speed < 1.8 m/s and Precipitation > 80 mm/year, then roof material is:
Reed Mats
- If Wind Speed > 1.8 m/s and Precipitation > 80 mm/year, then roof material is:
Polished Aluminum (Reflection 90 - 70%),
Isolated Aluminum or Burnt-Clay Bricks
- If Wind Speed > 1.8 m/s and Precipitation < 80 mm/year, then roof material is:
Polished Aluminum (Reflection 90 - 70%),
Isolated Aluminum or Burnt-Clay Bricks

Building Materials

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

Orientation

- East-West (recommended)
- North-South

Floor Materials

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

3.3.1.3 Shade Calculation

The following mathematical models developed to compute the shade specifications:

$$A_{FP} = L_{FP} \times W_{FP} \quad (39)$$

$$R_A = \frac{A_{FP}}{A_C} \quad (40)$$

$$A_{SHF} = A_H \times R_A \times \left(\frac{S_F}{100} \right) \quad (41)$$

$$A_{SHL} = A_H \times (1 - R_A) \times \left(\frac{S_L}{100} \right) \quad (42)$$

$$A_{SH} = A_{SHF} + A_{SHL} \quad (43)$$

$$W_{SH} = \frac{A_{SH}}{L_{SH}} \quad (44)$$

where,

$$L_{SH} = L_H \quad (45)$$

$$W_{FP} = f \text{ (breed, manure handling system)} \quad (46)$$

3.3.1.4 Facilities' Area

The total area the dairy farm facilities, can be calculates as follows:

$$N_{HF} = \frac{N_{CF}}{N_{CH}} \quad (47)$$

$$A_{tF} = (N_{HF} \times A_H) + A_M + A_{MC} + A_{FS} + A_O \quad (48)$$

3.3.2 Concrete Base

The objective of making such a model is to decide 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.

3.3.2.1 Concrete Volume

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

Two Sides of Corrals

In order to compute the required concrete volume for constructing the concrete base of two sides of corrals, the following mathematical model is developed:

$$L_{CB} = L_H \quad (49)$$

$$V_{LB} = L_{CB} \times W_{LB} \times T_{LB} \quad (50)$$

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

$$V_{FP} = 2 \times L_{CB} \times (W_{FP} + W_{BB} + W_{RC}) \times T_{FP} \quad (52)$$

$$V_{RC} = 2 \times L_{CB} \times W_{RC} \times H_{RC} \quad (53)$$

$$V_{CB} = V_{LB} + V_{BB} + V_{FP} + V_{RC} \quad (54)$$

where,

$$T_{LB} = f \text{ (feeding system)} \quad (55)$$

$$T_{FP} = f \text{ (breed)} \quad (56)$$

$$H_{BB} = 0.50 \quad (57)$$

$$0.20 \leq H_{RC} \leq 0.25 \quad (58)$$

One Side of Corrals

In case of configuring one side of corrals, the following mathematical model can be used for estimating the required concrete volume for constructing the concrete base:

$$L_{CB} = L_H \quad (59)$$

$$V_{LB} = L_{CB} \times W_{LB} \times T_{LB} \quad (60)$$

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

$$V_{FP} = L_{CB} \times (W_{FP} + W_{BB} + W_{RC}) \times T_{FP} \quad (62)$$

$$V_{RC} = L_{CB} \times W_{RC} \times H_{RC} \quad (63)$$

$$V_{CB} = V_{LB} + V_{BB} + V_{FP} + V_{RC} \quad (64)$$

One Corral

This type requires that concrete base length be equal to house width, hence:

$$L_{CB} = W_H \quad (65)$$

$$V_{LB} = L_{CB} \times W_{LB} \times T_{LB} \quad (66)$$

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

$$V_{FP} = L_{CB} \times (W_{FP} + W_{BB} + W_{RC}) \times T_{FP} \quad (68)$$

$$V_{RC} = L_{CB} \times W_{RC} \times H_{RC} \quad (69)$$

$$V_{CB} = V_{LB} + V_{BB} + V_{FP} + V_{RC} \quad (70)$$

3.3.2.2 Construction Materials

The required amounts of construction materials (cement, sand, and gravels) can be estimated as follows:

$$M_C = C \times V_{CB} \quad (71)$$

$$V_G = G \times V_{CB} \quad (72)$$

$$V_S = S \times V_{CB} \quad (73)$$

where,

$$C = 325 \quad (74)$$

$$G = 0.8 \quad (75)$$

$$S = 0.4 \quad (76)$$

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

$$N_{IL} = [(N_{IML} \times W_{CB}) + 1] \times 1.05 \times L_{CB} \quad (77)$$

$$N_{IW} = [(N_{IML} \times L_{CB}) + 1] \times 1.05 \times W_{CB} \quad (78)$$

$$N_{iG} = N_{IL} + N_{IW} \quad (79)$$

$$N_{iI} = N_G \times N_{iG} \quad (80)$$

$$N_{tSI} = \frac{N_{iI}}{L_{SI}} \quad (81)$$

$$M_I = N_{SI} \times M_{IML} \times L_{SI} \quad (82)$$

where,

$$L_{SI} = 12 \quad (83)$$

with the following conditions:

$$\text{if } N\phi D/m = 6\phi 6/m, \text{ then } M_{IML} = 0.666 \quad (84)$$

$$\text{if } N\phi D/m = 6\phi 8/m, \text{ then } M_{IML} = 0.888 \quad (85)$$

where, M_I in kg

The unit of M_I should be converted from kg to Ton in order to be used in the costs calculation. 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. Thus, the iron rod here has a width of 1 m.

Costs Calculation

The costs of the required construction materials can be estimated as follows:

$$P_{IC} = P_C \times M_C \quad (86)$$

$$P_{IG} = P_G \times V_G \quad (87)$$

$$P_{IS} = P_S \times V_S \quad (88)$$

$$P_{II} = P_I \times M_I \quad (89)$$

$$C_{IEC} = C_{EC} \times V_{CB} \quad (90)$$

$$C_{ICB} = P_{IC} + P_{IG} + P_{IS} + P_{II} + C_{IEC} \quad (91)$$

$$C_{FCB} = \frac{C_{ICB}}{t_P} \quad (92)$$

$$C_{TCB} = C_{FCB} + C_{VCB} \quad (93)$$

where,

$$t_P = 20 \quad (94)$$

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} .

3.3.3 Roof Materials and Structure

This model assists the designer in making decisions to select the roof material, roof type, and corral distribution; then, specifying the roof and structure dimensions. Moreover, RSM calculates the capital investment and the fixed, variable, and total costs. However, if the designer input some data and the output data are impractical, hence the designer should adjust the input data to be reasonable in order to get rational output data.

3.3.3.1 General Factors and Concepts

Some general factors affect directly the decision making. The following mathematical model summarizes those factors:

$$W_{SH} = \frac{A_{SH}}{L_{SH}} \quad (95)$$

$$\tan \alpha = \frac{m}{100} \quad (96)$$

where,

$$L_{SH} = L_H = L_R = L_S \quad (97)$$

with the following conditions:

$$\text{if } H_c \geq 5, \text{ then } 30 \leq W_{SH} \leq 50 \quad (98)$$

$$19 \leq m \leq 45 \quad (99)$$

3.3.3.2 Corrals Distribution and Roof Types

- If 2 Sides of Corrals under One Cowshed, then:
Horizontal Roof, Open Ridge Roof (recommended), or Compound Roof (3 Parts)

Open Ridge Roof: $R = 4$ (108)

Compounds (2 parts) Roof: $R = 3$ (109)

Compounds (3 parts) Roof: $R = 4$ (110)

Horizontal Roof

Figure 3.9 shows the horizontal roof, where its specifications can be calculated as:

$$W_R = W_{SH} \quad (111)$$

$$A_R = W_R \times L_R \quad (112)$$

$$A_R = A_{SH} \quad (113)$$

$$W_S = W_R - (2 \times M) \quad (114)$$

$$N_P = \frac{L_S}{S_P} + 1 \quad (115)$$

$$N_{Pt} = N_P \times R \quad (116)$$

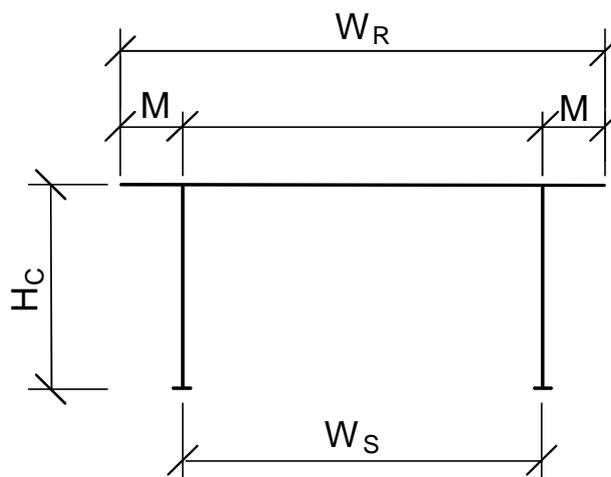


Figure 3.9: Horizontal roof

Mono-Slope Roof

Figure 3.10 shows the mono-slope roof, where its specifications can be computed as:

$$W_R = \frac{W_{SH}}{\cos \alpha} \quad (117)$$

$$A_R = W_R \times L_R \quad (118)$$

$$W_S = [W_R - (2 \times M)] \times \cos \alpha \quad (119)$$

$$N_P = \frac{L_S}{S_P} + 1 \quad (120)$$

$$N_{Pt} = N_P \times R \quad (121)$$

$$H_{CS} = H_C - \{[W_R - (2 \times M)] \times \sin \alpha\} \quad (122)$$

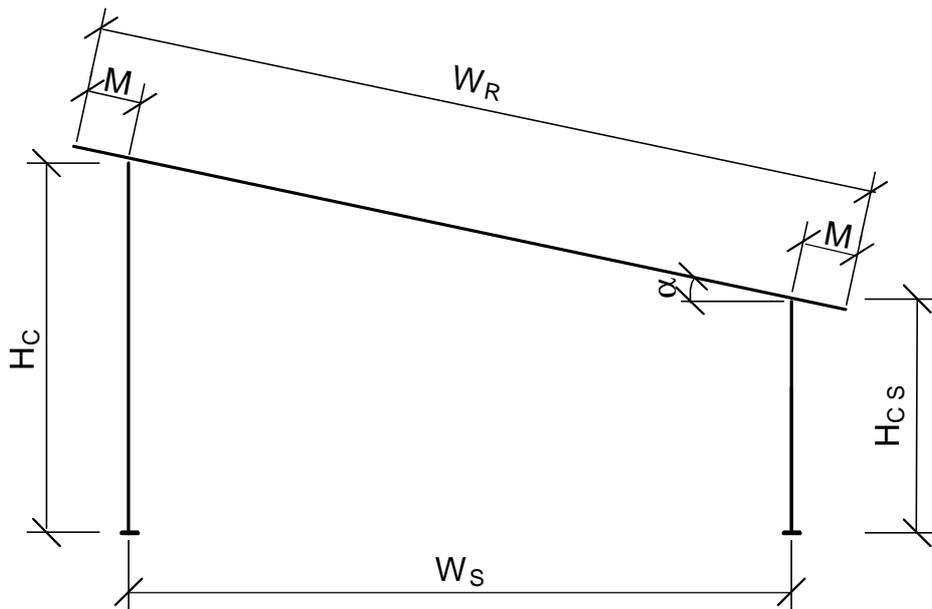


Figure 3.10: Mono-slope roof

Open Ridge Roof

This roof type (Figure 3.11) is made from 2 Mono-Slope roofs, thus:

$$W_{WR} = \frac{W_{SH}}{2 \times \cos \alpha} \quad (123)$$

$$W_{LR} = W_{WR} \quad (124)$$

$$A_R = (W_{WR} \times L_R) + (W_{LR} \times L_R) \quad (125)$$

$$W_{OR} = W_{LB} - (2 \times M \times \cos \alpha) \quad (126)$$

$$W_{WS} = [W_{WR} - (2 \times M)] \times \cos \alpha \quad (127)$$

$$W_{LS} = [W_{LR} - (2 \times M)] \times \cos \alpha \quad (128)$$

$$W_S = W_{LB} + W_{WS} + W_{LS} \quad (129)$$

$$N_P = \frac{L_S}{S_P} + 1 \quad (130)$$

$$N_{Pt} = N_P \times R \quad (131)$$

$$H_{CS} = H_C - \{[W_{WR} - (2 \times M)] \times \sin \alpha\} \quad (132)$$

where,

$$0.5 \leq W_{OR} \leq 2 \quad (133)$$

The designer might re-input other value of Margins to adjust W_{OR} value between 0.5 and 2 m.

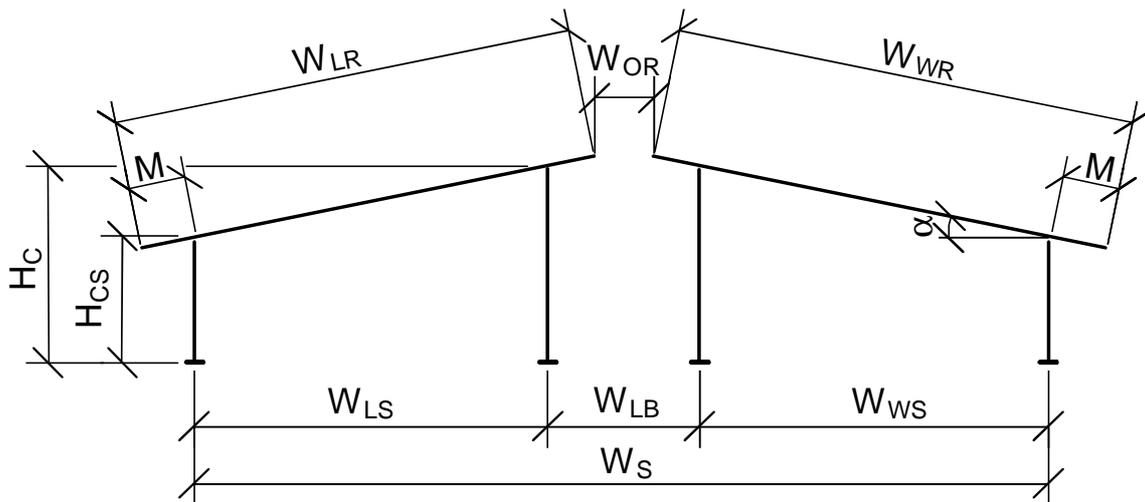


Figure 3.11: Open ridge roof

Compounds (2 Parts)

This roof type is made from 1 Main Horizontal Roof and 1 Mono-Slope Roof (Figure 3.12), thus:

$$W_{MR} = \frac{W_{SH}}{2} + M \quad (134)$$

$$W_{LR} = \frac{W_{SH}}{2 \times \cos \alpha} \quad (135)$$

$$A_R = (W_{MR} \times L_R) + (W_{LR} \times L_R) \quad (136)$$

$$W_{MS} = W_{MR} - (2 \times M) \quad (137)$$

$$W_{LS} = (W_{LR} - M) \times \cos \alpha \quad (138)$$

$$W_S = W_{MS} + W_{LS} \quad (139)$$

$$N_P = \frac{L_S}{S_P} + 1 \quad (140)$$

$$N_{Pt} = N_P \times R \quad (141)$$

$$H_{CS} = (H_C - 0.5) - [(W_{LR} - M) \times \sin \alpha] \quad (142)$$

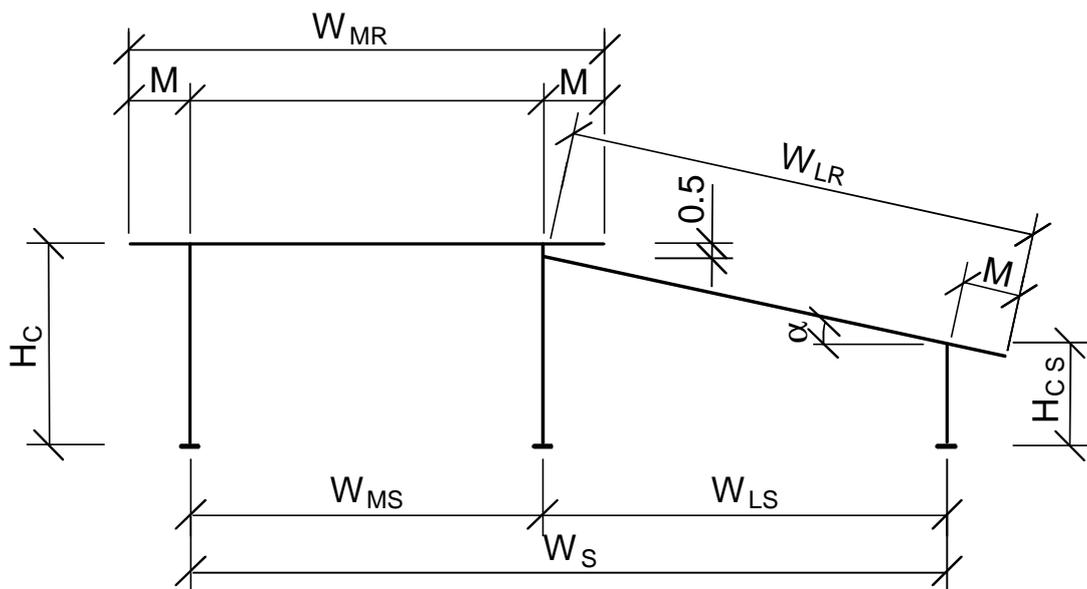


Figure 3.12: Compounds (2 Parts)

Compounds (3 Parts)

This roof type is made from 1 Main Horizontal Roof & 2 Mono-Slope Roofs (Figure 3.13), hence:

$$W_{MR} = W_{CB} + (2 \times M) \quad (143)$$

$$W_{WR} = \frac{W_{SH} - [W_{MR} - (2 \times M)]}{2 \times \cos \alpha} \quad (144)$$

$$W_{LR} = W_{WR} \quad (145)$$

$$A_R = (W_{WR} \times L_R) + (W_{MR} \times L_R) + (W_{LR} \times L_R) \quad (146)$$

$$W_{WS} = (W_{WR} - M) \times \cos \alpha \quad (147)$$

$$W_{LS} = (W_{LR} - M) \times \cos \alpha \quad (148)$$

$$W_S = W_{WS} + W_{CB} + W_{LS} \quad (149)$$

$$N_P = \frac{L_S}{S_P} + 1 \quad (150)$$

$$N_{Pt} = N_P \times R \quad (151)$$

$$H_{CS} = (H_C - 0.5) - [(W_{WR} - M) \times \sin \alpha] \quad (152)$$

where, $W_{CB} = W_{MS} \quad (153)$

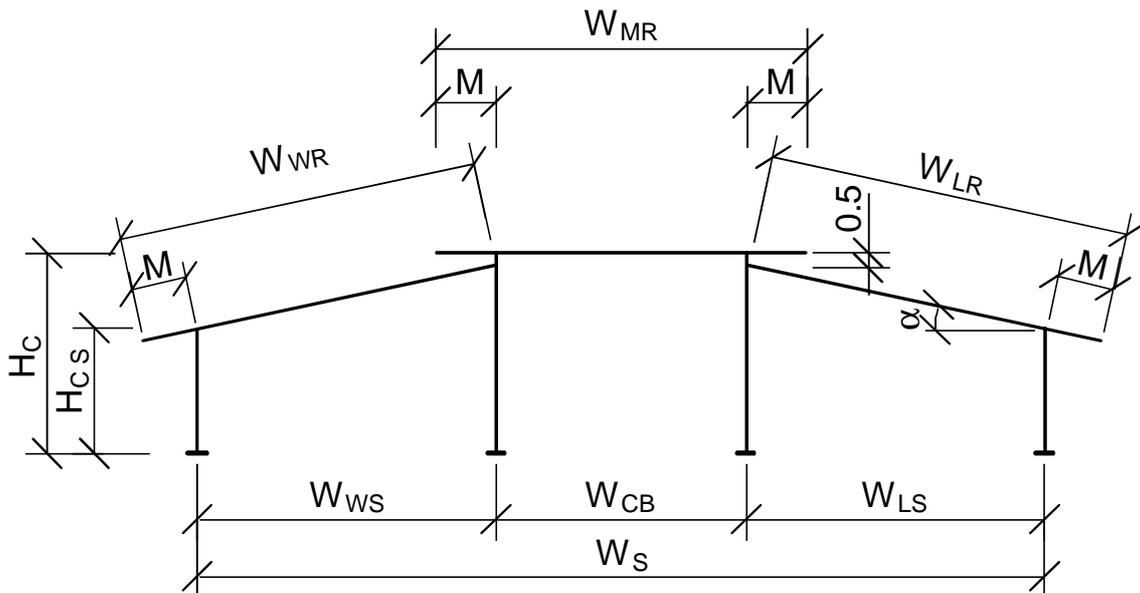


Figure 3.13: Compounds (3 Parts)

3.3.3.4 Roof Materials

The method of choosing the roof material is already described in DM. Several materials are used as roof covering material:

- **Reed Mats**

The total number, mass, and price of required reed mats can be computed as:

$$N_{RM} = \frac{A_R}{A_{RM}} \quad (154)$$

$$M_{iRM} = N_{RM} \times M_{RM} \quad (155)$$

$$P_{iRM} = N_{RM} \times P_{RM} \quad (156)$$

- **Straw Mats**

The total number, mass, and price of required straw mats can be estimated as:

$$N_{SM} = \frac{A_R}{A_{SM}} \quad (157)$$

$$M_{iSM} = N_{SM} \times M_{SM} \quad (158)$$

$$P_{iSM} = N_{SM} \times P_{SM} \quad (159)$$

- **Polished Aluminum**

The total mass and price of required polished aluminum can be calculated as:

$$M_{iPA} = A_R \times M_{PA} \quad (160)$$

$$P_{iPA} = A_R \times P_{PA} \quad (161)$$

- **Isolated Aluminum**

The total mass and price of required isolated aluminum can be computed as:

$$M_{iIA} = A_R \times M_{IA} \quad (162)$$

$$P_{iIA} = A_R \times P_{IA} \quad (163)$$

- **Burnt-Clay Bricks**

The total mass and price of required burnt-clay bricks can be estimated as:

$$M_{iBC} = A_R \times M_{BC} \quad (164)$$

$$P_{iBC} = A_R \times P_{BC} \quad (165)$$

Costs Calculation

The capital investment and the fixed, variable and total costs of the shed can be calculated as follows:

$$C_{IS} = P_{RCM} + P_{ISC} \quad (166)$$

$$C_{FS} = \frac{C_{IS}}{t_S} \quad (167)$$

$$C_{TS} = C_{FS} + C_{VS} \quad (168)$$

where,

$$t_B = t_S = 20 \quad (169)$$

The value of P_{RCM} will be equal to the total price of the chosen roof material. A civil engineer should be consulted to make the final design and the concrete piers of the posts, hence P_{ISC} could be calculated.

3.3.4 Manure Handling Constructions

The objective of MHM P1 is to calculate the monthly and daily manure storage volume for a farm, and the volume of slurry and compost. Moreover, MHM P1 makes the piles' design of the compost and calculates its dimensions and the required area for the composted product, and specifies the required manure mechanical system. Furthermore, MHM P1 is able to calculate the capital investment and the fixed, variable, and total costs. MHM P2 makes the design and calculates the dimension of manure, raw slurry, and treated liquid storage tanks.

The manure storage volume per cow and month is 1.8 m^3 (incl. flushing system water). About 75-80% of the waste is gathered from the feeding places (which are also considered as small manure canals) using a flushing system that drives the manure to an outlet at the end of each canal and then the manure flows to the manure tank through some plastic tubes, thus there is no need to design the conventional manure canals (deep closed manure canals). On the other hand, 20-25% of the waste is scrapped from the corrals either every month or in a cycle of 6 months depending on the farm management. However, the liquid manure will be stored in aerated lagoons (aerobic system), because it is a simple low-cost system, which requires a relatively small investment. The scrapped waste will be either used directly for land application or composted. Thus, the manure storage volume will be calculated as:

$$V_{iMM} = \psi \times N_{CF} \times V_{MCM} \quad (170)$$

$$V_{iMD} = \frac{V_{iMM}}{30} \quad (171)$$

where,

$$V_{MCM} = 1.8 \quad (172)$$

While calculating the internal tank volume for any storage tank in the following steps, the internal tank volume is considered to be equal to the volume of the stored material in the tank, and the designer should add 10% so that level of the stored material in the tank will never reach the tank rim.

3.3.4.1 Raw Slurry Storage

The raw slurry storage is the storage where mixing and pumping processes take place. The duration of mixing and pumping processes is between 4 hours till 3 days, if the duration is less than 1 day, so the input data should be 1 day, in order to give more flexibility. Thus,

$$V_{RS} = D_{MP} \times V_{iMD} \quad (173)$$

where,

$$1 \leq D_{MP} \leq 3 \quad (174)$$

The manure mixer and manure pump should be implemented by the designer, and the prices will be used for costs calculation.

3.3.4.2 Aeration Storage

The raw slurry will be separated to solid and liquid materials using a mechanical separator. Hence, there are many types of separators, such as: rotary screen, roller press, screw press, run-down screen, belt separator, and vibrating bed. However, the decision should be made by the designer.

The solid materials will be composted to get the composted product, and the liquid will be treated in the aeration storage which is a mechanically aerated tank to get the treated liquid; therefore, the aeration storage requires a surface aerator. The volume of the aeration storage can be calculated using the following equation:

$$V_A = \left[\frac{V_{iMM} \times D_A}{30} \right] \times \left[1 - \left(\frac{P_{DMM} \times R_E}{100 \times 100} \right) \right] \quad (175)$$

where,

$$20 \leq D_A \leq 30 \quad (176)$$

3.3.4.3 Treated Liquid Storage

After treating the liquid in the aeration storage, it will be transmitted to the treated liquid storage. The treated liquid is ready to be used, but it may be stored for a long time (till 6 months). Thus,

$$V_{TL} = [V_{iMM} \times D_{TL}] \times \left[1 - \left(\frac{P_{DMM} \times R_E}{100 \times 100} \right) \right] \quad (177)$$

where,

$$D_{TL} \leq 6 \quad (178)$$

3.3.4.4 Composted Product

The duration of composted product storage is 2 till 4 months (8 till 16 weeks). Instead of storage volume, the product volume is required.

In case of manure, 1000 kg = 1000 liter = 1 m³

Thus,

$$V_{CP} = \frac{V_{iMM} \times D_{CP} \times P_{DMM} \times R_E}{100 \times 100} \quad (179)$$

where,

$$2 \leq D_{CP} \leq 4 \quad (180)$$

The amount of composted product is depending on the elimination rate, which is percentage of separated solids (by separator) from the manure. This rate is depending on the percentage of dry matter in the raw manure.

The composted product should be kept in a pile or a heap covered by pure straw, wood shavings, sawdust, or peat moss. The pile is aerated by 100 mm pipes each is drilled with 2 rows of 15 mm holes and spaced 300 mm apart, but in case that no pipes were used for aeration, the composted product requires a self-propelled turning

equipment to introduce air inside the product. However, the sectional area of the pile is arc with 3 m cord and 1.2 m arrow.

Thus,

$$L_p = \frac{3 \times V_{CP}}{2 \times N_{CPP} \times L_{PA} \times L_{PC}} \quad (181)$$

While calculating the total required area for the piles, some factors should be considered, which are:

- The distance between 2 piles is 1 m
- The free margins should be 1 m

Thus,

$$A_p = [(4 \times N_{CPP}) + 1] \times [L_p + 2] \quad (182)$$

Costs Calculation

The most important operation to be accomplished, before making the costs calculation of the whole system, is to make design and costs calculation for each tank using MHM P2, and then the designer should input the results in this part:

$$C_{IMM} = P_{MM} + P_{MP} + P_{MS} + P_{SA} + P_{TE} \quad (183)$$

$$C_{IMC} = C_{ISS} + C_{IAS} + C_{ILS} \quad (184)$$

$$C_{FMM} = \frac{C_{IMM}}{t_{MM}} \quad (185)$$

$$C_{FSS} = \frac{C_{ISS}}{t_{SS}} \quad (186)$$

$$C_{FAS} = \frac{C_{IAS}}{t_{AS}} \quad (187)$$

$$C_{FLS} = \frac{C_{ILS}}{t_{LS}} \quad (188)$$

$$C_{FMC} = C_{FSS} + C_{FAS} + C_{FLS} \quad (189)$$

$$C_{VMC} = C_{VSS} + C_{VAS} + C_{VLS} \quad (190)$$

$$C_{TMM} = C_{FMM} + C_{VMM} \quad (191)$$

$$C_{TSS} = C_{FSS} + C_{VSS} \quad (192)$$

$$C_{TAS} = C_{FAS} + C_{VAS} \quad (193)$$

$$C_{TLS} = C_{FLS} + C_{VLS} \quad (194)$$

$$C_{TMC} = C_{TSS} + C_{TAS} + C_{TLS} \quad (195)$$

3.3.4.5 Storage Tanks

The manure handling system requires several tanks, i.e. MHM P2 will be used to design each tank (Figure 3.14). This part is dedicated to calculate tank dimensions, and then the amount of cement, sand, gravels, and iron rods required to build the tank. Furthermore, MHM P2 calculates the capital investment and the fixed, variable, total costs of the required tank. The costs should be used as input data in MHM P1 in the cells dedicated for the costs of each tank (raw slurry tank, aeration tank, and treated liquid tank). The designer should consider that a part of the tank (about 10%) is empty to prevent the manure/liquid to reach the top rim of the tank.

In order to design the different tanks, MHM P2 is used several times, one time for each tank. However, V_M in MHM P2 is substituted by V_{RS} to design raw slurry tank, or by V_A to design aeration tank, or by V_{TL} to design the treated liquid tank.

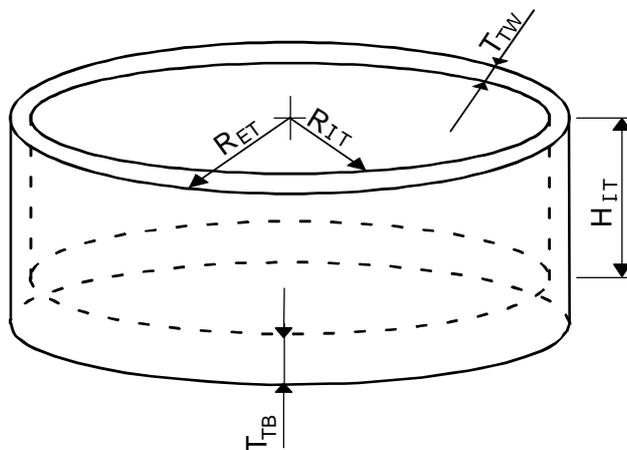


Figure 3.14: Tank design

Tank Specifications

The tank dimensions should be calculated to get the concrete volume of the tank:

$$V_{IT} = V_M \times 1.10 \quad (196)$$

$$R_{IT} = \sqrt{\frac{V_{IT}}{\pi \times H_{IT}}} \quad (197)$$

$$R_{ET} = R_{IT} + T_{TW} \quad (198)$$

$$A_{MT} = \pi \times R_{ET}^2 \quad (199)$$

$$V_{CT} = [(R_{ET}^2 - R_{IT}^2) \times \pi \times H_{IT}] + [\pi \times R_{ET}^2 \times T_{TB}] \quad (200)$$

Construction Materials

The required amounts of the different construction materials can be computed as:

$$M_C = C \times V_{CT} \quad (201)$$

$$V_G = G \times V_{CT} \quad (202)$$

$$V_S = S \times V_{CT} \quad (203)$$

where,

$$C = 325 \quad (204)$$

$$G = 0.8 \quad (205)$$

$$S = 0.4 \quad (206)$$

The designer should decide the type of iron rods. The different types of iron rods used to make such concrete constructions are 6Ø6/m and 6Ø8/m, hence:

$$N_{IP} = \{[(N_{IML} \times H_{IT}) + 1] \times 1.05 \times 2 \times \pi \times R_{ET}\} + \{[(N_{IML} \times R_{ET}) + 1] \times 1.05 \times R_{ET}\} \quad (207)$$

$$N_{IH} = \{[(N_{IML} \times 2 \times \pi \times R_{ET}) + 1] \times 1.05 \times H_{IT}\} + \{[(N_{IML} \times R_{ET}) + 1] \times 1.05 \times R_{ET}\} \quad (208)$$

$$N_{IG} = N_{IP} + N_{IH} \quad (209)$$

$$N_{II} = N_G \times N_{IG} \quad (210)$$

$$N_{tSI} = \frac{N_{II}}{L_{SI}} \quad (211)$$

$$M_I = N_{tSI} \times M_{IML} \times L_{SI} \quad (212)$$

where,

$$L_{SI} = 12 \quad (213)$$

with the following conditions:

$$\text{if } N\phi D/m = 6\phi 6/m, \text{ then } M_{IML} = 0.666 \quad (214)$$

$$\text{if } N\phi D/m = 6\phi 8/m, \text{ then } M_{IML} = 0.888 \quad (215)$$

where, M_I in kg

The unit of M_I should be converted from kg to Ton in order to be used in the costs calculation. 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 (elongation with temp, handling by unskilled workers). Thus the iron rod here has a width of 1 m.

Costs Calculation

The costs of the required amounts of building materials can be estimated as follows:

$$P_{IC} = P_C \times M_C \quad (216)$$

$$P_{IG} = P_G \times V_G \quad (217)$$

$$P_{IS} = P_S \times V_S \quad (218)$$

$$P_{II} = P_I \times M_I \quad (219)$$

$$C_{IEC} = C_{EC} \times V_{CT} \quad (220)$$

$$C_{IMT} = P_{IC} + P_{IG} + P_{IS} + P_{II} + C_{IEC} \quad (221)$$

$$C_{FMT} = \frac{C_{IMT}}{t_P} \quad (222)$$

$$C_{TMT} = C_{FMT} + C_{VMT} \quad (223)$$

$$t_P = 20 \quad (224)$$

where, M_I in Ton

The manure tank should be coated by a chemical material in order to protect it. This operation may be carried out in a determined time interval. The costs of this operation are considered as part/whole value of C_{VMT} .

After using MHM P2 for designing the tanks, the designer should input the costs resulting from MHM P2 in the costs calculation of MHM P1. Thus, MHM P2 will be used 3 times to make 3 tanks which are raw slurry tank, aeration tank, and treated liquid tank. Moreover, the designer may split any tank to many tanks. However, while transporting the costs values from MHM P2 to MHM P1, the designer should pay attention for the symbols change of each tank, e.g. if the tank is a raw slurry storage, in this case C_{IMT} , C_{FMT} , C_{VMT} , and C_{TMT} should be considered and substituted as C_{ISS} , C_{FSS} , C_{VSS} , and C_{TSS} respectively.

3.3.5 Milking Parlor Constructions

The main task of the milking parlor constructions sub-model (MPC) is to assist the designer in planning and designing the milking center (milking parlor, parlor rooms, and collecting yard) concerning concrete, roof, and structure constructions. Thus, MPC is divided into 2 parts.

3.3.5.1 Concrete Constructions

MPC P1 assists in deciding the values of the concrete layer dimensions of cow platform, alleys, parlor rooms, and collecting yard (waiting area). Afterwards, MPC P1 calculates the volume of the required concrete, and then the required amount of

cement, iron rods, sand, and gravels. MPC P1 is able to calculate the capital investment and the fixed, variable, and total costs of concrete constructions.

Parlor and Collecting Yard

The parlor size and the milking machine should be selected according to number of cows in farm and some other parameters. The length of cow platform can be specified according to the parlor size using parlor size/length tables, also the cow platform and pit width and other dimensions can be then determined. Thus,

$$A_{CP} = L_{CP} \times W_{CP} \quad (225)$$

$$A_{EA} = L_{EA} \times W_{EA} \quad (226)$$

$$A_{FEA} = L_{FEA} \times W_{FEA} \quad (227)$$

$$A_{RA} = L_{RA} \times W_{RA} \quad (228)$$

$$A_{CY} = N_{CY} \times A_{CCY} \quad (229)$$

$$A_{MPR} = A_{MR} + A_{MRP} + A_{PR} \quad (230)$$

$$A_{IPA} = 2 \times (A_{CP} + A_{EA} + A_{FEA} + A_{RA}) \quad (231)$$

$$m_{EA} = \frac{D_P}{\sqrt{L_{EA}^2 - D_P^2}} \quad (232)$$

$$m_{FEA} = \frac{D_P}{\sqrt{W_{FEA}^2 - D_P^2}} \quad (233)$$

$$m_{RA} = \frac{D_P}{\sqrt{L_{RA}^2 - D_P^2}} \quad (234)$$

Parlor with front exit alley:

$$L_{PM} = L_{CP} + \left(\frac{D_P}{m_{EA}} \right) \quad (235)$$

Parlor without front exit alley:

$$L_{PM} = L_{CP} + \left(\frac{D_P}{m_{EA}} \right) + \left(\frac{D_P}{m_{RA}} \right) \quad (236)$$

Parlor with front exit alley:

$$W_{PM} = W_P + (2 \times W_{CP}) + \left(2 \times \frac{D_P}{m_{FEA}} \right) \quad (237)$$

Parlor without front exit alley:

$$W_{PM} = W_P + (2 \times W_{CP}) \quad (238)$$

Then the following items can be computed:

$$A_{PM} = L_{PM} \times W_{PM} \quad (239)$$

$$A_{CBP} = A_{PM} - A_{IPA} \quad (240)$$

$$A_{MC} = A_{PM} + A_{CY} + A_{MPR} \quad (241)$$

hence,

$$L_{MC} = \frac{A_{MC}}{W_{MC}} \quad (242)$$

Parlor with front exit alley:

$$A_{PS} = 4 \left(\frac{D_P^2}{2m_{EA}} \right) + 2(L_{MP} \times D_P) + 4 \left(\frac{D_P^2}{2m_{FEA}} \right) + 2(W_{CP} \times D_P) + 2[(W_{CP} - W_{EA}) \times D_P] \quad (243)$$

Parlor without front exit alley:

$$A_{PS} = 4 \left(\frac{D_P^2}{2m_{EA}} \right) + 4(L_{MP} \times D_P) + 4 \left(\frac{D_P^2}{2m_{RA}} \right) + 2[(W_{CP} - W_{EA}) \times D_P] + 2[(W_{CP} - W_{RA}) \times D_P] \quad (244)$$

The concrete layers of the milking parlor are built using reinforced concrete and this requires calculating the total area of concrete layers. Thus,

$$A_{ICL} = A_{IPA} + A_{MPR} + A_{CY} + A_{CBP} + A_{PS} \quad (245)$$

$$L_{CL} = \sqrt{A_{ICL}} \quad (246)$$

$$V_{CCP} = T_{CL} \times A_{ICL} \quad (247)$$

where,

$$L_{CP} = L_{MP} = L_{FEA} \quad (248)$$

$$W_{MC} = W_{PM} \quad (249)$$

$$W_{CP} = f \text{ (parlor layout)} \quad (250)$$

$$L_{CP} = f \text{ (parlor size)} \quad (251)$$

$$N_{CY} = f \text{ (parlor size, group size, number of milkers, waiting time)} \quad (252)$$

and

$$A_{CCY} = f \text{ (breed)} \quad (253)$$

e.g. For Holstein,

$$A_{CCY} = 1.6 \quad (254)$$

A_{iCL} is supposed to be a square with L_{CL} as side length.

Usually,

$$T_{CL} = 0.18 \quad (255)$$

$$L_{EA} = L_{RA} \quad (256)$$

$$W_{EA} = W_{RA} \quad (257)$$

$$A_{EA} = A_{RA} \quad (258)$$

$$m_{EA} = m_{RA} \quad (259)$$

This means that the entry and return alleys are similar, but it is flexible in MPC to make each of them with other specific dimensions. However, in case of parlor with front exit alleys, the parlor does not require return alleys (Figure 3.15); thus their input values will be zero, i.e. L_{RA} and W_{RA} are equal to zero. But in case of parlor without front exit alleys, the input data of L_{FEA} and W_{FEA} will be zero, and the parlor will require return alleys, where their input data are usually equal to those of entry alleys (Figure 3.16).

MPC is suitable for the different parlor sizes and layouts except rotary milking parlor, because W_{CP} is a function of parlor layout (parallel, herringbone and tandem) and L_{CP} is a function of parlor size.

Concerning the collecting yard, the cows should not stay more than one hour in the collecting yard. Some equipment requires extra space, at least 1.5 m extra length is required. Future plans should be considered. The slope of the collecting yard should be 3% ascending to the parlor. The number of cows in the collecting yard should be a multiple of the number of stalls in parlor. Moreover, the number of cows in each group determines the size of the collecting yard. Note that it is the largest group that decides the size. Furthermore, the number of milkers should be considered. If there is one milker and one person for the cow traffic the collecting yard must hold the whole group. If the milker also handles the cow traffic, the collecting area can be reduced by the number of cows in the parlor.

Construction Materials

The required amounts of construction materials can be computed as follows:

$$M_C = C \times V_{CCP} \quad (260)$$

$$V_G = G \times V_{CCP} \quad (261)$$

$$V_S = S \times V_{CCP} \quad (262)$$

Parlor with front exit alley:

$$V_{PR} = \left[2 \left(W_{EA} \times \frac{D_P^2}{2m_{EA}} \right) + 2 \left(L_{FEA} \times \frac{D_P^2}{2m_{FEA}} \right) + 2(D_P \times L_{MP} \times W_{CP}) \right] - [T_{CL} \times A_{IPA}] \quad (263)$$

Parlor without front exit alley:

$$V_{PR} = \left[2 \left(W_{EA} \times \frac{D_P^2}{2m_{EA}} \right) + 2 \left(W_{RA} \times \frac{D_P^2}{2m_{RA}} \right) + 2(D_P \times L_{MP} \times W_{CP}) \right] - [T_{CL} \times A_{IPA}] \quad (264)$$

where, $C = 325$ (265)

$$G = 0.8 \quad (266)$$

$$S = 0.4 \quad (267)$$

The designer should decide the type of iron rods. The different types ($N\phi D/m$, where N is the number of iron rods per meter length, and D is the diameter of the iron rod) of iron rods used to make such concrete bases are $6\phi 6/m$ and $6\phi 8/m$:

$$N_{IL} = [(N_{IML} \times L_{CL}) + 1] \times 1.05 \times L_{CL} \quad (268)$$

$$N_{IW} = [(N_{IML} \times L_{CL}) + 1] \times 1.05 \times L_{CL} \quad (269)$$

$$N_{IG} = N_{IL} + N_{IW} \quad (270)$$

$$N_{II} = N_G \times N_{IG} \quad (271)$$

$$N_{tSI} = \frac{N_{II}}{L_{SI}} \quad (272)$$

$$M_I = N_{tSI} \times M_{IML} \times L_{SI} \quad (273)$$

where,

$$N_{IL} = N_{IW} \quad (274)$$

$$L_{SI} = 12 \quad (275)$$

with the following conditions:

$$\text{if } N\phi D/m = 6\phi 6/m, \text{ then } M_{IML} = 0.666 \quad (276)$$

$$\text{if } N\phi D/m = 6\phi 8/m, \text{ then } M_{IML} = 0.888 \quad (277)$$

M_I in kg

The unit of M_I should be converted from kg to Ton in order to be used in the costs calculation. 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. Thus, the iron rod here has a width of 1 m.

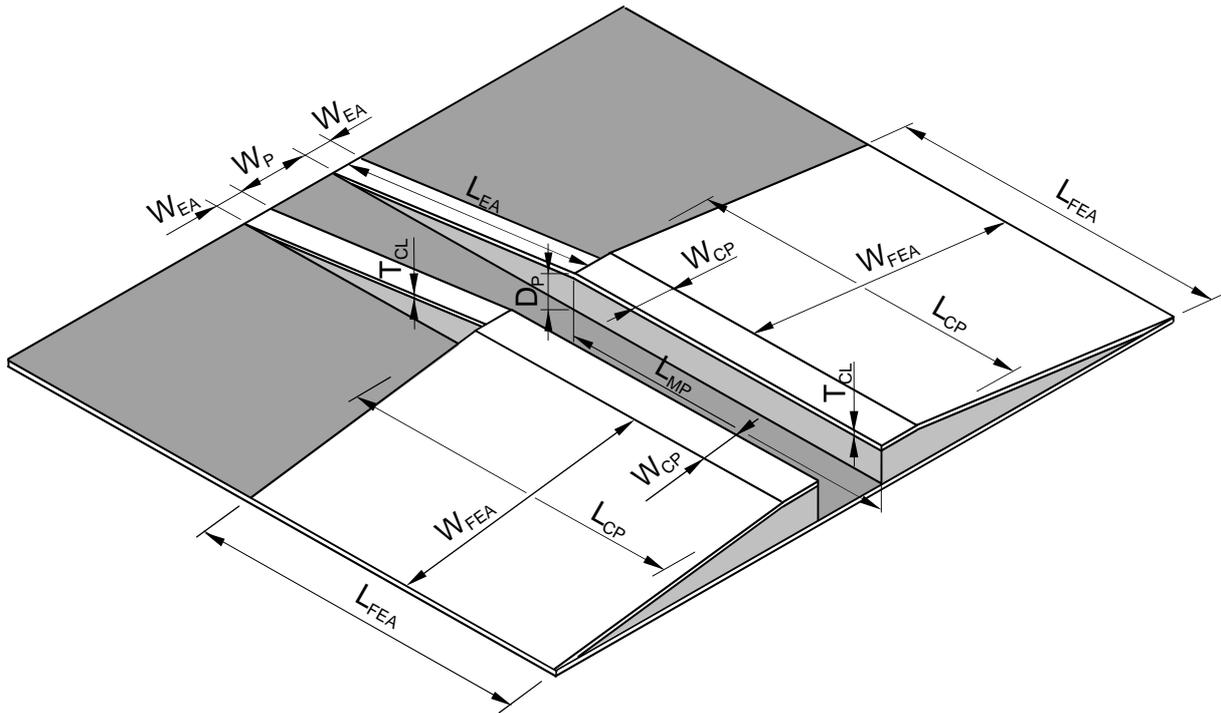


Figure 3.15: Concrete construction for parlor with front exit alley (SAMER et al., 2008c)

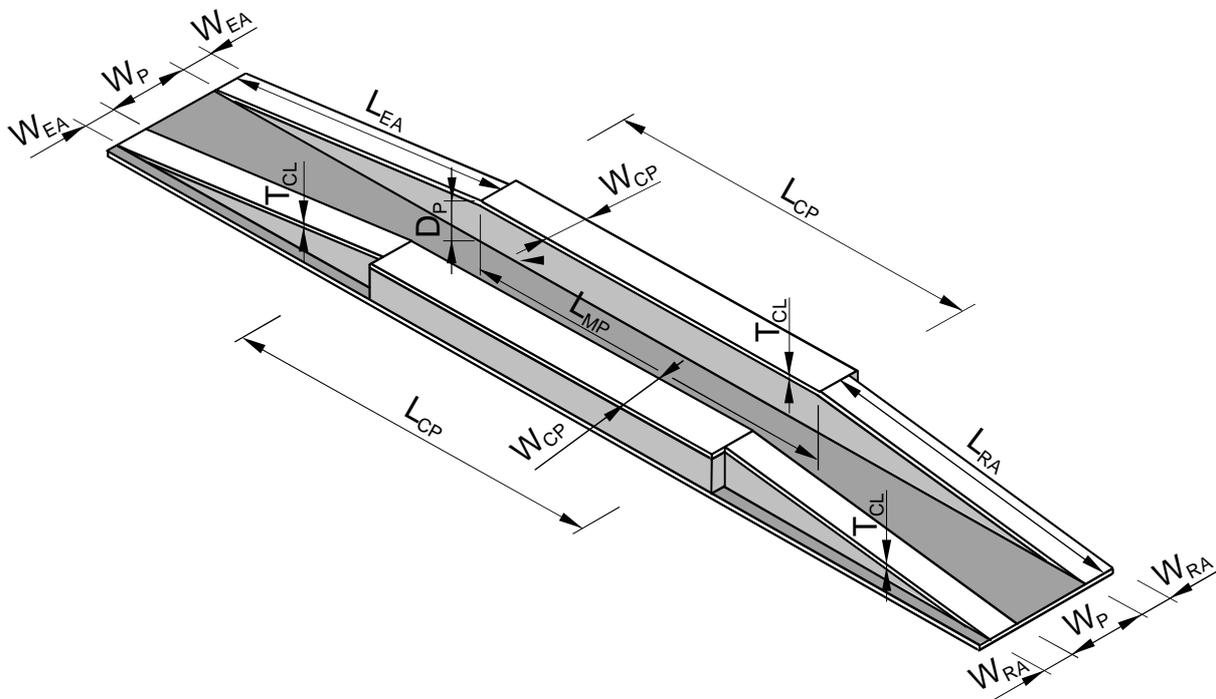


Figure 3.16: Concrete construction for parlor without front exit alley (SAMER et al., 2008c)

Costs Calculation

The costs of the required amounts of construction materials can be calculated as:

$$P_{IC} = P_C \times M_C \quad (278)$$

$$P_{IG} = P_G \times V_G \quad (279)$$

$$P_{IS} = P_S \times V_S \quad (280)$$

$$P_{IR} = P_R \times V_{PR} \quad (281)$$

$$P_{II} = P_I \times M_I \quad (282)$$

$$C_{IEC} = C_{EC} \times V_{CCP} \quad (283)$$

$$C_{ICM} = P_{IC} + P_{IG} + P_{IS} + P_{II} + P_{IR} + C_{IEC} \quad (284)$$

$$C_{FCM} = \frac{C_{ICM}}{t_P} \quad (285)$$

$$C_{TCM} = C_{FCM} + C_{VCM} \quad (286)$$

$$t_P = 20 \quad (287)$$

where, M_I in Ton

The concrete layer may be covered by some chemical materials. This operation may be carried out in a determined time interval. The costs of this operation are considered as part/whole value of C_{VCM} .

3.3.5.2 Parlor Shed

MPC P2 assists the designer in making decisions to select the roof material, and roof type; then, specifying the roof and structure dimensions. Moreover, MPC P2 calculates the capital investment and the fixed, variable, and total costs.

General Factors and Concepts

Some general factors affect directly the decision making. The following mathematical analysis summarizes those factors:

$$W_{SH} = \frac{A_{SH}}{L_{SH}} \quad (288)$$

$$\tan \alpha = \frac{m}{100} \quad (289)$$

$$L_S = L_R \quad (290)$$

where,

$$L_{SH} = L_{MC} = L_R \quad (291)$$

$$19 \leq m \leq 45 \quad (292)$$

Furthermore, minimum distance to ceiling is 2.4 m.

In order to avoid direct sun intrusion,

$$A_{SH} \geq A_{MC} \quad (293)$$

In case of horizontal roof,

$$W_{SH} = W_R \quad (294)$$

always

$$W_S = W_{MC} \quad (295)$$

$$W_{SH} = W_{MC} + (2 \times M) \quad (296)$$

$$W_{SH} \geq W_{MC} \quad (297)$$

with the following conditions:

- Case 1:

$$\text{if } W_{SH} = W_{MC}, \text{ then } M = 0 \quad (298)$$

and

$$W_{SH} = W_S = W_{MC} \quad (299)$$

- Case 2:

$$\text{if } W_{SH} > W_{MC}, \text{ then } M > 0 \quad (300)$$

and

$$W_{SH} > W_S \quad (301)$$

Roof and Structure Specifications

R is a constant depends on roof type, where

$$\text{Horizontal (2 rows of posts):} \quad R = 2 \quad (302)$$

$$\text{Gable (2 rows of posts):} \quad R = 2 \quad (303)$$

- Horizontal Roof

The specifications of the horizontal roof can be determined as follows:

$$W_R = W_{SH} \quad (304)$$

$$A_R = W_R \times L_R \quad (305)$$

$$A_R = A_{SH} \quad (306)$$

$$W_S = W_R - (2 \times M) \quad (307)$$

$$N_P = \frac{L_S}{S_P} + 1 \quad (308)$$

$$N_{Pt} = N_P \times R \quad (309)$$

- Gable Roof

The specifications of the gable roof can be determined as follows:

$$W_{WR} = \frac{W_{SH}}{2 \times \cos \alpha} \quad (310)$$

$$W_{LR} = W_{WR} \quad (311)$$

$$A_R = (W_{WR} \times L_R) + (W_{LR} \times L_R) \quad (312)$$

$$W_S = 2 \times (W_{WR} - M) \times \cos \alpha \quad (313)$$

$$N_P = \frac{L_S}{S_P} + 1 \quad (314)$$

$$N_{Pt} = N_P \times R \quad (315)$$

$$H_{SS} = H_S - [(W_{WR} - M) \times \sin \alpha] \quad (316)$$

Roof Materials

Several materials are used as roof covering material. However reed mats and straw mats are not suitable as roof materials for milking parlor structure, because if it anytime rains the milking machine will be affected.

- Polished Aluminum

The mass and price of the required amount of polished aluminum is calculated as:

$$M_{iPA} = A_R \times M_{PA} \quad (317)$$

$$P_{iPA} = A_R \times P_{PA} \quad (318)$$

- Isolated Aluminum

The mass and price of the required amount of isolated aluminum can be calculated as follows:

$$M_{iIA} = A_R \times M_{IA} \quad (319)$$

$$P_{iIA} = A_R \times P_{IA} \quad (320)$$

- Burnt-Clay Bricks

The mass and price of the required amount of burnt-clay bricks can be estimated as:

$$M_{iBC} = A_R \times M_{BC} \quad (321)$$

$$P_{iBC} = A_R \times P_{BC} \quad (322)$$

Costs Calculation

The costs of the required parlor shed can be calculated as following:

$$C_{IS} = P_{RCM} + P_{ISC} \quad (323)$$

$$C_{FS} = \frac{C_{IS}}{t_S} \quad (324)$$

$$C_{TS} = C_{FS} + C_{VS} \quad (325)$$

where,

$$t_S = 20 \quad (326)$$

The value of P_{RCM} will be equal to the total price of the chosen roof material. A civil Engineer should be consulted to make the final design and the concrete piers of the posts, hence P_{ISC} could be calculated.

3.3.6 Forage Storage Constructions

The main task of the forage storage constructions sub-model (FSC) is to assist the designer in planning and designing the forage storage constructions (shed, and silo) concerning concrete and structure constructions. Thus, FSC is divided into 3 parts.

3.3.6.1 Annual Forage Storage

FSC P1 assists in calculating the amount of yearly silage, grain, straw, hay, and potatoes storage. The calculated values will be then used by FSC P2 and P3. The number of cows housed in the farm is the main parameter. Thus,

$$V_{iST} = N_{CF} \times V_{STC} \quad (327)$$

$$V_{iHS} = N_{CF} \times V_{HC} \quad (328)$$

$$V_{iPS} = N_{CF} \times V_{PC} \quad (329)$$

$$V_{iGS} = N_{CF} \times V_{GC} \quad (330)$$

$$V_{iSS} = N_{CF} \times V_{SC} \quad (331)$$

$$V_{iFS} = V_{iST} + V_{iHS} + V_{iPS} + V_{iGS} + V_{iSS} \quad (332)$$

where,

$$V_{IFS} = N_{CF} \times V_{FSC} \quad (333)$$

$$V_{FSC} = V_{STC} + V_{HC} + V_{PC} + V_{GC} + V_{SC} \quad (334)$$

Costs Calculation

After calculating the costs of structure and roof material using FSC P2 and the costs of horizontal silo using FSC P3 and after collecting information from the market about the costs of tower silo; FSC P1 will be then used to calculate the final costs, which are the costs of forage storage constructions. Thus,

$$C_{IFC} = C_{IS} + C_{ICH} + C_{ITS} \quad (335)$$

$$C_{FFC} = C_{FS} + C_{FCH} + C_{FTS} \quad (336)$$

$$C_{VFC} = C_{VS} + C_{VCH} + C_{VTS} \quad (337)$$

$$C_{TFC} = C_{TS} + C_{TCH} + C_{TTS} \quad (338)$$

However, the designer may use the shed structure for storing hay and straw, and the horizontal silo for storing silage, grains, and potatoes; without the need to buy a tower silo, then the input data of the tower silo will be zero. But, in case of using horizontal and tower silos, the designer will input a part of the required silage, grains, and potatoes storage in FSC P3 to design the horizontal silo, and the second part will be the capacity of tower silo.

3.3.6.2 Forage Shed

FSC P2 assists the designer in making decisions to select the roof material, and roof type; then, specifying the roof and structure dimensions of shed structure where straw and hay will be stored. Moreover, FSC P2 calculates the capital investment and the fixed, variable, and total costs of shed structure.

General Factors and Concepts

Some general factors affect directly the decision making. The following mathematical analysis summarizes those factors:

$$V_{tSF} = V_{tST} + V_{tHS} \quad (339)$$

$$W_{SH} = \frac{A_{SH}}{L_{SH}} \quad (340)$$

$$\tan \alpha = \frac{m}{100} \quad (341)$$

$$L_S = L_R = L_{SH} \quad (342)$$

where,

$$19 \leq m \leq 45 \quad (343)$$

Furthermore, minimum distance to ceiling is 1.5 m to ease the work of the feeding system.

Roof and Structure Specifications

R is a constant depends on roof type, where

$$\text{Horizontal (2 rows of posts):} \quad R = 2 \quad (344)$$

$$\text{Gable (2 rows of posts):} \quad R = 2 \quad (345)$$

- Horizontal Roof

The specifications of forage shed with horizontal roof, can be determined as follows:

$$W_R = W_{SH} \quad (346)$$

$$A_R = W_R \times L_R \quad (347)$$

$$A_R = A_{SH} \quad (348)$$

$$W_S = W_R - (2 \times M) \quad (349)$$

$$N_P = \frac{L_S}{S_P} + 1 \quad (350)$$

$$N_{Pt} = N_P \times R \quad (351)$$

$$H_S = \frac{V_{ISF}}{L_S \times W_S} + 1.5 \quad (352)$$

- Gable Roof

The specifications of forage shed having a gable roof, can be determined as following:

$$W_{WR} = \frac{W_{SH}}{2 \times \cos \alpha} \quad (353)$$

$$W_{LR} = W_{WR} \quad (354)$$

$$A_R = (W_{WR} \times L_R) + (W_{LR} \times L_R) \quad (355)$$

$$W_S = 2 \times (W_{WR} - M) \times \cos \alpha \quad (356)$$

$$N_P = \frac{L_S}{S_P} + 1 \quad (357)$$

$$N_{Pt} = N_P \times R \quad (358)$$

$$H_S = \frac{V_{ISF}}{L_S \times W_S} + 1.5 \quad (359)$$

$$H_{SS} = H_S - [(W_{WR} - M) \times \sin \alpha] \quad (360)$$

Roof Materials

Several materials are used as roof covering material. However reed mats and straw mats are not suitable as roof materials for forage storage structure, because if it anytime rains the forage will be affected.

- Polished Aluminum

The mass and price of the required polished aluminum for the forage shed can be estimated as follows:

$$M_{iPA} = A_R \times M_{PA} \quad (361)$$

$$P_{iPA} = A_R \times P_{PA} \quad (362)$$

- Isolated Aluminum

The mass and price of the required isolated aluminum for the forage shed can be determined as follows:

$$M_{iIA} = A_R \times M_{IA} \quad (363)$$

$$P_{iIA} = A_R \times P_{IA} \quad (364)$$

- Burnt-Clay Bricks

The mass and price of the required burnt-clay bricks for the forage shed can be estimated as follows:

$$M_{iBC} = A_R \times M_{BC} \quad (365)$$

$$P_{iBC} = A_R \times P_{BC} \quad (366)$$

Costs Calculation

The costs of the required forage shed can be calculated as following:

$$C_{IS} = P_{RCM} + P_{ISC} \quad (367)$$

$$C_{FS} = \frac{C_{IS}}{t_S} \quad (368)$$

$$C_{TS} = C_{FS} + C_{VS} \quad (369)$$

where,

$$t_S = 20 \quad (370)$$

The value of P_{RCM} will be equal to the total price of the chosen roof material. A civil Engineer should be consulted to make the final design and the concrete piers of the posts, hence P_{ISC} could be calculated.

3.3.6.3 Horizontal Silo

After using FSC P1 in specifying the amount of silage, grain, and potatoes storage which depend on the number of cows housed in the farm, FSC P3 is used to assist the designer in specifying the dimensions and the required amounts of building materials used to build the horizontal silo (Figure 3.17). Moreover, FSC P1 calculates the capital investment and the fixed, variable, and total costs of horizontal silo construction. However, the designer may divide the amount of silage and grain storage into two parts, the first part is stored in the horizontal silo and the second one is stored in tower silo. The tower silo is assembled in the farm using pre-built parts.

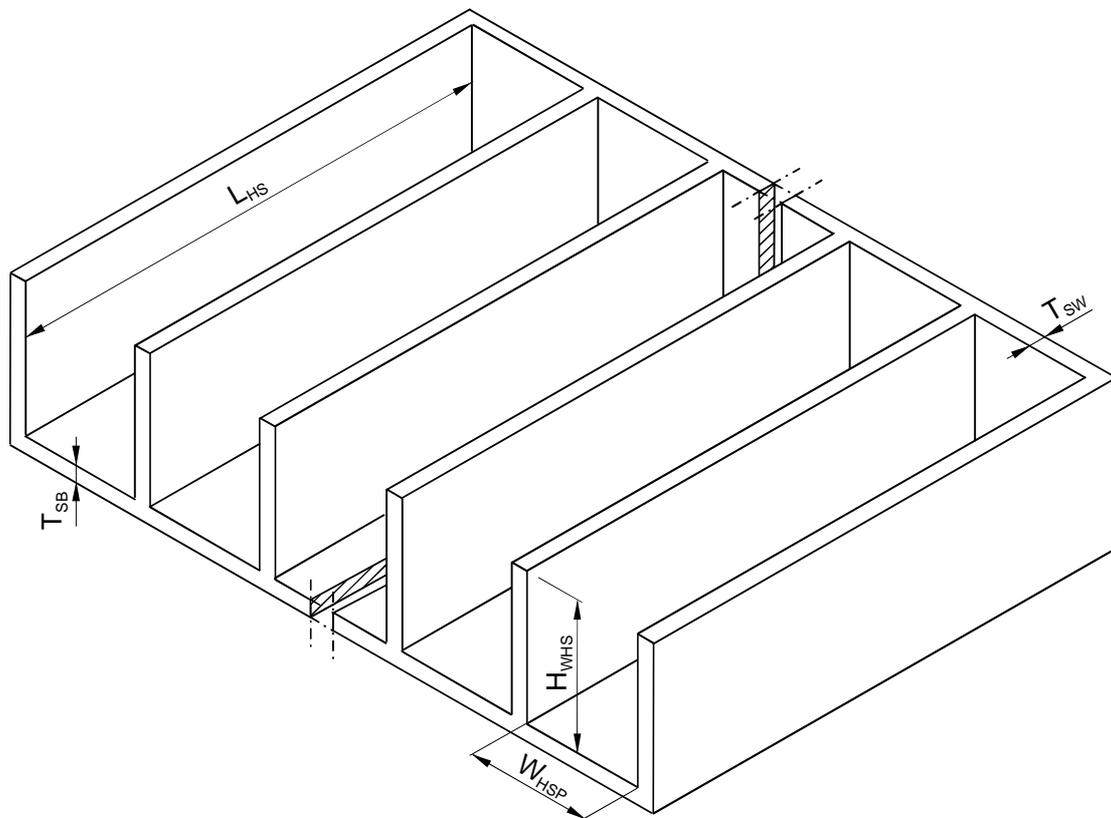


Figure 3.17: Horizontal silo

Specifications

The horizontal silo should be wide enough to allow a minimum amount of forage (silage, potatoes, or grains) to be removed from the open face each day. However, the width of one horizontal silo pit should be double of the tractor width. The length of horizontal silo is determined by the total Forage needed for the year.

The amount of silage, grain (maize or barley), and potatoes storages are the main parameters. Thus,

$$V_{tHF} = V_{tSS} + V_{tGS} + V_{tPS} \quad (371)$$

$$L_{HS} = \frac{V_{tHF}}{W_{HSP} \times H_{WHS} \times N_{HSP}} \quad (372)$$

$$V_{BHS} = N_{HSP} \times L_{HS} \times W_{HSP} \times T_{SB} \quad (373)$$

$$V_{WHS} = [N_{HSP} \times W_{HSP} \times T_{SW} \times (H_{WHS} + T_{SB})] + [(N_{HSP} + 1) \times (L_{HS} + T_{SW}) \times T_{SW} \times (H_{WHS} + T_{SB})] \quad (374)$$

$$V_{CHS} = V_{BHS} + V_{WHS} \quad (375)$$

$$A_{PHS} = (N_{HSP} \times W_{HSP} \times L_{HS}) + [(N_{HSP} + 1) \times (L_{HS} + T_{SW}) \times (H_{WHS} + T_{SB})] + [N_{HSP} \times (H_{WHS} + T_{SB}) \times W_{HSP} \times T_{SW}] \quad (376)$$

$$L_{PHS} = \sqrt{A_{PHS}} \quad (377)$$

where,

$$2 \leq H_{WHS} \leq 3 \quad (378)$$

$$W_{PHS} = L_{PHS} \quad (379)$$

Construction Materials

The required amounts of construction materials for the constructing a horizontal silo, can be estimated as follows:

$$M_C = C \times V_{CHS} \quad (380)$$

$$V_G = G \times V_{CHS} \quad (381)$$

$$V_S = S \times V_{CHS} \quad (382)$$

where, $C = 325$ (383)

$$G = 0.8 \quad (384)$$

$$S = 0.4 \quad (385)$$

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

$$N_{IL} = [(N_{IML} \times W_{PHS}) + 1] \times 1.05 \times L_{PHS} \quad (386)$$

$$N_{IW} = [(N_{IML} \times L_{PHS}) + 1] \times 1.05 \times W_{PHS} \quad (387)$$

$$N_{IG} = N_{IL} + N_{IW} \quad (388)$$

$$N_{II} = N_G \times N_{IG} \quad (389)$$

$$N_{tSI} = \frac{N_{II}}{L_{SI}} \quad (390)$$

$$M_I = N_{tSI} \times M_{IML} \times L_{SI} \quad (391)$$

where,

$$N_{IL} = N_{IW} \quad (392)$$

$$L_{SI} = 12 \quad (393)$$

with the following conditions:

$$\text{if } N\phi D / m = 6\phi 6 / m, \text{ then } M_{IML} = 0.666 \quad (394)$$

$$\text{if } N\phi D / m = 6\phi 8 / m, \text{ then } M_{IML} = 0.888 \quad (395)$$

M_I in kg

The unit of M_I should be converted from kg to Ton in order to be used in the costs calculation. 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 constructions. Thus, the iron rod here has a width of 1 m.

Costs Calculation

The costs of constructing a horizontal silo can be calculated as following:

$$P_{iC} = P_C \times M_C \quad (396)$$

$$P_{iG} = P_G \times V_G \quad (397)$$

$$P_{iS} = P_S \times V_S \quad (398)$$

$$P_{iI} = P_I \times M_I \quad (399)$$

$$C_{iEC} = C_{EC} \times V_{CCP} \quad (400)$$

$$C_{ICH} = P_{iC} + P_{iG} + P_{iS} + P_{iI} + C_{iEC} \quad (401)$$

$$C_{FCH} = \frac{C_{ICH}}{t_p} \quad (402)$$

$$C_{TCH} = C_{FCH} + C_{VCH} \quad (403)$$

$$t_p = 20 \quad (404)$$

where, M_I in Ton

The concrete may be covered by some chemical materials. This operation may be carried out in a determined time interval. The costs of this operation are considered as part/whole value of C_{VCH} .

3.3.7 Farmstead Layout

The objective of developing the farmstead layout sub-model (FSL) is to assist the designer in planning the dairy farm. FSL is divided into two parts, FSL P1 and FSL P2. In Europe, the land areas are limited somehow, thus the designers plan first the dairy farm according to the available area. But, in hot climates where the huge desert areas and the suitable soils for reclamation, the designers start with making designs for each of the farm facilities (cowsheds, milking parlor...) and then they make the farmstead layout, because the land area is unlimited and cheap. Hence, FSL will be used just at the end, after the other models. Furthermore, FSL requires a lot of the output data of the other models.

Dairy Farm Planning

The farmstead layout is a two dimensional distribution of the farm buildings. FSL P1 is used to determine farm perimeter, farm total area, and costs of farm fence. However, the input data are the dimensions of each building and the distances between the buildings. Thus, the dimensions and the distances will be considered in the x-axis/y-axis in order to calculate the length of the farm side in the x-axis/y-axis (Figure 3.18). Afterwards, the area and the perimeter of the farm will be calculated. Furthermore, FSL P1 requires just the distances and the dimensions of the buildings adjacent to the farm axes.

The mathematical model of FSL P1 can be represented as the following:

$$X_F = d_{X1F} + \sum d_{XIJ} + \sum D_{Xn} + d_{XnF} \quad (405)$$

$$Y_F = d_{Y1F} + \sum d_{YIJ} + \sum D_{Yn} + d_{YnF} \quad (406)$$

$$A_{IFA} = X_F \times Y_F \quad (407)$$

$$P_F = 2 \times (X_F + Y_F) \quad (408)$$

$$P_{IFF} = P_{MFF} \times P_F \quad (409)$$

$$C_{FFF} = \frac{C_{IFF}}{t_{FF}} \quad (410)$$

$$C_{TFF} = C_{FFF} + C_{VFF} \quad (411)$$

where,

$$C_{IFF} = P_{IFF} \quad (412)$$

$$d_{XIJ} \geq 30 \quad (413)$$

$$d_{YIJ} \geq 30 \quad (414)$$

If Building (n) is a silo or a manure tank, then the dimension will be equal to the diameter.

In some cases, the buildings are not parallel/perpendicular to the farm axes. Therefore, FSL P2 was developed.

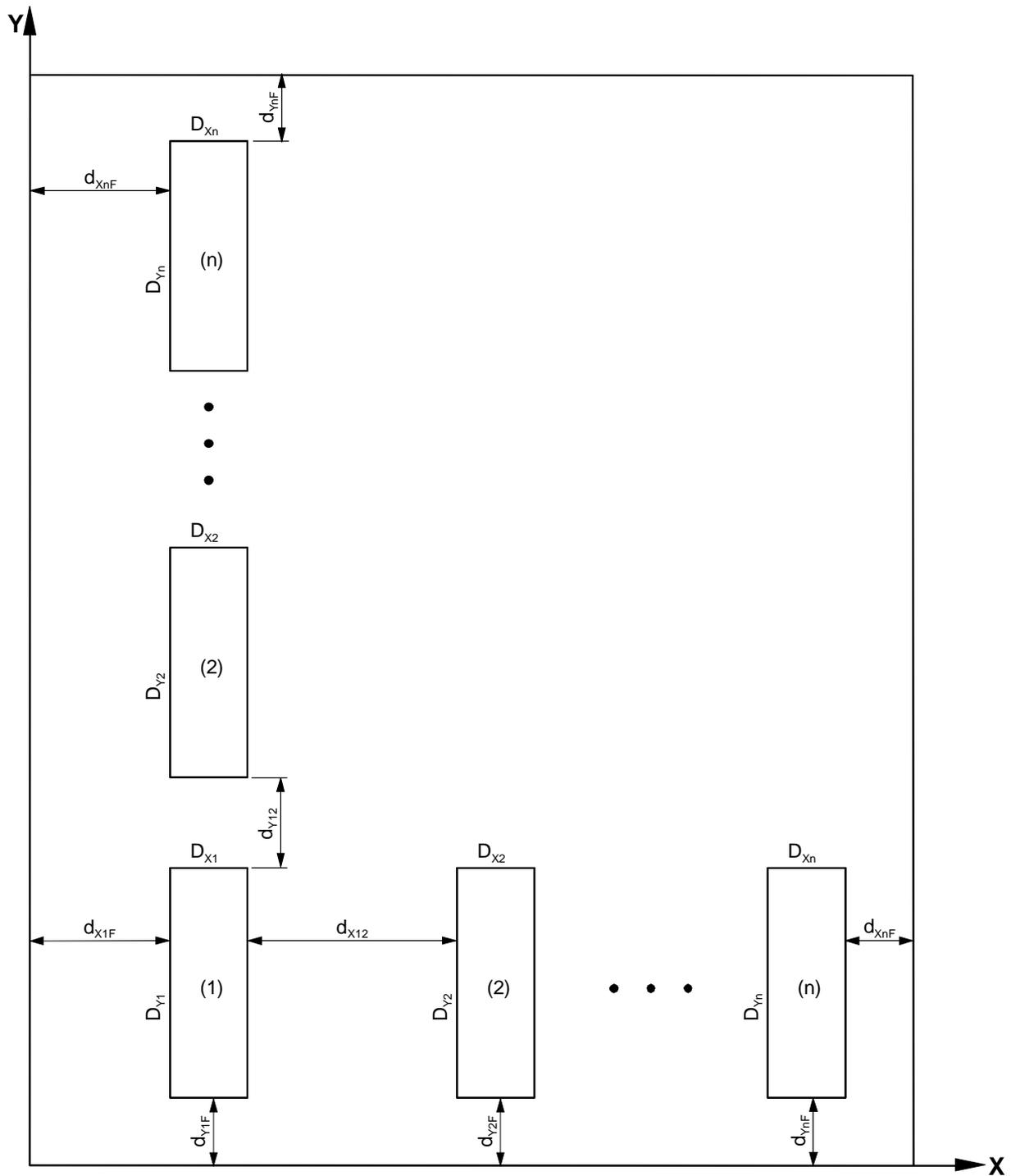


Figure 3.18: Parallel/perpendicular buildings distribution (SAMER et al., 2008a)

Angled Buildings

Most of farmstead layouts comprise angled buildings in relation to the axes. FSL P2 solves this problem, where the building is encompassed with a rectangle which his sides are parallel to the farm axes. Afterwards, FSL P2 calculates the projection of

each side of the angled building to the rectangle sides which are parallel to the farm axes (Figure 3.19). This solution is suitable for angled buildings distribution (Figures 3.20 and 3.21).

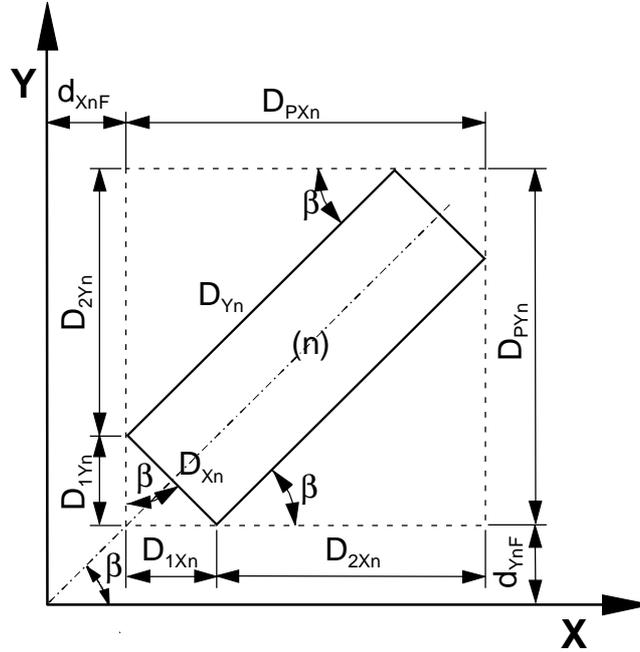


Figure 3.19: Projection of angled building sides (SAMER et al., 2008a)

The mathematical model of FSL P2 can be summarized as the following:

$$D_{1Xn} = D_{Xn} \times \cos(90 - \beta) \quad (415)$$

$$D_{2Xn} = D_{Yn} \times \cos \beta \quad (416)$$

$$D_{PXn} = D_{1Xn} + D_{2Xn} \quad (417)$$

$$D_{1Yn} = D_{Xn} \times \sin(90 - \beta) \quad (418)$$

$$D_{2Yn} = D_{Yn} \times \sin \beta \quad (419)$$

$$D_{PYn} = D_{1Yn} + D_{2Yn} \quad (420)$$

The output data of FSL P2 should be inserted into FSL P1 in order to make the calculation of farm perimeter, farm area, and costs of farm fence. Thus, D_{PXn} and D_{PYn} of FSL P2 will be substituted by D_{Xn} and D_{Yn} in FSL P1 respectively.

Sometimes, the farm plan is not a square or a rectangle; hence, the farm should be divided into several parts each part is a square or a rectangle. Afterwards, FSL will be used to perform the calculations of each part. But, the designer should consider that some sides of the perimeter of each part are also sides of the perimeter of the other parts; thus, the designer may not make directly a summation of the perimeters of the different parts, but he should consider the reciprocal sides. However, the designer may make a summation of the areas of the different parts.

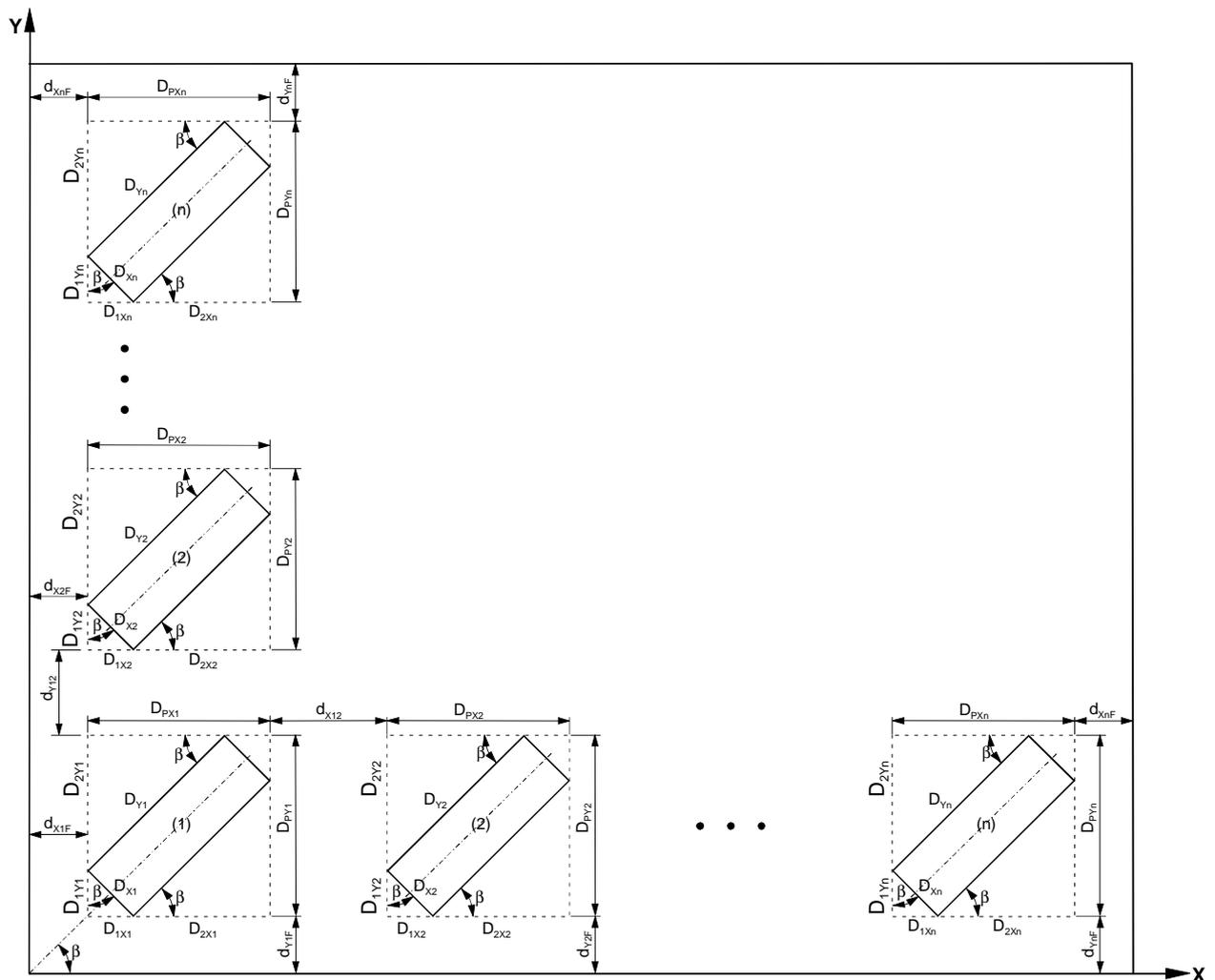


Figure 3.20: Angled buildings distribution (SAMER et al., 2008a)

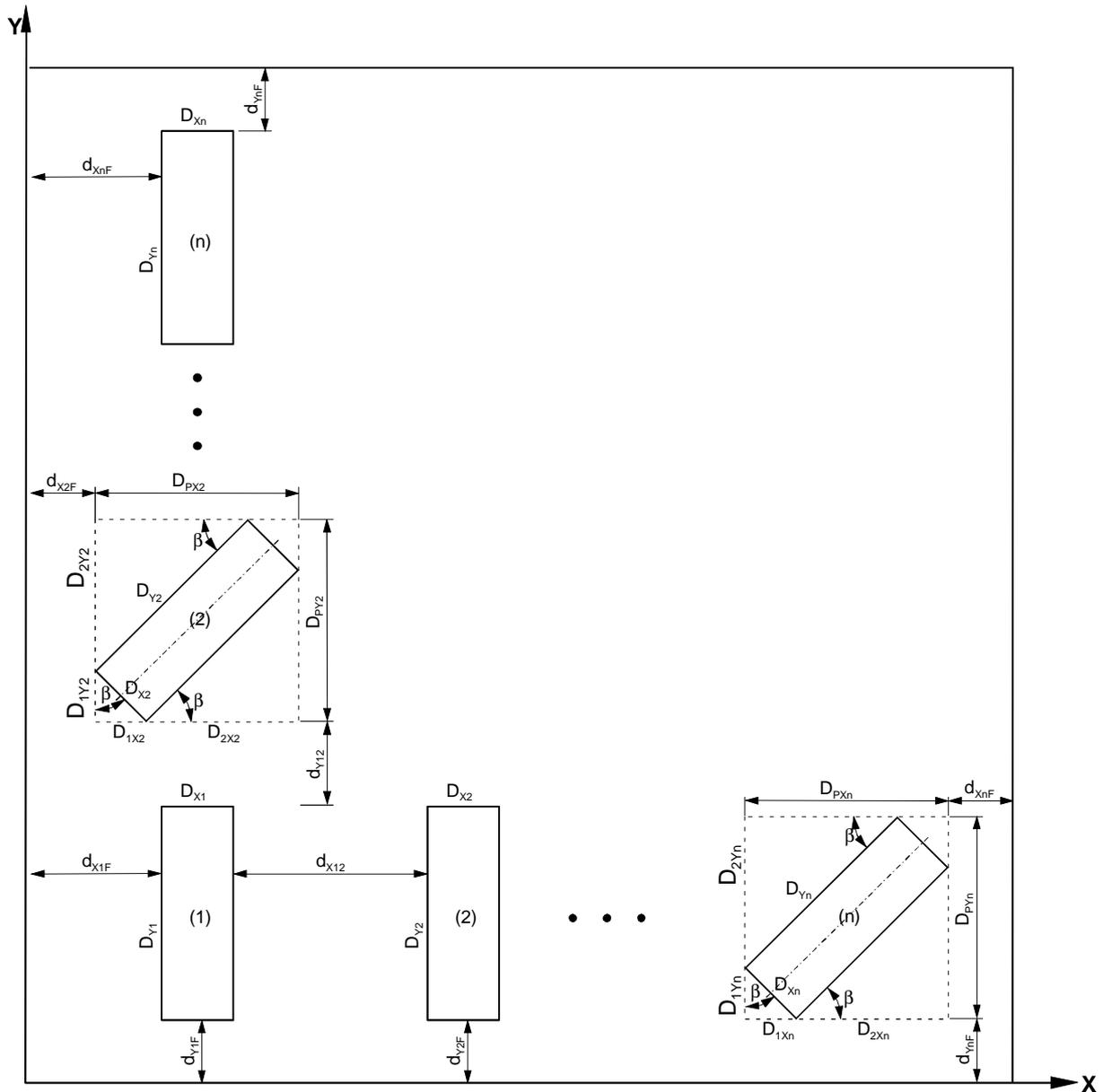


Figure 3.21: Mixed buildings distribution (SAMER et al., 2008a)

3.3.8 Cooling System

The objective of making CSM is to design the cooling system and to decide some parameters, such as: discharge and pressure of the micros sprinklers and the pump. Moreover, CSM determines the dimensions of the main line, sub-main line, and pipe lines. Also, CSM calculates the capital investment and the fixed, variable, and total costs.

3.3.8.1 Fans

The preferred specifications of the cooling fans are: diameter 90 cm, ½ hp, 825 rpm, and 60 Hz. The required number of cooling fans is dependent on the cooling line length. Thus,

$$N_{iCF} = \frac{L_{CO} \times N_{CLC}}{S_{CF}} \quad (421)$$

The cooling line consists of microsprinklers, fans, and pipe line. However, the number of cooling lines for one cowshed is depending on the applied corrals system, i.e. if 2 sides of corrals then 2 cooling lines are required, if one side of corrals or just one corral then 1 cooling line is required. In general, the fans should be spaced by about 6 m. However, the cooling system lifetime is about 10 years.

3.3.8.2 Pump

Some instructions should be considered while selecting the pump, which are:

- Pressure difference between the first microsprinkler and the last one in the pipe line is about 5%.
- For 100 m length of pipe line, the pump should have additional pressure by about 10% of the microsprinkler's pressure.
- The required discharge and pressure of the pump should be compared to tables of pumps technical data, in order to choose a pump which has a determined pressure and a range of discharges.
- Sometimes it is impossible to find the exact pressure in the market; thus, the near greater pressure than the required pressure should be chosen.
- Sometimes it is impossible to find the exact discharge in the market; thus, the near greater discharge than the required discharge should be chosen.

However, the discharge and the pressure of the pump will be calculated as:

$$Q_{CP} = \frac{Q_{MS} \times N_M \times 60}{1000} \quad (422)$$

$$P_{rCP} = \frac{P_{rMS} \times 105}{100} + \frac{L_{CO} \times N_{CLC} \times P_{rMS} \times 10}{100 \times 100} \quad (423)$$

where,

$$L_{CO} = L_H \quad (424)$$

$$N_M = \frac{L_{CO} \times N_{CLC}}{S_M} \quad (425)$$

$$Q_{MS} = 0.42 \quad (426)$$

$$P_{rMS} = 176 \quad (427)$$

3.3.8.3 Water Lines

The cooling system water lines are: main line, sub-main line, and pipe line(s). Usually, the main line is made from PVC, with standard length of 6 m, and diameter of 1.5 inches (38.1 mm). However, the sub-main line is made from PVC, with standard length of 6 m, and diameter of 1 inch (25.4 mm). The pipe line(s) should be flexible and made of PVC. However, the total length of the pipe lines is calculated as:

$$L_{tCP} = N_{CLC} \times L_{CO} \quad (428)$$

When specifying the pipe line diameter, some design parameters should be taken into consideration:

- For laminar flow, $V = 1.5 - 2.0$ m/s, but to be secure it is better to substitute it as 1 m/s in the equations.

- Sometimes it is impossible to find the exact diameter in the market; thus, the near greater diameter than the required diameter should be chosen.
- The available standard diameters are: 11, 16, 18, 20, and 32 mm which are made from PE; and 40, 50, 63, 75, 90, 100, 110, and 125 mm which are made from UPVC or from PVC.

However, the pipe line diameter is calculated as:

$$d_{CP} = \sqrt{\frac{4 \times Q_{CP} \times 10^6}{\pi \times 1 \times 3600}} \quad (429)$$

Usually, 2 taps (2 inches \emptyset) are required, and a filter of 100 meshes should be installed.

Costs Calculation

The costs of the different parts of the cooling system are calculated as:

$$P_{iCF} = N_{iCF} \times P_{CF} \quad (430)$$

$$P_{iM} = N_M \times P_M \quad (431)$$

$$P_{iCT} = N_{CT} \times P_{CT} \quad (432)$$

$$P_{iCP} = P_{CPL} \times L_{iCP} \quad (433)$$

$$P_{iCL} = P_{CML} \times L_{CML} \quad (434)$$

$$P_{iCS} = P_{CSL} \times L_{CSL} \quad (435)$$

$$C_{ICS} = P_{iCF} + P_{CP} + P_{iCP} + P_{iCL} + P_{iCS} + C_{ECS} + P_{iM} + P_A + P_{PG} + P_{iVF} + P_{iCT} + P_{FC} \quad (436)$$

$$C_{FCS} = \frac{C_{ICS}}{t_{CS}} \quad (437)$$

$$C_{TCS} = C_{FCS} + C_{VCS} \quad (438)$$

3.3.9 Water Requirements and Sources

The Water Sub-Model (WCM) is developed to specify the water requirements of the farm, and to study the available sources such as the governmental supply and the well. Furthermore, WCM calculates the capital investments and the fixed, variable, and total costs.

3.3.9.1 Water Requirements

Milking System

The water requirements of the milking system(s) can be expressed as:

$$W_{MSY} = \frac{W_{MSH} \times D_{DMS} \times N_{MSF} \times 365}{1000} \quad (439)$$

Cooling System

The water requirements of the cooling system(s) can be expressed as:

$$W_{CSY} = \frac{N_M \times W_M \times D_{HM} \times D_{DOC} \times 30 \times D_{YOC} \times N_{CSF}}{1000} \quad (440)$$

The yearly operating duration of cooling system is usually 6 Months, and the daily operating duration is usually 12-16 hours.

Manure Handling System

The water requirements of the manure handling system(s) can be expressed as:

$$W_{MHY} = W_{MHD} \times N_{MHF} \times 365 \quad (441)$$

Drinking Water

The drinking water requirements of the cows can be expressed as:

$$W_{YRC} = Y \times N_{CF} \times 365 \times 10^{-3} \quad (442)$$

According to TILLIE (1999):

$$Y = (2.53 \times X_1) + (0.45 \times X_2) - 6.99 \quad (443)$$

Other Systems

Some other systems may be implemented in a dairy farm, so system (1), system (2), system (3)... system (7). Those systems will be considered as system (n):

$$\text{where,} \quad n \in \{1,2,3,4,5,6,7\} \quad (444)$$

$$\text{thus,} \quad W_{YSn} = W_{HSn} \times D_{DSn} \times N_{Sn} \times 365 \times 10^{-3} \quad (445)$$

this can be exchanged to:

$$W_{YS1} = W_{HS1} \times D_{DS1} \times N_{S1} \times 365 \times 10^{-3} \quad (446)$$

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$$W_{YS7} = W_{HS7} \times D_{DS7} \times N_{S7} \times 365 \times 10^{-3} \quad (447)$$

Total Water Consumption

The total water consumption of a farm can be expressed as:

$$W_{FY} = W_{MSY} + W_{CSY} + W_{MHY} + W_{YRC} + \sum_{n \in K} W_{YSn} \quad (448)$$

$$\text{where,} \quad K = \{1,2,3,4,5,6,7\} \quad (449)$$

3.3.9.2 Water Sources

The backwater should be considered not only in case of governmental supply, but also in case of drilling a well. Thus,

$$V_{BW} = \frac{3 \times W_{FY}}{365} \quad (450)$$

$$N_{BWC} = \frac{V_{BW}}{V_{CC}} \quad (451)$$

$$P_{tWC} = N_{BWC} \times P_{BWC} \quad (452)$$

Governmental Supply

The costs of the governmental supply can be calculated as:

$$C_{VWG} = P_{WG} \times W_{FY} \times 1.2 \quad (453)$$

where, the total water consumption is multiplied by 1.2 to consider the losses.

$$C_{IWG} = P_{MWS} + P_{tWC} \quad (454)$$

$$C_{FWG} = \frac{C_{IWG}}{t_{GW}} \quad (455)$$

$$C_{TWG} = C_{FWG} + C_{VWG} \quad (456)$$

The main watershed consists of water meter, main tube, and some other components. However, its lifetime is 10-20 years.

Well

In case of drilling a well, the well depth is between 100 and 120 m. However, the well requires a pump, with 8 hours per day as optimal operating duration. Thus,

$$Q_{WP} = \frac{3 \times W_{FY}}{24 \times 365} \quad (457)$$

and

$$C_{IDW} = (D_W \times C_{DPW}) + (D_W \times C_{MDW}) + P_{WF} + P_{WP} + C_{OW} + P_{tWC} \quad (458)$$

The operation costs of well pump depend on whether the pump electric or diesel, and the other costs of well are: stainless steel tube, chemicals, and workers. The other variable costs are: well cleaning, filter cleaning ...thus,

$$C_{VWP} = W_{FY} \times C_{OWP} \quad (459)$$

$$C_{FW} = \frac{C_{IDW}}{t_W} \quad (460)$$

$$C_{VW} = C_{VWP} + C_{VOW} \quad (461)$$

$$C_{TW} = C_{FW} + C_{VW} \quad (462)$$

3.3.10 Electricity Requirements and Sources

The Electricity Sub-Model (ECM) is developed to specify the energy requirements of the farm, and to study the available sources such as the governmental supply and the electric generators. Furthermore, ECM calculates the capital investments and the fixed, variable, and total costs.

3.3.10.1 Electricity Requirements

Milking System

The electricity requirements of the milking system(s) can be expressed as:

$$E_{MSY} = E_{MSH} \times N_{MD} \times D_M \times N_{MSF} \times 365 \quad (463)$$

Cooling System

The electricity requirements of the cooling system(s) can be expressed as:

$$E_{CSY} = [(N_{ICF} \times E_{CF}) + E_{CP}] \times D_{DOC} \times D_{YOC} \times 30 \times N_{CSF} \quad (464)$$

The yearly operating duration of cooling system is usually 6 Months.

Manure Handling System

The electricity requirements of the manure handling system(s) can be expressed as:

$$E_{MHY} = E_{MHH} \times D_{DOM} \times N_{MHF} \times 365 \quad (465)$$

Daily operating duration of manure handling system is usually 24 hours.

Lighting System

The electricity requirements of the lighting system(s) can be expressed as:

$$E_{LSY} = [(N_{LC} \times N_{HF}) + N_{LO}] \times E_L \times 10^{-3} \times D_{NL} \times 365 \quad (466)$$

The average of night lighting duration is 10 hours, which are 8 hours in winter and 12 hours in summer.

Other Systems

Some other systems may be implemented in a dairy farm, so system (1), system (2), system (3)... system (7). Those systems will be considered as system (n):

where,
$$n \in \{1,2,3,4,5,6,7\} \quad (467)$$

thus,
$$E_{YSn} = E_{HSn} \times D_{DSn} \times N_{Sn} \times 365 \quad (468)$$

this can be exchanged to:

$$E_{YS1} = E_{HS1} \times D_{DS1} \times N_{S1} \times 365 \quad (469)$$

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$$E_{YS7} = E_{HS7} \times D_{DS7} \times N_{S7} \times 365 \quad (470)$$

Total Electricity Consumption

The total electricity consumption of a farm can be expressed as:

$$E_{FY} = E_{MSY} + E_{CSY} + E_{MHY} + E_{LSY} + \sum_{n \in K} E_{YSn} \quad (471)$$

where,

$$K = \{1,2,3,4,5,6,7\} \quad (472)$$

3.3.10.2 Electricity Sources

Governmental Supply

The costs of the governmental supply can be calculated as:

$$C_{VEG} = E_{FY} \times P_{EG} \quad (473)$$

$$C_{IEG} = t_{GC} \times C_{FEG} \quad (474)$$

$$C_{TEG} = C_{FEG} + C_{VEG} \quad (475)$$

The fixed costs may represent the circuit components such as: Electric meter, main line, etc...

Electric Generators

In case of using electric generators, some generators are required, each one operates $\frac{24}{N_{EG}}$ hours. Thus,

$$E_{GP} = \frac{E_{FY}}{24 \times 365} \quad (476)$$

$$C_{FGS} = C_{FG} \times N_{EG} \quad (477)$$

$$C_{VGS} = C_{VG} \times N_{EG} \quad (478)$$

$$C_{TGS} = C_{FGS} + C_{VGS} \quad (479)$$

$$C_{IGE} = t_{EG} \times C_{FGS} \quad (480)$$

The required power of the electric generator is dependent on the total farm requirements.

3.3.11 Costs Calculation

The costs calculation model (CM) is developed to calculate the capital investment of the farm and the fixed, variable, and total costs. However, there is a part of each sub-model is dedicated to calculate the capital investment and the costs of the sub-model in operation. Afterwards, the capital investment and the costs of each sub-model will be inserted in CM as input data, and then CM will calculate the capital investment and the costs of the farm using its own mathematical model. Therefore, CM is divided into two parts: CM P1 and CM P2. CM P1 is responsible of fixed, variable, and total costs calculation, and CM P2 is responsible of the calculation of capital investment.

3.3.11.1 Annual Costs

CM P1 is divided into several parts: technology costs, cow costs, land costs, operating supply items costs, construction costs, and model brain.

Technology Costs

The technology costs calculation comprises feeding, cooling, milking, and manure handling systems. Thus,

$$C_{FT} = C_{FFS} + C_{FCS} + C_{FMS} + C_{FMH} \quad (481)$$

$$C_{VT} = C_{VFS} + C_{VCS} + C_{VMS} + C_{VMH} \quad (482)$$

$$C_{TT} = C_{TFS} + C_{TCS} + C_{TMS} + C_{TMH} \quad (483)$$

Costs of the Cows

The costs of the cows housed in the dairy farm, can be calculated as following:

$$P_{iCO} = N_{CF} \times P_{OH} \quad (484)$$

$$C_{FC} = \frac{P_{iCO}}{N_{SC}} \quad (485)$$

$$C_{VC} = N_{CF} \times C_{VOC} \quad (486)$$

$$C_{TC} = C_{FC} + C_{VC} \quad (487)$$

Land Costs

The costs of the required land for establishing the dairy farm can be estimated as following:

$$P_L = A_{tFA} \times P_{ha} \quad (488)$$

$$C_{FL} = \frac{P_L}{t_P} \quad (489)$$

$$C_{TL} = C_{FL} + C_{VL} \quad (490)$$

Costs of Operating Supply Items

- **Electricity**

In case of governmental supply:

$$C_{TEG} = C_{FEG} + C_{VEG} \quad (491)$$

In case of using generators:

$$C_{TGS} = C_{FGS} + C_{VGS} \quad (492)$$

- **Water**

In case of governmental supply:

$$C_{TWG} = C_{FWG} + C_{VWG} \quad (493)$$

In case of drilling a well:

$$C_{TW} = C_{FW} + C_{VW} \quad (494)$$

The fixed costs of operating supply items will be equal to the summation of fixed costs of water and electricity, and the same is for variable and total costs.

Construction Costs

The construction costs calculation is divided into several parts: manure handling, cow buildings, forage storage, and milking center constructions.

- **Manure Handling**

The costs of manure handling constructions can be calculated as follows:

$$C_{TMC} = C_{FMC} + C_{VMC} \quad (495)$$

- **Forage Storage**

The costs of forage storage constructions can be determined as following:

$$C_{TFC} = C_{FFC} + C_{VFC} \quad (496)$$

- **Milking Center**

The costs of milking center constructions can be calculated as follows:

$$C_{FCC} = C_{FCM} + C_{FS} \quad (497)$$

$$C_{VCC} = C_{VCM} + C_{VS} \quad (498)$$

$$C_{TCC} = C_{FCC} + C_{VCC} \quad (499)$$

- **Cow Buildings**

The costs of cow buildings can be determined as following:

$$C_{TCB} = C_{FCB} + C_{VCB} \quad (500)$$

$$C_{TS} = C_{FS} + C_{VS} \quad (501)$$

$$C_{FB} = C_{FCB} + C_{FS} \quad (502)$$

$$C_{VB} = C_{VCB} + C_{VS} \quad (503)$$

$$C_{TB} = C_{FB} + C_{VB} \quad (504)$$

$$C_{FAB} = N_{BF} \times C_{FB} \quad (505)$$

$$C_{VAB} = N_{BF} \times C_{VB} \quad (506)$$

$$C_{TAB} = C_{FAB} + C_{VAB} \quad (507)$$

where,

$$N_{BF} = N_{HF} \quad (508)$$

- **Costs of Farm Constructions**

In general, the costs of all farm constructions can be calculated as following:

$$C_{FCF} = C_{FMC} + C_{FAB} + C_{FFC} + C_{FCC} \quad (509)$$

$$C_{VCF} = C_{VMC} + C_{VAB} + C_{VFC} + C_{VCC} \quad (510)$$

$$C_{TCF} = C_{FCF} + C_{VCF} \quad (511)$$

Model Brain

The model brain is the part where the farm costs calculation will be carried out. Thus,

$$C_{FF} = C_{FC} + C_{FL} + C_{FOS} + C_{FCF} + C_{FT} + C_{FO} \quad (512)$$

$$C_{VF} = C_{VC} + C_{VL} + C_{VOS} + C_{VCF} + C_{VT} + C_{IP} + C_{SW} + C_T + C_{VO} \quad (513)$$

$$C_{TF} = C_{FF} + C_{VF} \quad (514)$$

$$C_{TPC} = \frac{C_{TF}}{N_{CF}} \quad (515)$$

Two parameters, C_{FO} and C_{VO} , were added to the model in order to be used in case of other costs were dispensed. Those parameters include the costs of farm fence (if the farm owner wants to build a fence), internal farm routes, and any other costs. A routes company should be consulted to build the internal routes of the farm and to estimate the costs.

3.3.11.2 Capital Investment

CM P2 calculates the capital investment of the farm. Thus,

$$C_{IB} = C_{ICB} + C_{IS} \quad (516)$$

$$C_{IAB} = N_{BF} \times C_{IB} \quad (517)$$

$$C_{IM} = C_{ICM} + C_{IS} \quad (518)$$

$$C_{IOS} = C_{IEG} + C_{IWG} \quad (519)$$

$$C_{IF} = C_{IAB} + C_{IMC} + C_{IFC} + C_{IM} + C_{IOS} + C_{IL} + C_{IC} + C_{IFS} + C_{ICS} + C_{IMS} + C_{IMH} + C_{IO} \quad (520)$$

$$C_{IPC} = \frac{C_{IF}}{N_{CF}} \quad (521)$$

3.4 Programming

An electronic spark map (decision tree) was developed, using MS-Excel, for each simulation model, i.e. for each dairy farm facility. Subsequently, the simulation models were integrated into the relevant spark maps (CD 2). The equations (algorithms), inequation (constraints), and If-Then rules, of each simulation model, are written in the input cells of the relevant spark map with descriptive characteristics at each branch code and a decision at each terminal node. The spark maps were configured to form the heuristics of the expert system, i.e. they are the coupling method and transition phase between the simulation models and the expert system.

Afterwards, C# language (C#, 2005), which is an object-oriented programming language, was used to develop the expert system via the simulation models and the electronic spark maps in order to form the back diagram code of the expert system, and then to develop the user interface.

I have developed all equations, constraints, rules, spark maps, and expert-system architecture and structure; and then the task of writing the syntax was assigned to an Egyptian software company. Fifteen demo versions (CD 2) had been developed in order to attain the expert-system prototype (CD 1). The corrections to each version

were written in MS-Word files and sent to the company per email, and then a video conference had been held to discuss the required corrections. Making the corrections, leads to get a new version which in turn had been reviewed and checked using actual data and the resulting corrections had been sent to the company and a video conference had been held to discuss the required amendments, and so on till the expert-system prototype has been developed.

3.5 Validation and Evaluation

The validation of an expert system aims to determine if the system is operating correctly or not. However, the evaluation of an expert system aims to determine the system's accuracy.

3.5.1 Data Acquisition and Dairy Farms Selection

Validation and evaluation of the expert system were carried out using data of 6 Egyptian dairy farms and their facilities, as examples of dairy farms in hot climates. The data were acquired from the Cattle Information System of Egypt (CISE). Therefore, the required data had been listed in several pre-structured MS-Excel tables (CD 2) in order to be filled by the retrieved data from the electronic recording system of the CISE. Subsequently, the acquired data had been used to carry out the models' validation.

On the other hand, direct contacts were made with the dairy farms in order to check the acquired data from the CISE, and to further acquire the missing data either from the individual recording system of the farm or by measuring the missing engineering parameters such as: corral dimensions, roof slope, etc...

Further information, data, and costs were acquired from several Egyptian ministries, which are: Ministry of Agriculture and Land Reclamation, Ministry of Electricity and Energy, Ministry of Water Resources and Irrigation, and Ministry of State for Economic Development.

All the acquired data were compiled and summarized in specially structured tables (Tables A1 through A10) which represent all models and sub-models. These data had been used as actual data to be compared with the calculated data by the expert system in order to carry out the system's validation and evaluation.

Six dairy farms were selected in order to use their data for achieving the system's validation and evaluation. Therefore, the following guidelines were developed to be used for selecting the dairy farms which should:

- be modern dairy farms, in order to have as many as possible technologies which their data will be used to evaluate the technology and machinery implementation procedures followed by the developed expert system
- represent different dairy farm sizes (25, 72, 100, 480, 600, and 700 cows), which lead to evaluate the ability of the developed expert system to plan and design different dairy farms' sizes
- encompass as many facilities as possible, in order to use their data for the validation and evaluation of the different sub-models and to uproot system errors regarding each sub-model separately
- be recorded in the CISE, which allows easy data acquisition not only regarding the different dairy farm facilities but also concerning the different operating supply items (water and electricity consumptions vs. sources), animal welfare, and milk production of each cow and the whole farm
- have an individual data recording system, in order to cover the remaining data which has not been recorded in the CISE; because the CISE has a specially customized data acquisition system which does not encompasses all the required data for the validation and evaluation of the expert system

3.5.2 Expert System Validation

Validation determines if the problem was solved correctly. Therefore, the differences between the actual values acquired from the dairy farms and the calculated values by the expert system were determined. Afterwards, the standard deviation (σ) and the coefficient of variation (COV) were calculated for each output value/parameter.

3.5.3 Expert System Evaluation

Evaluation measures the system's accuracy. Consequently, the percentage of the calculated value by the expert system to the actual value acquired from the CISE was calculated for each output data and then the average, which is the system's accuracy, was computed.

4 RESULTS

The expert system had been prototyped to be used either as separated units, i.e. each model and each sub-model can be used as a stand-alone unit as in the case of an existing farm having several facilities but it is required to plan and design a new facility which is not existing on farm; or as a complete unit, i.e. a new farm will be planned and designed using all models and sub-models by means of follow wizard.

When using follow wizard, a multitude of the output data of one model/sub-model will be used as input data in other models/sub-models. Furthermore, several input data inserted into one model/sub-model will be transmitted automatically as input data for other models/sub-models. Figure 4.1 shows the main window of the expert system, where the menus are also shown.

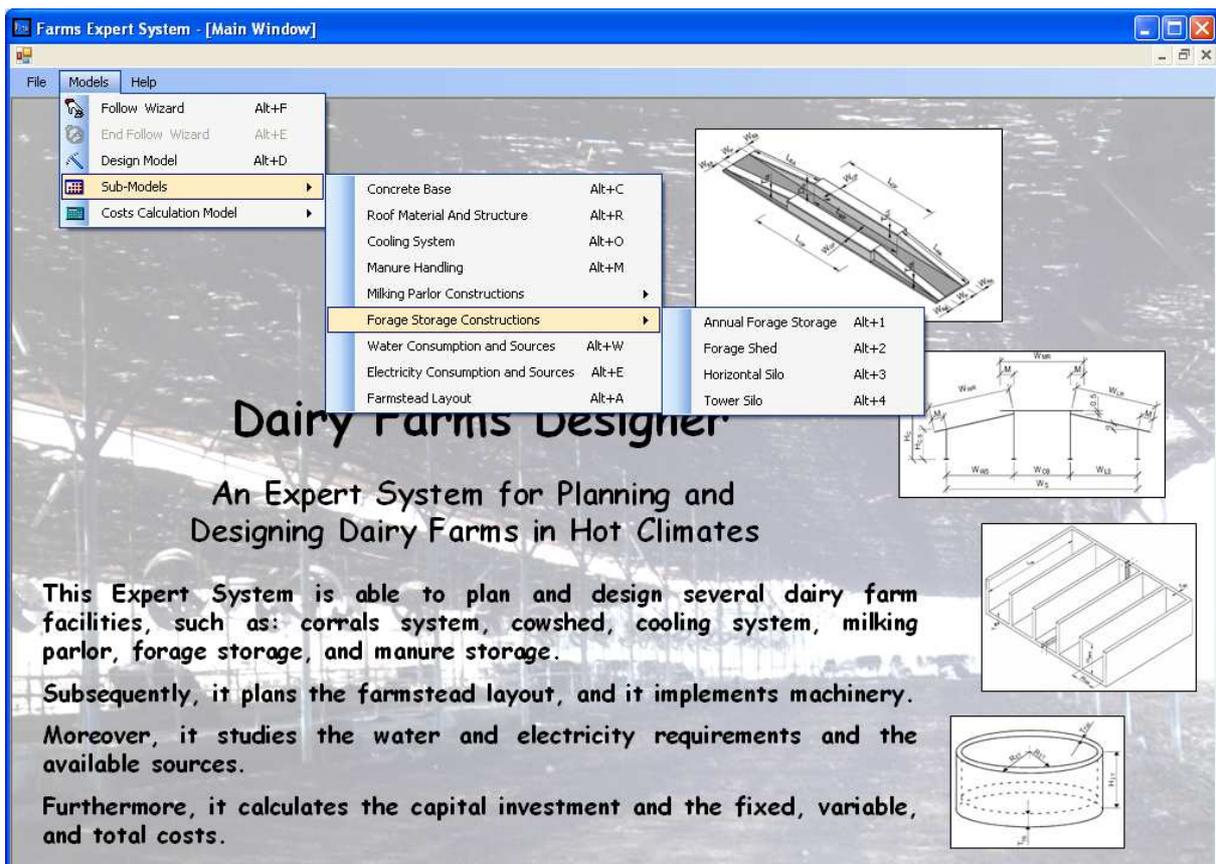


Figure 4.1: Main window of the expert system (SAMER et al., 2008d)

The developed expert system has been called Dairy Farms Designer (DFD) referring to its main task which is designing dairy farms. DFD, which is a stand-alone system that can be easily installed (CD 1) with some prerequisites (Figure A1), requires 358 input data thereof a multitude will be recommended by the expert system itself; consequently, it computes and displays 372 output data with the ability of saving and retrieving data. However, the DFD's syntax includes 22106 lines, and the system's accuracy is 98.6%.

4.1 Design Model

The Design Model requires 20 input data; subsequently, it displays 18 output data. However, these excessive input data will be used by the wizard next sub-models.

Input Data Windows

The farm, house, and corral capacities should be decided by the designer and inserted into the window (Figure 4.2). Some other design parameters concerning the feeding line and the feeding bunks should be specified by the designer. Selecting an appropriate corrals distribution is a key issue in designing the dairy cows housing, this step will decide which design will be configured (Figures 3.3, 3.5, or 3.7).

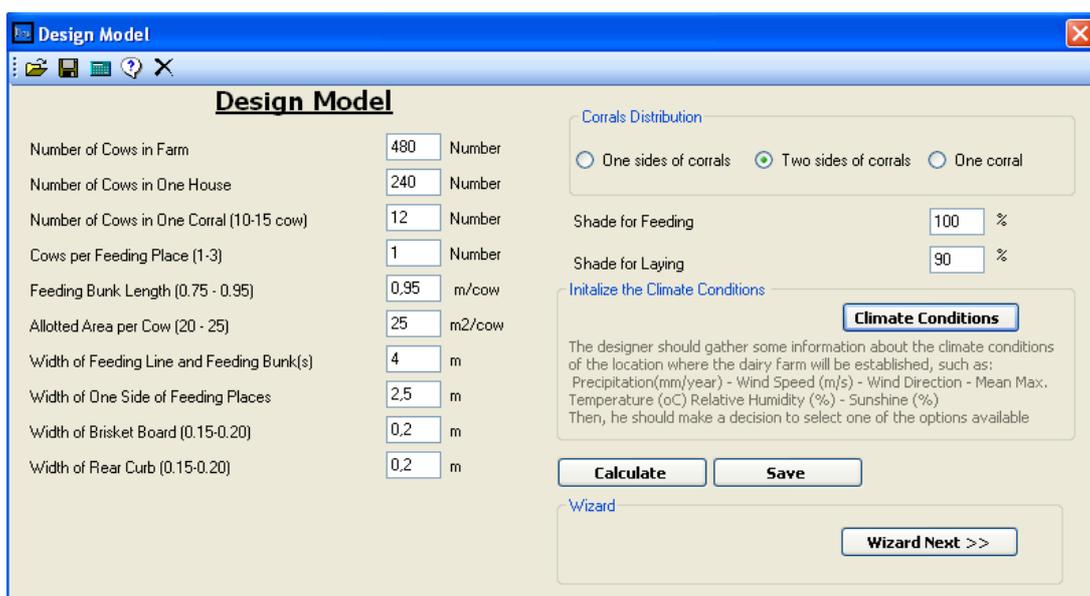


Figure 4.2: Input data window of design model (SAMER et al., 2008b)

On the other hand, the climate conditions -on farm site- should be inserted into climate conditions window (Figure 4.3), which will be used in order to recommend appropriate roof material and cowshed orientation.

Figure 4.3: Input data window of climate conditions (SAMER et al., 2008b)

Output Data Window

The output data window (Figure 4.4) shows the specifications of corral, dairy cow house, and shade. The qualitative reasoning outputs are shown as recommendations of cowshed orientation and roof material. Furthermore, DFD explains the output data by means of displaying the description and the unit of each output.

On the other hand, the data can be saved in MS-Excel files as well as in specially customized data files which have been suffixed by “.dfd” extension in order to express the name of this expert system which is Dairy Farms Designer (DFD). In addition, retrieving data can be easily made by opening the already saved files.

If the outputs are not satisfying, the designer may maneuver by changing some input data and then re-click the button “Calculate”. Consequently, the output data will be changed according to changed input data. Hence, the designer may make a comparison study.

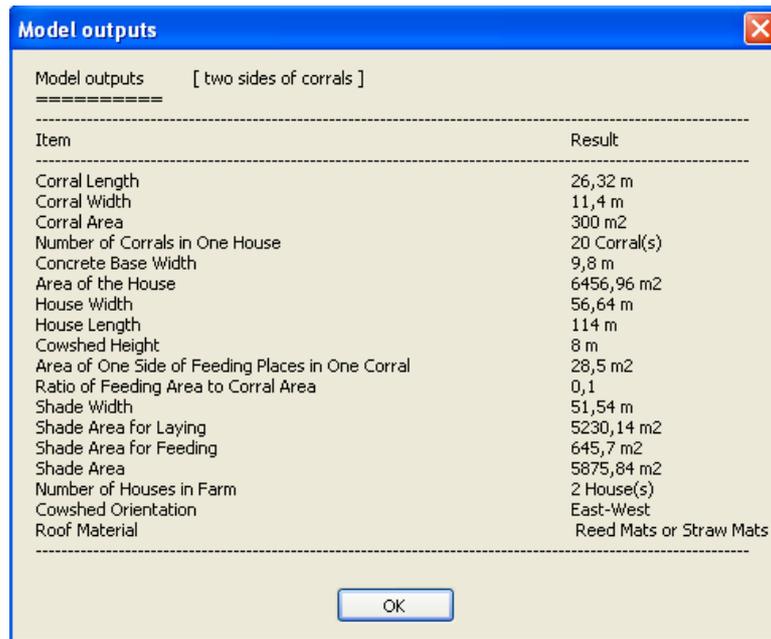


Figure 4.4: Output data window of design model (SAMER et al., 2008b)

Validation and Evaluation

Data of 6 dairy farms were used to perform the validation and evaluation of Design Model. The statistical analysis of the actual and calculated values (Table 4.1) elucidated that COV were 4.12% ($\sigma = 0.03$) and 3.28% ($\sigma = 0.04$) for corral length and corral width, respectively. On the other hand, the actual and calculated values of number of corrals in one house and ratio of feeding area to corral area were identical. The calculated accuracy of Design Model is 98.8%.

Table 4.1: Data of design model (SAMER et al., 2008b)

	Parameter	L _C	W _C	N _{HC}	R _A
Farm 1	Actual Value	26.15	11.52	20	0.1
	Calculated Value	26.32	11.4	20	0.1
Farm 2	Actual Value	22.37	9.1	20	0.09
	Calculated Value	22.22	9	20	0.09
Farm 3	Actual Value	21.85	20.22	1	0.06
	Calculated Value	22	20	1	0.06
Farm 4	Actual Value	23.38	17.18	1	0.09
	Calculated Value	23.53	17	1	0.09
Farm 5	Actual Value	35.52	14.33	1	0.06
	Calculated Value	35.29	14.17	1	0.06
Farm 6	Actual Value	27.96	9.7	6	0.07
	Calculated Value	28.13	9.6	6	0.07

4.2 Sub-Models

4.2.1 Concrete Base Sub-Model

This sub-model requires 25 input data; subsequently, it displays 23 output data. However, 14 input data are already shown in their input boxes where some of them are automatically transmitted from Design Model by means of follow wizard and the others are shown as recommendations though the designer may substitute them.

Input Data Window

The designer should specify some dimensions of the concrete base, such as: concrete base thickness, height of bricket board and rear curb, and number of gridirons. Moreover, the costs of construction materials should be inserted into the input data window (Figure 4.5) according to market prices.

The screenshot shows the 'Concrete Base Sub-Model' input data window. The window is titled 'Concrete Base Sub-Model' and contains various input fields for dimensions, material costs, and project parameters. It includes radio buttons for 'Corrals Distribution' and 'Type of Iron Rods', and buttons for 'Calculate', 'Save', 'Close', and 'Wizard' navigation.

Input Field	Value	Unit
Concrete Base Length	114	m
Width of Feeding Line and Feeding Bunks	4	m
Width of One Side of Feeding Places	2,5	m
Width of Rear Curb (≈ 0.15-0.20 m)	0,2	m
Width of Bricket Board (≈ 0.15-0.20 m)	0,2	m
Concrete Base Thickness (Feeding Line)	0,25	m
Concrete Base Thickness (Feeding Places)	0,2	m
Height of Bricket Board (≈ 0.50 m)	0,50	m
Height of Rear Curb (≈ 0.20-0.25 m)	0,2	m
Length of One Standard Iron Rod	12	m
Mass of 1 m Long of Iron Rod	0,67	kg/m
Price of 1 m ³ Gravels	25	Currency/m ³
Price of 1 kg Cement	0,3	Currency/kg
Price of 1 m ³ Sand	60	Currency/m ³
Employment Costs for 1 m ³ of Concrete	25	Currency/m ³
Price of One Ton of Iron Rods	2800	Currency/Ton
Project Lifetime	20	Year
Variable Costs of Concrete Base	0	Currency/Year
Volume of Required Gravels for Making 1 m ³ Concrete	0,8	m ³ /m ³
Mass of Required Cement for Making 1 m ³ Concrete	325	kg/m ³
Volume of Required Sand for Making 1 m ³ Concrete	0,4	m ³ /m ³
Corrals Distribution	Two sides of corrals	
Type of Iron Rods	6Ø6/m	
Number of Iron Rods per One Meter Length of Concrete	6	Rod(s)/m
Number of Gridirons	1	Gridiron

Figure 4.5: Input data window of concrete base sub-model (SAMER et al., 2008b)

Output Data Window

The output data window (Figure 4.6) shows the different specifications of the concrete base which is required for the feeding line and the feeding places. The sensitive parameter is the clicked type of corrals distribution in the input data window. Selecting corrals distribution will configure different concrete base designs (Figures 3.4, 3.6, or 3.8), and then the calculation will follow the relevant algorithm. However, the most important specifications are total volume of the concrete base, capital investment, and the required amounts of the different construction materials.

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

Figure 4.6: Output data window of concrete base sub-model (SAMER et al., 2008b)

Validation and Evaluation

Data of 6 dairy farms were used to execute the validation and evaluation of Concrete Base Sub-Model. The statistical analysis of the actual and calculated values (Table 4.2) elucidated that COV were 2.90% ($\sigma = 0.01$), 5.54% ($\sigma = 0.03$), 4.12% ($\sigma = 0.01$), 7.31 % ($\sigma = 0.13$), and 3.59% ($\sigma = 0.03$) for amounts of concrete, gravels, cement, sand, and iron rods, respectively. The accuracy of this sub-model is 99.1%.

Table 4.2: Data of concrete base sub-model (SAMER et al., 2008b)

	Parameter	V _{CB}	V _G	M _C	V _S	M _I
Farm 1	Actual Value	282.50	225.98	91415	114.50	9.64
	Calculated Value	278.16	222.53	90402	111.26	9.52
Farm 2	Actual Value	194.06	155.19	62785	78.50	7.38
	Calculated Value	193.05	154.44	62741	77.22	7.32
Farm 3	Actual Value	23.52	18.82	7609	9.52	1.06
	Calculated Value	23.40	18.72	7605	9.36	1.05
Farm 4	Actual Value	24.87	19.91	8049	10.07	1.00
	Calculated Value	24.75	19.80	8043	9.90	0.99
Farm 5	Actual Value	27.16	21.74	8789	11.03	1.22
	Calculated Value	27.03	21.62	8783	10.81	1.21
Farm 6	Actual Value	95.97	76.79	31060	38.90	3.41
	Calculated Value	95.50	76.40	31037	38.20	3.38

4.2.2 Roof Materials and Structure Sub-Model

The Roof Materials and Structure Sub-Model requires 20 input data, actually they are 29 input data but 12 of them are dedicated for the different roof materials thereof one will be selected/checked. However, 11 input data are already shown in their input boxes thereof some data are automatically transmitted from Design Model and Concrete Base Sub-Model by means of follow wizard and the others are shown as recommendations although the designer may substitute them.

Subsequently, the sub-model displays 36 output data thereof 12 output data are equal to zero because they belongs to different roof materials and roof types thereof one roof material and one roof type will be selected/checked.

Input Data Window

Some engineering parameters should be specified by the designer, such as: roof, slope, roof type, and span between two posts. Moreover, the specifications of the selected roof material should be inserted to the input data window (Figure 4.7) e.g. surface area of one reed/straw mat, price per mat or per square meter, mass per mat or per square meter, and the expected variable costs of the selected roof material.

The selected/checked roof type will decide which design will be followed by the system (Figures 3.9, 3.10, 3.11, 3.12, or 3.13), and then the relevant algorithm.

Roof Material And Structure Sub-Model

Shade Area: 5875,8 m²
 Shade Length: 114 m
 Roof Slope: 8 %
 Cowshed Height: 8 m

Corrals Distribution
 One sides of corrals Two sides of corrals One corral

Roof Type
 Horizontal Roof Mono-Slope Roof
 Open Ridge Roof Compound 2 Parts
 Compound 3 Parts

Margins
 Margins: 2 m
 Span or distance between geometric centers of 2 Posts in the direction of structure length: 5,8 m
 Constant depends on roof type: 4
 Concrete Base Width: 9,8 m
 Width of Feeding Line and Feeding Bunks: 4 m

Climate Conditions
 Wind Speed (m/s): 1,4
 Precipitation (mm/year): 8

Roof Material
 The recommended roof material by Design Model is Reed Mats or Straw Mats
 Reed Mats Straw Mats Polished Aluminum
 Burnt-Clay Bricks Isolated Aluminum

Surface Area of One Reed Mat: 9 m²
 Surface Area of One Straw Mat: m²
 Price of one square meter of Polished Aluminum: Currency/m²
 Price of one square meter of Isolated Aluminum: Currency/m²
 Price of one square meter of Burnt-Clay Bricks: Currency/m²
 Price of One Reed Mat: 12 Currency/Mat
 Price of One Straw Mat: Currency/Mat
 Mass of one square meter of Polished Aluminum: kg/m²
 Mass of one square meter of Isolated Aluminum: kg/m²
 Mass of one square meter of Burnt-Clay Bricks: kg/m²
 Mass of one Reed Mat: 3 kg/Mat
 Mass of one Straw Mat: kg/Mat
 Total Price of the Steel Construction incl. Concrete Piers and Rails (railed corrals): 93000 Currency
 Lifetime of the Shed: 20 Year
 Variable Costs of the Shed: 1000 Currency/Year

Buttons: Calculate, Save, Close

Wizard: << Wizard Previous, Wizard Next >>

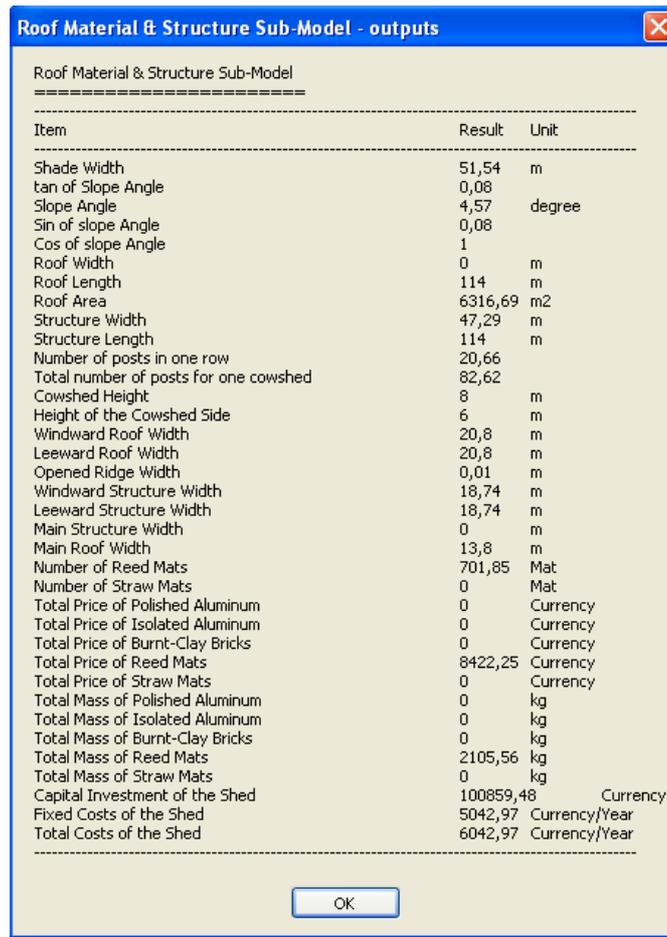
Figure 4.7: Input data window of roof material and structure sub-model

Output Data Window

The different specifications of the configured shed are shown in the output data window (Figure 4.8). The most effective specifications are those concerning roof dimensions, which are dependent on the selected roof type i.e. roof design, and consequently the structure dimensions, and the costs.

Validation and Evaluation

Data of 6 dairy farms were used to carry out the validation and evaluation of Roof Material and Structure Sub-Model. Several calculated and actual output data have been found to be identical. The calculated accuracy of this sub-model is 99.4%.



Item	Result	Unit
Shade Width	51,54	m
tan of Slope Angle	0,08	
Slope Angle	4,57	degree
Sin of slope Angle	0,08	
Cos of slope Angle	1	
Roof Width	0	m
Roof Length	114	m
Roof Area	6316,69	m2
Structure Width	47,29	m
Structure Length	114	m
Number of posts in one row	20,66	
Total number of posts for one cowshed	82,62	
Cowshed Height	8	m
Height of the Cowshed Side	6	m
Windward Roof Width	20,8	m
Leeward Roof Width	20,8	m
Opened Ridge Width	0,01	m
Windward Structure Width	18,74	m
Leeward Structure Width	18,74	m
Main Structure Width	0	m
Main Roof Width	13,8	m
Number of Reed Mats	701,85	Mat
Number of Straw Mats	0	Mat
Total Price of Polished Aluminum	0	Currency
Total Price of Isolated Aluminum	0	Currency
Total Price of Burnt-Clay Bricks	0	Currency
Total Price of Reed Mats	8422,25	Currency
Total Price of Straw Mats	0	Currency
Total Mass of Polished Aluminum	0	kg
Total Mass of Isolated Aluminum	0	kg
Total Mass of Burnt-Clay Bricks	0	kg
Total Mass of Reed Mats	2105,56	kg
Total Mass of Straw Mats	0	kg
Capital Investment of the Shed	100859,48	Currency
Fixed Costs of the Shed	5042,97	Currency/Year
Total Costs of the Shed	6042,97	Currency/Year

Figure 4.8: Output data window of roof material and structure sub-model

4.2.3 Manure Handling/Constructions Sub-Model

This sub-model requires 76 input data; subsequently, it displays 105 output data. However, the number of cows in farm, which is already inserted by the designer into Design Model, is automatically transmitted into its relevant box in the Manure Handling Sub-Model. Furthermore, range of values are shown and recommended for several input data in order to assist the designer in deciding the value of the relevant input data.

Input Data Windows

The designer should specify and insert some parameters into the input data window of Manure Handling Sub-Model (Figure 4.9).

Manure Handling/Constructions Sub-Model

Ratio of gathered waste from manure canals to total waste:

Number of Cows in Farm: Cow(s)

Manure Storage Volume per Cow and Month: m³/Animal.Month

Duration of Mixing and Pumping (1 -3): Day

Price of Manure Mixer: Currency

Price of Manure Pump: Currency

Price of Manure Separator: Currency

Percentage of DM in Raw Manure: %

Elimination Rate: %

Duration of Aeration (20 - 30): Day

Price of Surface Aerator: Currency

Duration of Treated Liquid Storage (≤6): Month

Duration of Composted Product Storage (2 - 4): Month

Number of Composted Product Piles:

Length of Pile Arrow: m

Length of Pile Cord: m

Price of Turning Equipment: Currency

Manure Mechanical System Lifetime: Year

Variable Costs of Manure Mechanical System: Currency/Year

Initialize storage Tanks:

Initialize the Raw Slurry Storage Tank.

Initialize the Aeration Storage Tank.

Initialize the Treated Liquid Storage Tank.

Calculations:

Wizard:

Figure 4.9: Input data window of manure handling sub-model

Those parameters belong to different categories, such as: duration of several operations, dimensions, and prices. The inserted data will be used to determine the capacity of raw slurry, aeration, and treated liquid storage tanks.

Subsequent to filling the data in the input window (Figure 4.9), the tanks should be initialized consecutively. The first tank that should be initialized is the raw slurry storage tank (Figure 4.10). The capacity of the tank is calculated according to the inserted data into the input data window (Figure 4.9) and automatically shown in its relevant input box in the input window of raw slurry storage tank (Figure 4.10).

On the other hand, several input data (Figure 4.9) will be recommended such as: the durations of mixing and pumping, aeration, treated liquid storage, and composted product storage. If any of the recommended range limits have been jeopardized, the system will notify the user/designer leaving the decision for him.

While selecting a type of iron rods (Figure 4.10) the specifications of the chosen type will be automatically displayed, allowing the designer to change them if needed.

Figure 4.10: Input data window for initializing the raw slurry tank

Output Data Window

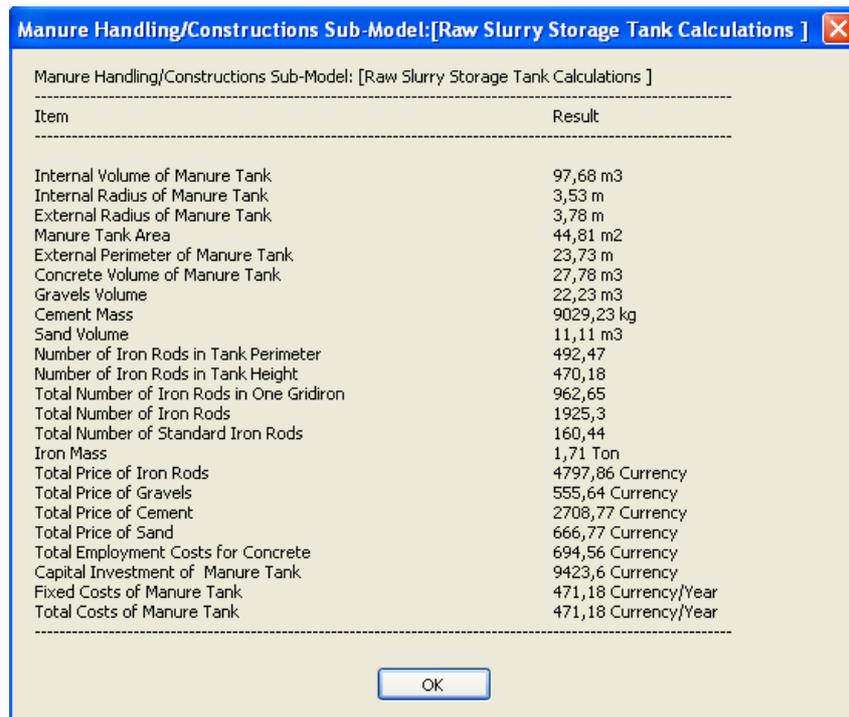
The output data window (Figure 4.11) displays the required construction materials, design parameters, and costs of the initialized raw slurry storage tank. Similarly, other output windows will display the data of the consecutive tanks.

Validation and Evaluation

Data of 3 manure tanks were used to achieve the validation and evaluation of Manure Handling Sub-Model. The statistical analysis of the actual and calculated values (Table 4.3) showed that COV were 2.51% ($\sigma = 0.04$), 4.30% ($\sigma = 0.05$), 4.24% ($\sigma = 0.01$), 5.80% ($\sigma = 0.15$), and 5.56% ($\sigma = 0.20$) for amounts of concrete, gravels, cement, sand, and iron rods, respectively. The model's accuracy is 97.8 %.

Table 4.3: Data of manure handling/constructions sub-model (SAMER et al., 2008d)

Parameter	Tank 1		Tank 2		Tank 3	
	Actual Value	Calculated Value	Actual Value	Calculated Value	Actual Value	Calculated Value
V_{CT}	28.50	28.04	25.80	26.22	5.25	5.17
V_G	22.70	22.43	20.75	20.98	4.18	4.13
M_C	9120.10	9113.28	8516.50	8522.45	1680.80	1679.63
V_s	11.50	11.22	10.21	10.49	2.12	2.07
M_i	1.79	1.72	2.78	2.87	0.16	0.16



Item	Result
Internal Volume of Manure Tank	97,68 m3
Internal Radius of Manure Tank	3,53 m
External Radius of Manure Tank	3,78 m
Manure Tank Area	44,81 m2
External Perimeter of Manure Tank	23,73 m
Concrete Volume of Manure Tank	27,78 m3
Gravels Volume	22,23 m3
Cement Mass	9029,23 kg
Sand Volume	11,11 m3
Number of Iron Rods in Tank Perimeter	492,47
Number of Iron Rods in Tank Height	470,18
Total Number of Iron Rods in One Gridiron	962,65
Total Number of Iron Rods	1925,3
Total Number of Standard Iron Rods	160,44
Iron Mass	1,71 Ton
Total Price of Iron Rods	4797,86 Currency
Total Price of Gravels	555,64 Currency
Total Price of Cement	2708,77 Currency
Total Price of Sand	666,77 Currency
Total Employment Costs for Concrete	694,56 Currency
Capital Investment of Manure Tank	9423,6 Currency
Fixed Costs of Manure Tank	471,18 Currency/Year
Total Costs of Manure Tank	471,18 Currency/Year

Figure 4.11: Output data window of the initialized raw slurry tank

4.2.4 Milking Parlor Constructions Sub-Model

The Milking Parlor Constructions Sub-Model requires 50 input data; consequently, it displays 61 output data. The sub-model is divided into two main parts responsible for the different calculations, which are: Concrete Constructions, and Parlor Shed.

Input Data Windows

The input data window of milking parlor concrete constructions (Figure 4.12) requires 36 input data. However, several input data are recommended and shown automatically in the relevant input data boxes such as the specifications of construction materials. In case of selecting parlor design without front exit alley (Figure 3.16), the required input data of front exit alley will be automatically displayed as zeros; hence, the input data of return alley will be automatically displayed and equal to the relevant data of entry alley. On the other hand, when selecting parlor design with front exit alley (Figure 3.15), the input data of return alley will be displayed as zeros.

Farms Expert System - [Milking Parlor Constructions Sub-Model - Part1]

Milking Parlor Constructions Sub-Model: Concrete Constructions

Parlor Design

With Front Exit Alley Without Front Exit Alley

Parlor Size

Parlor Size: 2 x 12

Parlor Layout: Parallel

Length of Cow Platform of Milking Parlor: 10,5 m

Width of Cow Platform of Milking Parlor: 2,5 m

Length of Entry Alley of Milking Parlor: 4 m

Width of Entry Alley of Milking Parlor: 1 m

Length of Front Exit Alley of Milking Parlor: 0 m

Width of Front Exit Alley of Milking Parlor: 0 m

Width of Milking Parlor Pit: 2,6 m

Depth of Milking Parlor Pit: 1,24 m

Length of Return Alley of Milking Parlor: 10 m

Width of Return Alley of Milking Parlor: 1 m

Slope of Collecting Yard of Milking Parlor: 3 %

Number of Cows in Collecting Yard: 24 Cow(s)

Allotted Area per Cow in Collecting Yard of Milking Parlor: 2,5 m²/cow

Area of Milk Room: 30 m²

Area of Machinery Room of Milking Parlor: 24 m²

Area of Personnel Room of Milking Parlor: 12 m²

Type of Iron Rods

6Ø6/m 6Ø8/m

Number of Iron Rods per One Meter Length of Concrete: 6

Number of Gridirons: 1

Length of One Standard Iron Rod: 12 m

Mass of 1 m Long of Iron Rod: 0,67 kg/m

Price of One Ton of Iron Rods: 2800 Currency/Ton

Price of 1 m³ Gravels: 25 Currency/m³

Price of 1 kg Cement: 0,3 Currency/kg

Price of 1 m³ Sand: 60 Currency/m³

Employment Costs for 1 m³ of Concrete: 25 Currency/m³

Price of 1 m³ Rocks: 40 Currency/m³

Project Lifetime: 20 Year

Variable Costs of Concrete Constructions of Milking Center: 0 Currency/Year

Volume of Required Gravels for Making 1 m³ Concrete: 0,8 m³/m³

Mass of Required Cement for Making 1 m³ Concrete: 325 kg/m³

Volume of Required Sand for Making 1 m³ Concrete: 0,4 m³/m³

Calculate **Close** **Next**

Figure 4.12: Input data window for milking parlor concrete constructions (SAMER et al., 2008c)

Generally, the required input data are the intended dimensions of the different parts of the milking parlor, such as: entry alleys, front exit alleys or return alley, cow platform, and parlor pit. The aforementioned data are listed in specially customized tables (ALFA LAVAL AGRI, 1996), according to parlor size the different dimensions can be found and inserted into the expert system. On the other hand, the market prices should be surveyed in order to insert their values into the relevant boxes.

The input data window of milking parlor shed (Figure 4.13) requires 14 input data. Actually, it requires 18 input data thereof 4, which belongs to the unchecked roof materials, will be closed.

Milking Parlor Constructions Sub-Model: Parlor Shed

Roof Type: Horizontal Gable Roof

Shade Length: m

Margins: m

Shade Width: m

Roof Slope: %

Shed Height: m

Span or distance between geometric centers of 2 Posts in the direction of structure length: m

Constant depends on roof type:

Roof Material: Polished Aluminum Isolated Aluminum Burnt-Clay Bricks

Price of one square meter of Polished Aluminum: Currency/m²

Price of one square meter of Isolated Aluminum: Currency/m²

Price of one square meter of Burnt-Clay Bricks: Currency/m²

Mass of one square meter of Polished Aluminum: kg/m²

Mass of one square meter of Isolated Aluminum: kg/m²

Mass of one square meter of Burnt-Clay Bricks: kg/m²

Total Price of the Steel Construction incl. Concrete Piers and Rails (railed corrals): Currency

Lifetime of the Shed: Year(s)

Variable Costs of the Shed: Currency/Year

Figure 4.13: Input data window for milking parlor shed

Output Data Windows

The output data window of milking parlor concrete construction (Figure 4.14) displays 40 output data, and the output data window of parlor shed displays 21 output data (Figure 4.15). The displayed data are generally: design parameters of the milking parlor and the parlor shed, required amounts of construction materials, and the costs.

Validation and Evaluation

Data of 5 milking parlors were used to accomplish the validation and evaluation of the Milking Parlor Constructions Sub-Model. The statistical analysis of the actual and calculated values (Table 4.4) illustrated that COV were 4.24% ($\sigma = 0.01$), 5.70% ($\sigma = 0.01$), 5.75% ($\sigma = 0.003$), 6.05 % ($\sigma = 0.04$), and 5.19% ($\sigma = 0.05$) for amounts of concrete, gravels, cement, sand, and iron rods, respectively. The accuracy of this sub-model is 98.3%.

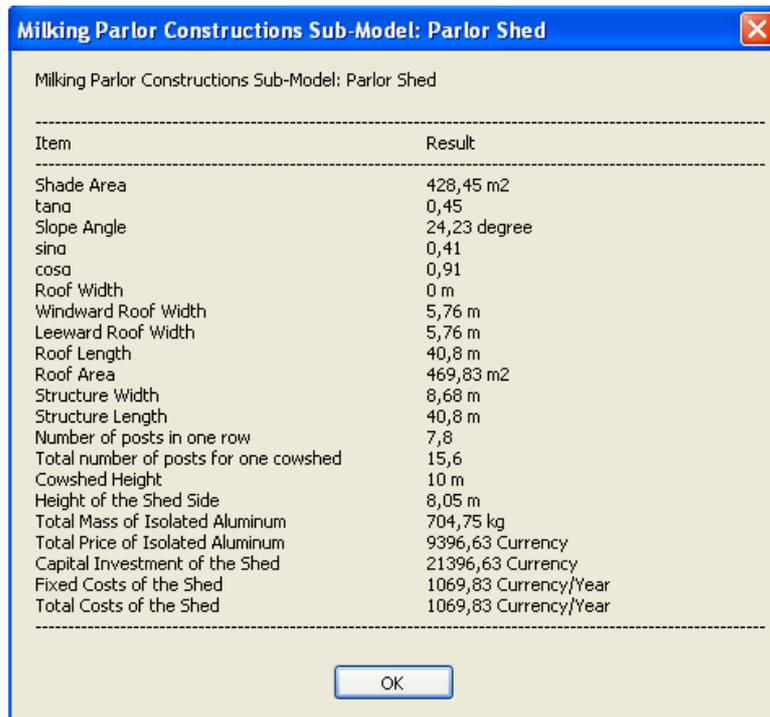
Table 4.4: Data of milking parlor constructions sub-model (SAMER et al., 2008c)

	Parameter	L _{PM}	W _{PM}	L _{MC}	W _{MC}	A _{CY}	V _{CCP}	V _G	M _C	V _S	M _I
Parlor 1	Actual Value	24.50	7.50	41.30	8	60	94.50	75.66	30680	38.00	4.02
	Calculated Value	24.23	7.60	40.80	7.6	60	94.35	75.48	30664	37.74	3.98
Parlor 2	Actual Value	27.00	10	38.50	10	56	108.9	87.20	35350	43.80	4.64
	Calculated Value	26.75	10	38.45	10	56	108.7	86.97	35333	43.48	4.59
Parlor 3	Actual Value	41.50	11.5	58.70	11.5	120	181.3	145.2	58860	72.90	7.71
	Calculated Value	41.19	11.5	58.58	11.5	120	181.03	144.8	58833	72.41	7.64
Parlor 4	Actual Value	17.00	9	25.00	9	20	55.06	44.10	17875	22.15	2.61
	Calculated Value	16.94	9	24.72	9	20	54.97	43.97	17866	21.98	2.58
Parlor 5	Actual Value	21.25	9	31.50	9	34	61.32	49.10	19905	24.68	3.49
	Calculated Value	21.20	9	31.26	9	33.6	61.22	48.97	19896	24.48	3.45

Milking Parlor Constructions Sub-Model: Concrete Constructions	
Item	Result
Slope of Entry Alley of Milking Parlor	0,33 %
Slope of Front Exit Alley of Milking Parlor	n. def. %
Slope of Return Alley of Milking Parlor	0,12 %
Length of Milking Parlor	24,23 m
Width of Milking Parlor	7,6 m
Area of Milking Parlor	184,12 m ²
Area of Concrete Base of Milking Parlor	103,62 m ²
Area of Milking Center	310,12 m ²
Width of Milking Center	7,6 m
Length of Milking Center	40,8 m
Area of Cow Platform of Milking Parlor	26,25 m ²
Area of Entry Alley of Milking Parlor	4 m ²
Area of Front Exit Alley of Milking Parlor	0 m ²
Area of Return Alley of Milking Parlor	10 m ²
Total Area of Cow Platforms and Alleys of Milking parlor	80,5 m ²
Area of collecting Yard of Milking Parlor	60 m ²
Area of Milking Parlor Rooms	66 m ²
Area of Concrete Sides of Milking Parlor	93,56 m ²
Total Area of Required Concrete Layer for Milking Center	403,68 m ²
Side Length of the supposed square which represents the total area of concrete layer required for milking center	20,09 m
Required Concrete Volume for Constructions of Milking Center	80,74 m ³
Gravels Volume	64,59 m ³
Cement Mass	26238,92 kg
Sand Volume	32,29 m ³
Volume of Milking Parlor Construction Rocks	134,79 m ³
Number of Iron Rods in Length	2564,25
Number of Iron Rods in Width	2564,25
Total Number of Iron Rods in One Gridiron	5128,51
Total Number of Iron Rods	5128,51
Total Number of Standard Iron Rods	427,38
Iron Mass	3,44 Ton
Total Price of Iron Rods	9621,08 Currency
Total Price of Gravels	1614,7 Currency
Total Price of Cement	7871,68 Currency
Total Price of Sand	1937,64 Currency
Total Price of Rocks	5391,73 Currency
Total Employment Costs for Concrete	2018,38 Currency
Capital Investment of Concrete Constructions of Milking Center	28455,21 Currency
Fixed Costs of Concrete Constructions of Milking Center	1422,76 Currency/Year
Total Costs of Concrete Constructions of Milking Center	1422,76 Currency/Year

OK

Figure 4.14: Output data window of milking parlor concrete constructions (SAMER et al., 2008c)



Item	Result
Shade Area	428,45 m2
tano	0,45
Slope Angle	24,23 degree
sino	0,41
cosa	0,91
Roof Width	0 m
Windward Roof Width	5,76 m
Leeward Roof Width	5,76 m
Roof Length	40,8 m
Roof Area	469,83 m2
Structure Width	8,68 m
Structure Length	40,8 m
Number of posts in one row	7,8
Total number of posts for one cowshed	15,6
Cowshed Height	10 m
Height of the Shed Side	8,05 m
Total Mass of Isolated Aluminum	704,75 kg
Total Price of Isolated Aluminum	9396,63 Currency
Capital Investment of the Shed	21396,63 Currency
Fixed Costs of the Shed	1069,83 Currency/Year
Total Costs of the Shed	1069,83 Currency/Year

Figure 4.15: Output data window of milking parlor shed

4.2.5 Forage Storage Constructions Sub-Model

The Forage Storage Constructions Sub-Model requires 48 input data; subsequently, it calculates and displays 61 output data. The sub-model is divided into 3 computational parts: Annual Forage Storage, Forage Shed, and Horizontal Silo.

Input Data Windows

The input data window of annual forage storage (Figure 4.16) requires 7 input data thereof 6, which are the storage volumes per cow and year of the different forages, will be recommended and automatically displayed by the system in their input data boxes, and the remaining one is the number of cows in farm which will be transmitted automatically from Design Model.

The input data window of forage shed (Figure 4.17) requires 15 input data. Actually, they are 19 input data thereof 4 belong to the other unchecked roof materials and they have closed input data boxes.

Forage Storage Constructions Sub-Model: Annual Forage Storage

Number of Cows in Farm	480	Cow(s)
Volume of Forage Storage per Cow and Year	10	m ³ /Cow.Year
Volume of Straw Storage per Cow and Year	1,75	m ³ /Cow.Year
Volume of Hay Storage per Cow and Year	0,35	m ³ /Cow.Year
Volume of Potatoes Storage per Cow and Year	0,50	m ³ /Cow.Year
Volume of Grain Storage per Cow and Year	0,65	m ³ /Cow.Year
Volume of Silage Storage per Cow and Year	6,75	m ³ /Cow.Year

Buttons: Calculate, Save, Close, Next

Wizard: << Previous

Figure 4.16: Input data window of annual forage storage

Forage Storage Constructions Sub-Model: Forage Shed: (Farm 1.dfd)

Total Volume of Straw Storage per Year	840	m ³ /Year	Price of one square meter of Polished Aluminum	15	Currency/m ²
Total Volume of Hay Storage per Year	168	m ³ /Year	Price of one square meter of Isolated Aluminum	0	Currency/m ²
Shade Length	50	m	Price of one square meter of Burnt-Clay Bricks	0	Currency/m ²
Shade Width	10	m	Mass of one square meter of Polished Aluminum	1,2	kg/m ²
Roof Slope (19 -45)	20	%	Mass of one square meter of Isolated Aluminum	0	kg/m ²
Roof Type	<input type="radio"/> Horizontal Roof <input checked="" type="radio"/> Gable Roof		Mass of one square meter of Burnt-Clay Bricks	0	kg/m ²
Margins	1	m	Total Price of the Steel Construction incl Concrete Piers and Rails (railed corrals)	13500	Currency
Span or distance between geometric centers of 2 Posts in the direction of structure length	10	m	Lifetime of the Shed	20	Years
Constant depends on roof type	2		Variable Costs of the Shed	0	Currency/Year
Roof Material	<input checked="" type="radio"/> Polished Aluminum <input type="radio"/> Isolated Aluminum <input type="radio"/> Burnt-Clay Bricks		Buttons: Calculate, Save, Close		
			Buttons: Previous, Next		

Figure 4.17: Input data window of forage shed

Several data of the required input data for configuring the forage shed (Figure 4.17) will be recommended by the system, e.g. the total volumes of straw and hay storages per year will be calculated, using the inputted data for the calculation of annual forage storage (Figure 4.16), and automatically displayed in their input data boxes (Figure 4.17).

The input data window of horizontal silo (Figure 4.18) requires 23 input data thereof a multitude will be recommended by the system, such as the specifications of the required construction materials (iron rods, gravels, cement, and sand), and will be shown automatically in the relevant input data boxes.

Parameter	Value	Unit
Total Volume of Potatoes Storage per Year	240	m ³ /Year
Total Volume of Silage Storage per Year	3240	m ³ /Year
Total Volume of Grain Storage per Year	312	m ³ /Year
Width of Horizontal Silo Pit	5	m
Number of Horizontal Silo Pits	15	
Height of Horizontal Silo Wall (2 - 3)	2	m
Thickness of Horizontal Silo Walls	0,2	m
Thickness of Horizontal Silo Base	0,2	m
Type of Iron Rods	<input checked="" type="radio"/> 606/m <input type="radio"/> 608/m	
Volume of Required Gravels for Making 1 m ³ Concrete	0,8	m ³ /m ³
Mass of Required Cement for Making 1 m ³ Concrete	325	kg/m ³
Volume of Required Sand for Making 1 m ³ Concrete	0,4	m ³ /m ³
Number of Iron Rods per One Meter Length of Concrete	6	Rod(s)
Number of Gridirons	1	Gridirons
Length of One Standard Iron Rod	12	m
Mass of 1 m Long of Iron Rod	0,67	kg/m
Price of One Ton of Iron Rods	2800	Currency/Ton
Price of 1 m ³ Gravels	25	Currency/m ³
Price of 1 kg Cement	0,3	Currency/Kg
Price of 1 m ³ Sand	60	Currency/m ³
Employment Costs for 1 m ³ of Concrete	25	Currency/m ³
Variable Costs of Concrete Construction of Horizontal Silo	0	Currency/Year
Project Lifetime	20	Year

Figure 4.18: Input data window of horizontal silo

Furthermore, the total volumes of silage and potatoes storages per year will be calculated, using the inputted data for the calculation of annual forage storage (Figure 4.16), and automatically displayed in their input data boxes (Figure 4.18).

The input data window of tower silo (Figure 4.19) requires 3 input data concerning the costs, where the tower silo will be bought as pre-constructed parts and will be assembled on farm site.

Forage Storage Constructions Sub-Model: Tower Silo

Capital Investment of Tower Silo Currency

Fixed Costs of Tower Silo Currency/Year

Variable Costs of Tower Silo Currency/Year

Wizard

Figure 4.19: Input data window of tower silo

Output Data Windows

The output data window of annual forage storage (Figure 4.20) displays 6 output data thereof 5 are the required total storage volumes of straw, hay, potatoes, grain, and silage per year. Moreover, it displays the required total volume of forage storage per year which is the summation of the storage volumes of the aforementioned forages.

Forage Storage Constructions Sub-Model: Annual Forage Storage

Forage Storage Constructions Sub-Model: Annual Forage Storage
=====

Item	Result	Unit
Total Volume of Straw Storage per Year	840	m3/Year
Total Volume of Hay Storage per Year	168	m3/Year
Total Volume of Potatoes Storage per Year	240	m3/Year
Total Volume of Grain Storage per Year	312	m3/Year
Total Volume of Silage Storage per Year	3240	m3/Year
Total Volume of Forage Storage per Year	4800	m3/Year

Figure 4.20: Output data window of annual forage storage

The output data window of forage shed (Figure 4.21) displays 26 output data which are the different design parameters and the costs of the configured forage shed. On the other hand, the output data window of horizontal silo (Figure 4.22) displays 25 output data which deal with the engineering parameters and the costs of the configured horizontal silo following the developed design in Figure 3.17.

Forage Storage Constructions Sub-Model: Forage Shed

Item	Result	Unit
Total Volume of Stored Forage under Shed per Year	1008	m3/Year
Shade Area	500	m2
tan of Slope Angle	0,2	
Slope Angle	11,31	degree
sin of slope Angle	0,2	
cos of slope Angle	0,98	
Roof Width	0	m
Roof Length	50	m
Windward Roof Width	5,1	m
Leeward Roof Width	5,1	m
Roof Area	509,9	m2
Structure Width	8,04	m
Structure Length	50	m
Number of posts in one row	6	
Total number of posts for one cowshed	12	
Cowshed Height	4,01	m
Height of the Shed Side	3,2	m
Total Price of Polished Aluminum	7648,53	Currency
Total Price of Isolated Aluminum	0	Currency
Total Price of Burnt-Clay Bricks	0	Currency
Total Mass of Polished Aluminum	611,88	kg
Total Mass of Isolated Aluminum	0	kg
Total Mass of Burnt-Clay Bricks	0	kg
Capital Investment of the Shed	21148,53	Currency
Fixed Costs of the Shed	1057,43	Currency/Year
Total Costs of the Shed	1057,43	Currency/Year

OK

Figure 4.21: Output data window of forage shed

Forage Storage Constructions Sub-Model: Horizontal Silo

Item	Result	Unit
Total Volume of Stored Forage in Horizontal Silo per Year	3792	m3/Year
Horizontal Silo Length	25,28	m
Concrete Volume of Horizontal Silo Walls	212,38	m3
Concrete Volume of Horizontal Silo Base	379,2	m3
Required Concrete Volume for Horizontal Silo	591,58	m3
Gravels Volume	473,26	m3
Cement Mass	192263,24	kg
Sand Volume	236,63	m3
Area of Concrete Plot of Horizontal Silo	2825,9	m2
Length of Concrete Plot of Horizontal Silo	53,16	m
Width of Concrete Plot of Horizontal Silo	53,16	m
Number of Iron Rods in Length	17858,96	
Number of Iron Rods in Width	17858,96	
Total Number of Iron Rods in One Gridiron	35717,92	
Total Number of Iron Rods	35717,92	
Total Number of Standard Iron Rods	2976,49	
Iron Mass	23,93	Ton
Total Price of Iron Rods	67006,83	Currency
Total Price of Gravels	11831,58	Currency
Total Price of Cement	57678,97	Currency
Total Price of Sand	14197,9	Currency
Total Employment Costs of Concrete	14789,48	Currency
Capital Investment of Concrete Construction of Horizontal Silo	165504,76	Currency
Fixed Costs of Concrete Construction of Horizontal Silo	8275,24	Currency/Year
Total Costs of Concrete Construction of Horizontal Silo	8275,24	Currency/Year

OK

Figure 4.22: Output data window of horizontal silo

The output data window of forage storage constructions' costs (Figure 4.23) displays the summation of the capital investments and the fixed, variable and total costs of all of the configured forage storage constructions.



Figure 4.23: Output data window of forage storage constructions' costs

Validation and Evaluation

Data of 4 horizontal silos were used to act upon the validation and evaluation of the Forage Storage Constructions Sub-Model. The statistical analysis of the actual and calculated data (Table 4.5) elucidated that COV were 3.4% ($\sigma = 0.03$), 5.5% ($\sigma = 0.04$), 5.2% ($\sigma = 0.01$), 7.3% ($\sigma = 0.07$), and 4.3% ($\sigma = 0.04$) for amounts of concrete, gravels, cement, sand, and iron rods, respectively. The calculated accuracy is 99%.

Table 4.5: Data of forage storage constructions sub-model (SAMER et al., 2008d)

	Parameter	V_{CHS}	V_G	M_C	V_S	M_I
Silo 1	Actual Value	600.3	479.2	193.2	240	24.17
	Calculated Value	594.2	475.4	193.1	237.7	23.92
Silo 2	Actual Value	732	585	235.8	292.5	29.49
	Calculated Value	725.2	580.1	235.7	290.1	29.21
Silo 3	Actual Value	972.5	776	313.1	389	33.35
	Calculated Value	962.9	770.3	312.9	385.2	33.04
Silo 4	Actual Value	100.9	80.6	32.5	40.4	3.82
	Calculated Value	99.9	79.9	32.5	39.9	3.78

4.2.6 Farmstead Layout Sub-Model

The required number of input data for Farmstead Layout sub-model is unpredictable, because it is directly proportional to the number of farm buildings which will be established on farm site.

Input Data Windows

The main input data window of farmstead layout sub-model (Figure 4.24) encompasses two buttons for inserting the buildings' dimensions and the distances among all adjacent buildings in the x-axis and y-axis, i.e. over two-dimensional layout. In addition, it includes input data boxes for the specifications of the farm fence.

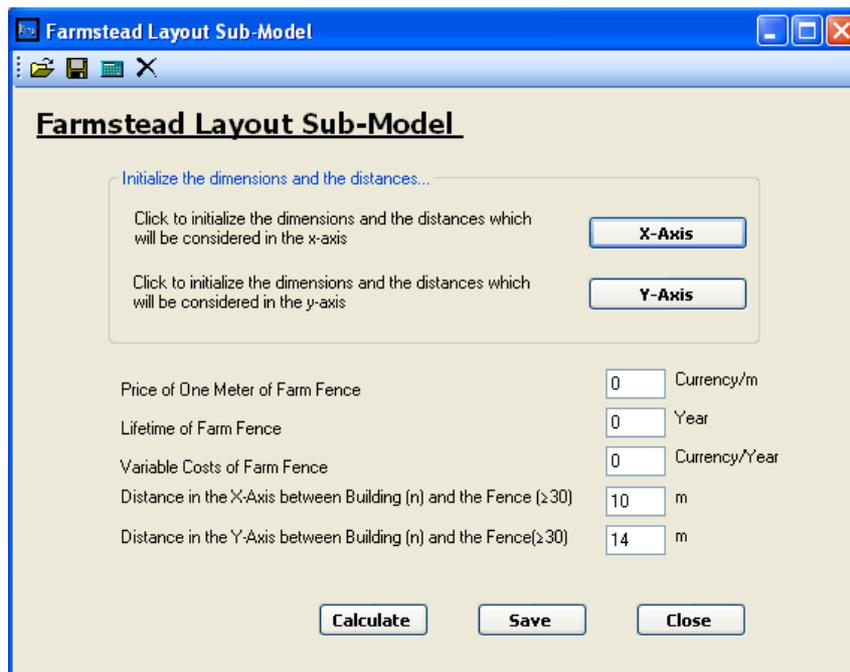


Figure 4.24: Main input data window of farmstead layout sub-model

When the user clicks the "X-Axis" button, the input data window of the dimensions and distances in the x-axis (Figure 4.25) will be displayed. This window will be used to insert the buildings' dimensions and the distances among all adjacent buildings in the x-axis. Furthermore, if the layout follows the angled buildings distribution (Figures 3.19, through 3.21) the angle, between the main axis of each building and the x-axis, can be inserted.

When the user clicks the "Y-Axis" button, the input data window of the dimensions and distances in the y-axis (Figure 4.26) will be displayed. This window will be used to insert the buildings' dimensions and the distances among all adjacent buildings in the y-axis.

Dimensions and the distances will be considered in the x-axis

Number of new added systems in X-Axis= 0

Dimension...	Distance...	Angle...
Dimension of Building (1) in the X-Axis: 9 m	Distance in the X-Axis between Building (1) and the Fence (≥30): 25 m	Angle between Building (1)-Axis and X-Axis: 0 degree
Dimension of Building (2) in the X-Axis: 90 m	Distance between Buildings (1) and (2) in the X-Axis (≥30): 14 m	Angle between Building (2)-Axis and X-Axis: 0 degree
Dimension of Building (3) in the X-Axis: 20 m	Distance between Buildings (2) and (3) in the X-Axis (≥30): 30 m	Angle between Building (3)-Axis and X-Axis: 0 degree
Dimension of Building (4) in the X-Axis: 0 m	Distance between Buildings (3) and (4) in the X-Axis (≥30): 0 m	Angle between Building (4)-Axis and X-Axis: 0 degree
Dimension of Building (5) in the X-Axis: 0 m	Distance between Buildings (4) and (5) in the X-Axis (≥30): 0 m	Angle between Building (5)-Axis and X-Axis: 0 degree
Dimension of Building (6) in the X-Axis: 0 m	Distance between Buildings (5) and (6) in the X-Axis (≥30): 0 m	Angle between Building (6)-Axis and X-Axis: 0 degree
Dimension of Building (7) in the X-Axis: 0 m	Distance between Buildings (6) and (7) in the X-Axis (≥30): 0 m	Angle between Building (7)-Axis and X-Axis: 0 degree
Dimension of Building (8) in the X-Axis: 0 m	Distance between Buildings (7) and (8) in the X-Axis (≥30): 0 m	Angle between Building (8)-Axis and X-Axis: 0 degree
Dimension of Building (9) in the X-Axis: 0 m	Distance between Buildings (8) and (9) in the X-Axis (≥30): 0 m	Angle between Building (9)-Axis and X-Axis: 0 degree
Dimension of Building (10) in the X-Axis: 0 m	Distance between Buildings (9) and (10) in the X-Axis (≥30): 0 m	Angle between Building (10)-Axis and X-Axis: 0 degree
Dimension of Building (11) in the X-Axis: 0 m	Distance between Buildings (10) and (11) in the X-Axis (≥30): 0 m	Angle between Building (11)-Axis and X-Axis: 0 degree
Dimension of Building (12) in the X-Axis: 0 m	Distance between Buildings (11) and (12) in the X-Axis (≥30): 0 m	Angle between Building (12)-Axis and X-Axis: 0 degree

Figure 4.25: Input data window of the dimensions and distances in the x-axis

Dimensions and the distances will be considered in the y-axis

Number of new added systems in X-Axis= 0

Dimension	Distance
Dimension of Building (1) in the Y-Axis: 55 m	Distance in the Y-Axis between Building (1) and the Fence (≥30): 12 m
Dimension of Building (2) in the Y-Axis: 7.2 m	Distance between Buildings (1) and (2) in the Y-Axis (≥30): 54.2 m
Dimension of Building (3) in the Y-Axis: 55 m	Distance between Buildings (2) and (3) in the Y-Axis (≥30): 54.1 m
Dimension of Building (4) in the Y-Axis: 0 m	Distance between Buildings (3) and (4) in the Y-Axis (≥30): 0 m
Dimension of Building (5) in the Y-Axis: 0 m	Distance between Buildings (4) and (5) in the Y-Axis (≥30): 0 m
Dimension of Building (6) in the Y-Axis: 0 m	Distance between Buildings (5) and (6) in the Y-Axis (≥30): 0 m
Dimension of Building (7) in the Y-Axis: 0 m	Distance between Buildings (6) and (7) in the Y-Axis (≥30): 0 m
Dimension of Building (8) in the Y-Axis: 0 m	Distance between Buildings (7) and (8) in the Y-Axis (≥30): 0 m
Dimension of Building (9) in the Y-Axis: 0 m	Distance between Buildings (8) and (9) in the Y-Axis (≥30): 0 m
Dimension of Building (10) in the Y-Axis: 0 m	Distance between Buildings (9) and (10) in the Y-Axis (≥30): 0 m
Dimension of Building (11) in the Y-Axis: 0 m	Distance between Buildings (10) and (11) in the Y-Axis (≥30): 0 m
Dimension of Building (12) in the Y-Axis: 0 m	Distance between Buildings (11) and (12) in the Y-Axis (≥30): 0 m

Number of new added systems in Y-Axis= 0

Figure 4.26: Input data window of the dimensions and distances in the y-axis

Output Data Window

The output data window of farmstead layout sub-model (Figure 4.27) displays the farm dimensions in the x-axis and y-axis, farm total area in square meter and in hectare, farm perimeter, and the fence costs. In case of no fence price and expected variable costs were inserted into the main input data window (Figure 4.24), the system displays the costs either as zeros or as not-defined values (Figure 4.27).

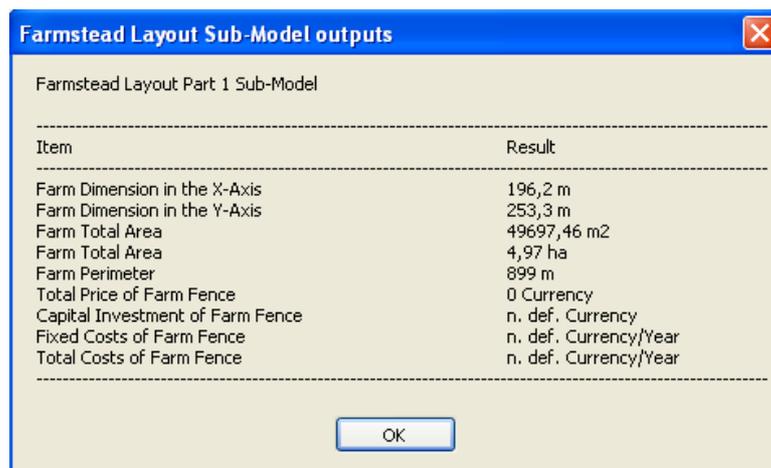


Figure 4.27: Output data window of farmstead layout sub-model

Validation and Evaluation

Data of 4 dairy farmstead layouts were used to carry out the validation and evaluation of the Farmstead Layout Sub-Model. The statistical analysis of the actual and calculated values (Table 4.6) clarified that COV were between 5.31% ($\sigma = 0.011$) and 7.63% ($\sigma = 0.008$). The calculated accuracy of this sub-model is 99.8%.

Table 4.6: Data of farmstead layout sub-model (SAMER et al., 2008a)

	Parameter	X _F	Y _F	A _{IFA}	P _F
Farm 1	Actual Value	200.40	178.00	3.56	757.00
	Calculated Value	200.20	177.60	3.55	755.60
Farm 2	Actual Value	198.23	252.00	4.99	900.46
	Calculated Value	196.20	253.30	4.97	899.00
Farm 3	Actual Value	119.64	91.20	10.91	421.68
	Calculated Value	119.50	91.00	10.87	421.00
Farm 4	Actual Value	113.82	117.35	1.34	462.34
	Calculated Value	113.70	117.10	1.33	461.60

New Farmstead Layouts

A farmstead layout was developed to be convenient for establishing dairy farms in hot climates. The farmstead layout is presented in three plans. The first plan shows the farmstead layout, the distance between the buildings, and one future expansion (Figure 4.28). The second plan shows different future expansions (Figure 4.29). The third plan shows routes of the dairy farm (Figure 4.30).

The prevailing summer wind is north or north-west (Figure 4.28), i.e. the prevailing summer wind is perpendicular or angled to the main axis of the cowshed, and the longer side of the cowshed is facing the prevailing summer wind. The horizontal and vertical distances between two cowsheds are at least 30 m (Figure 4.28), in order to minimize the negative and utilize the positive effects of climatic elements (sun, wind...). Furthermore, the minimum distance between the farm house/office and any other building is 45 m, and the wind should strike first the house/office and then the other buildings to avoid carrying odors and dusts from the corrals to the house/office by the wind. In addition, the distance between the house/office and the road is at least 45 m and preferably 90 m to avoid noises, and contaminants (Figure 4.28). The milking center is located between two cowsheds to minimize the walking distance under hot climate conditions. However the distance between the cowshed and the milking center is at last 15 m (Figure 4.28). The electric generators are located at the end of the farm and downward the wind to let the wind carry the smoke away from the farm. The way to field is also shown on the plan (Figure 4.28). The direction of north is also indicated. The water tanks are located in the middle of the farm in order to ease the water distribution to the cowsheds and the other facilities. The machinery shop is located in the middle near to the farm house and the operation center to facilitate the farm operations and to increase efficiency and safety. The manure tanks are located near to farm fence to ease the direct land application, and to be away from the middle of the farm where the water tanks and the forage storage are located in order to avoid contamination and odors (Figures 4.28 and 4.29).

Different future expansions are shown in the plan (Figure 4.29). However, the future expansions are planned using symmetry in order to maximize the utility of the different farm facilities.

The width of any route of the farm routes should be a minimum of 5 m (Figure 4.30). However, the designer should take into consideration the width of the farm machine, e.g. width of the feeding trailer. The route width should be double of the biggest machine width among the farm machines. In addition, there should be several meters of clearance on each side to accommodate machinery overhang, and drainage. The area, where the horizontal and tower silos are located, is totally covered by asphalt in order to facilitate the operation of forage handling.

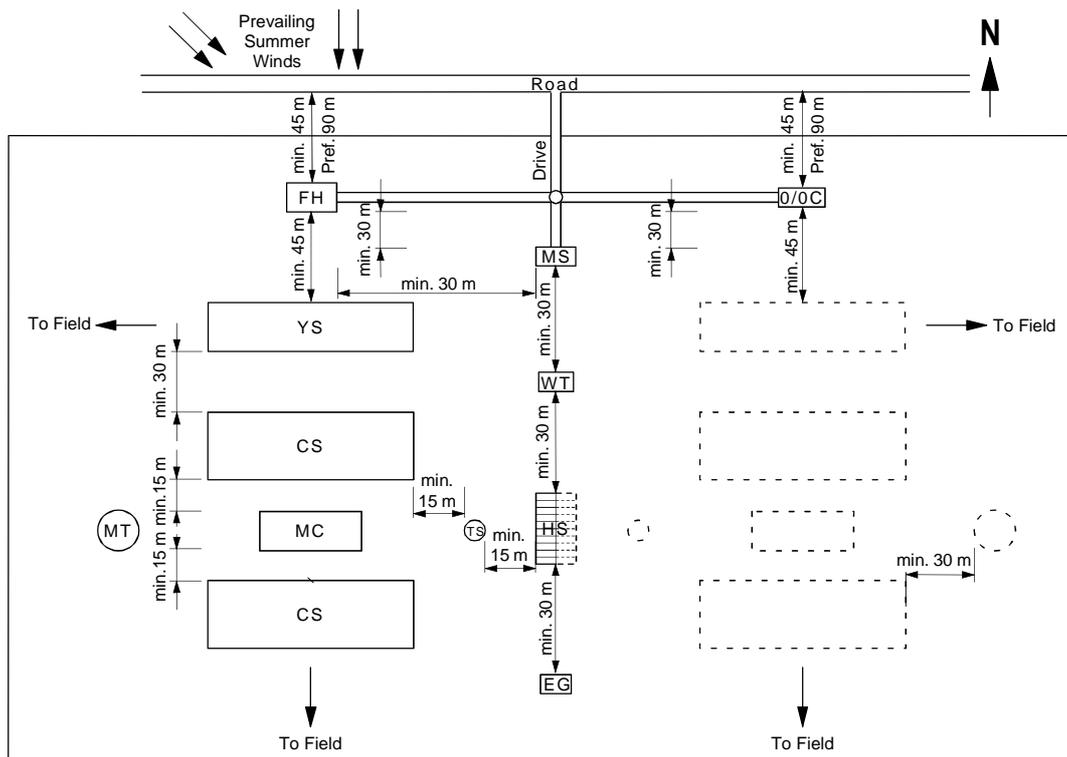


Figure 4.28: Farmstead layout (SAMER et al., 2008a)

The field should surround the dairy farm, if possible. Moreover, the vacant areas between the buildings should be planted with alfalfa. However, this is the best solution for reducing the enthalpy of the air. On the other hand, the fence of the farm should not be a row of trees like the farms located in cold climates, because the trees will be an obstacle facing the summer winds. Thus, the fence should be built by wires and staples. Note that the designer should plan the dairy farm to house at most 700 cows in order to be economically feasible. However, if it is required to plan a large dairy farm, the designer should split it into several smaller farms (500-700 cows) which should be scattered in a large area where the vacant areas between the farms should be planted by alfalfa or other forages.

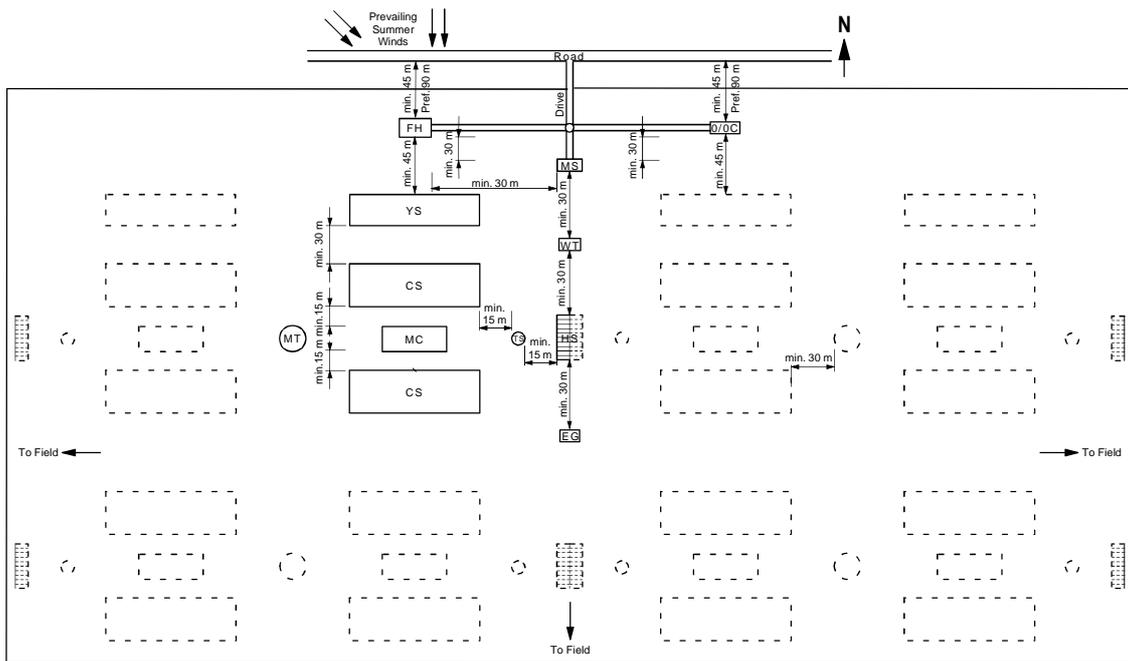


Figure 4.29: Future expansions (SAMER et al., 2008a)

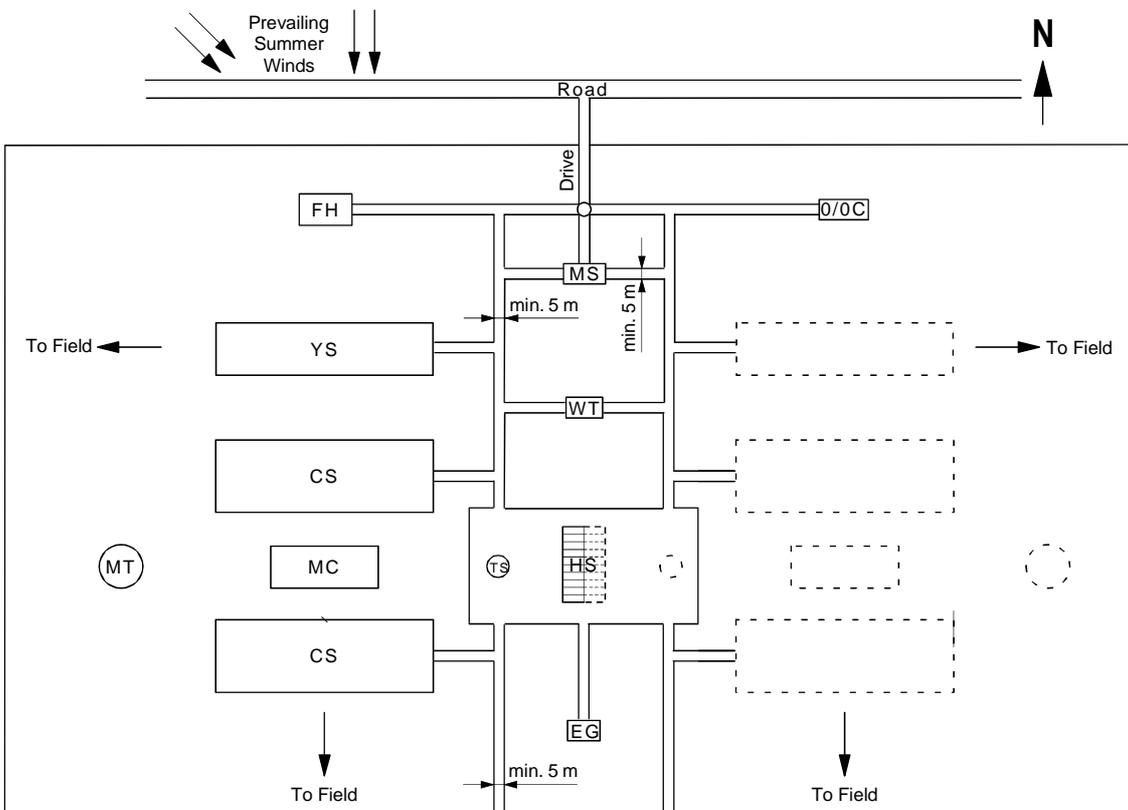


Figure 4.30: Farm routes (SAMER et al., 2008a)

Previous to establishing a new dairy farm, the designer should collect some information about the site where the farm will be founded. It is better if there are several available locations, so that the designer will be able to make a comparison study for the sites, and then select one among them. The required information to be collected about the site, are: longitude and latitude, speed and direction of prevailing summer wind, soil, topography, slopes, and availability of water and electricity. Moreover, contour lines are required.

A climatic analysis should be made for each country located in hot climates to specify the best regions to establish the dairy farms. A good region offers a minimum of 60-70% of the comfort zone (CZ) of the cow breed, and the rest of the comfort zone can be compensated by the different means of physical alleviation (shade structures and cooling systems) to reach a minimum of 80-90% and the rest will be compensated by the ability of the cows to be adapted. However, the fields should surround the dairy farms in hot climates in order to let the air come over plants cover where the air will be cooled and the enthalpy of the air will be minimized, but if deserts i.e. sandy soils are surrounding the dairy farm, the heat will be transferred by convection from the surrounding soils to the air. However, the fields should be planted by cow forages (maize, alfalfa ...) in order to deliver forages to the farm. In some cases, there is just one available site. If the site has different soil materials, e.g. some parts are sandy soils and the other are compacted (rock crust), the designer should use the sandy soils as a field, and the rock crust for buildings.

4.2.7 Cooling System Sub-Model

Input Data Window

The cooling system sub-model requires 23 input data (Figure 4.31). Some of these input data are transmitted from Design Model and automatically shown in the input boxes, such as: cooling line length which is equal to house length, and number of cooling lines for one cowshed which is dependent on corrals distribution. Furthermore, values of some input data will be recommended by the system e.g. the values of microsprinkler discharge and pressure. The other input data are the prices of the cooling system components which should be acquired from market prices.

Cooling System Sub-Model: (Farm 1.dfd)

Opened file: Farm 1.dfd

Cooling Line Length	114	m	Price of 1 m of Cooling System Sub-Main Line	6	Currency/m
Microsprinkler Discharge (0.42 l/min is preferred)	0,4	l/min	Span or Distance between 2 Microsprinklers	6	m
Microsprinkler Pressure (176 kPa is preferred)	175	kPa	Employment Costs of Cooling System	2000	Currency
Number of Cooling Lines for One Cowshed	2		Price One Microsprinkler	2,5	Currency/Microsprinkler
Cooling System Lifetime	5	Year	Price of Anemometer	550	Currency
Span or Distance between 2 Cooling Fans	6	m	Price of Pressure Gauge	80	Currency
Price of Cooling Fan	600	Currency	Total Price of Valves and Fittings	250	Currency
Price of Cooling System Pump	4500	Currency	Number of Required Taps for Cooling System	2	
Price of 1 m of Cooling System Pipe Line	1,5	Currency/m	Price of One Cooling System Tap	125	Currency/Tap
Length of Cooling System Main Line	6	m	Price of Cooling System Filter	1200	Currency
Price of 1 m of Cooling System Main Line	4,5	Currency/m	Variable Costs of Cooling System	250	Currency/Year
Length of Cooling System Sub-Main Line	12	m			

Buttons: Calculate, Save Inputs, Save Outputs, Close

Figure 4.31: Input data window of cooling system sub-model

Output Data Window

Subsequent to filling the input data boxes and clicking the button of “Calculate”, the system calculates and displays 15 output data (Figure 4.32) which are the design parameters and the costs.

Cooling System Sub-Model - Outputs

Item	Result
Total Number of Cooling Fans	38
Total Price of Cooling Fans	22800 Currency
Discharge of Cooling System Pump	0,96 m ³ /h
Pressure of Cooling System Pump	223,65 kPa
Total Length of Cooling System Pipe Lines	228 m
Diameter of Cooling System Pipe Line	18,4 mm
Total Price of Cooling System Pipe Lines	342 Currency
Total Price of Cooling System Main Line	27 Currency
Total Price of Cooling System Sub-Main Line	72 Currency
Number of Microsprinklers	38
Total Price of Microsprinklers	95 Currency
Total Price of Cooling System Taps	250 Currency
Capital Investment of Cooling System	32166 Currency
Fixed Costs of Cooling System	6433,2 Currency/Year
Total Costs of Cooling System	6683,2 Currency/Year

OK

Figure 4.32: Output data window of cooling system sub-model

Validation and Evaluation

Data of 3 cooling systems were used to complete the validation and evaluation of the Cooling System Sub-Model. The statistical analysis of the actual and calculated values (Table 4.7) demonstrated that COV were between 2.25% ($\sigma = 0.23$) and 4.13% ($\sigma = 0.13$). The calculated accuracy of this sub-model is 97.8%.

Table 4.7: Data of cooling system sub-model (SAMER et al., 2008d)

	Parameter	N_{tCF}	Q_{CP}	P_{rCP}	L_{tCP}	d_{CP}	N_M
System 1	Actual Value	37	1	230	224	18	37
	Calculated Value	37	0.9	223	224	18	37
System 2	Actual Value	36	1	230	180	18	36
	Calculated Value	36	0.9	222	180	18	36
System 3	Actual Value	10	0.27	200	57.6	11	10
	Calculated Value	10	0.24	194	57.6	11	10

4.2.8 Water Sub-Model

Input Data Windows

The Water Sub-Model requires 14 input data (Figure 4.33) of the main categories, which are: milking system, cooling system, manure handling system, and cow requirements as drinking water. Moreover, the user can initialize other systems (Figure 4.34) if the farm has other systems which consume water. Generally, the required input data of any system are: rate of water consumption, operating duration, and number of the similar systems on farm.

On the other hand, the user should initialize a source of water supply (Figure 4.35) either governmental supply or drilling a well; which requires 5 to 9 input data according to the selected supply source.

Output Data Window

The output data window (Figure 4.36) displays the yearly water consumption of each system, and then the farm total water consumption per year. Furthermore, it displays the capital investment and the fixed, variable and total costs.

Water Consumption and Sources Sub-Model

Milking System

Milking System Water Consumption per Hour: 65 l/h
 Daily Operating Duration of Milking System: 15 h/Day
 Number of Milking Systems in the Farm: 1

Cooling System

Number of Microsprinklers: 37
 Water Consumption of One Microsprinkler: 0.4 l/min
 Hourly Operating Duration of Microsprinkler: 20 min/h
 Daily Operating Duration of Cooling System: 10 h/Day
 Yearly Operating Duration of Cooling System: 6 Months/Year
 Number of Cooling Systems in Farm: 2

Manure Handling System

Manure Handling System Water Consumption per Day: 6 m3/Day
 Number of Manure Handling Systems in Farm: 2

Cow Requirements

Milk Production of One Cow: 35 Kg/Day
 Dry Matter Content of Forages: 30 %
 Number of Cows in Farm: 480

Buttons: Initialize other Systems, Initialize Supply, Calculate, Save, Close

Figure 4.33: Input data window of water sub-model (SAMER et al., 2008d)

Water Consumption and Sources Sub-Model (other Systems)

System (1)

Water Consumption per Hour of System 1: 0 l/h
 Daily Operating Duration of System 1: 0 h/Day
 Number of Systems 1 in Farm: 0

System (2)

Water Consumption per Hour of System 2: 0 l/h
 Daily Operating Duration of System 2: 0 h/Day
 Number of Systems 2 in Farm: 0

System (3)

Water Consumption per Hour of System 3: 0 l/h
 Daily Operating Duration of System 3: 0 h/Day
 Number of Systems 3 in Farm: 0

System (4)

Water Consumption per Hour of System 4: 0 l/h
 Daily Operating Duration of System 4: 0 h/Day
 Number of Systems 4 in Farm: 0

System (5)

Water Consumption per Hour of System 5: 0 l/h
 Daily Operating Duration of System 5: 0 h/Day
 Number of Systems 5 in Farm: 0

System (6)

Water Consumption per Hour of System 6: 0 l/h
 Daily Operating Duration of System 6: 0 h/Day
 Number of Systems 6 in Farm: 0

System (7)

Water Consumption per Hour of System 7: 0 l/h
 Daily Operating Duration of System 7: 0 h/Day
 Number of Systems 7 in Farm: 0

Add New System
 Click over this button every time you want to add a new system ...
 Add New System

Buttons: Ok, Cancel

Figure 4.34: Input data window for initializing other systems (SAMER et al., 2008d)

Figure 4.35: Input data window for initializing water supply (SAMER et al., 2008d)

Water Consumption and Sources Sub-Model		
=====		
Water supply type:	Governmental Supply	
Item	Result	Unit
Milking System Water Consumption per Year	355,88	m3/Year
Cooling System Water Consumption per Year	1065,6	m3/Year
Manure Handling System Water Consumption per Year	4380	m3/Year
Water Requirements for One Cow	95,06	kg/Day ≈ l/Day
Yearly Water Requirements of the Cows	16654,51	m3/Year
Water Consumption per Year of System 1	0	m3/Year
Water Consumption per Year of System 2	0	m3/Year
Water Consumption per Year of System 3	0	m3/Year
Water Consumption per Year of System 4	0	m3/Year
Water Consumption per Year of System 5	0	m3/Year
Water Consumption per Year of System 6	0	m3/Year
Water Consumption per Year of System 7	0	m3/Year
Farm Total Water Consumption per Year	22455,99	m3/Year
Variable Costs of Farm Water Consumption from Governmental Supply	47157,57	Currency/Year
Backwater Volume	184,57	m3
Number of Backwater Containers	36,91	
Total Price of Backwater Containers	7382,79	Currency
Capital Investment of Farm Water Consumption from Governmental Supply	7732,79	Currency
Fixed Costs of Farm Water Consumption from Governmental Supply	773,28	Currency/Year
Total Costs of Farm Water Consumption from Governmental Supply	47930,85	Currency/Year

Figure 4.36: Output data window of water sub-model (SAMER et al., 2008d)

Validation and Evaluation

Data of 5 dairy farms were used to make the validation and evaluation of Water Sub-Model. The statistical analyses of the actual and calculated values showed that COV was 5.9% ($\sigma = 0.14$) for water consumption of the different dairy farms (Figure 4.37). On the other hand, the calculated accuracy of this sub-model is 97%.

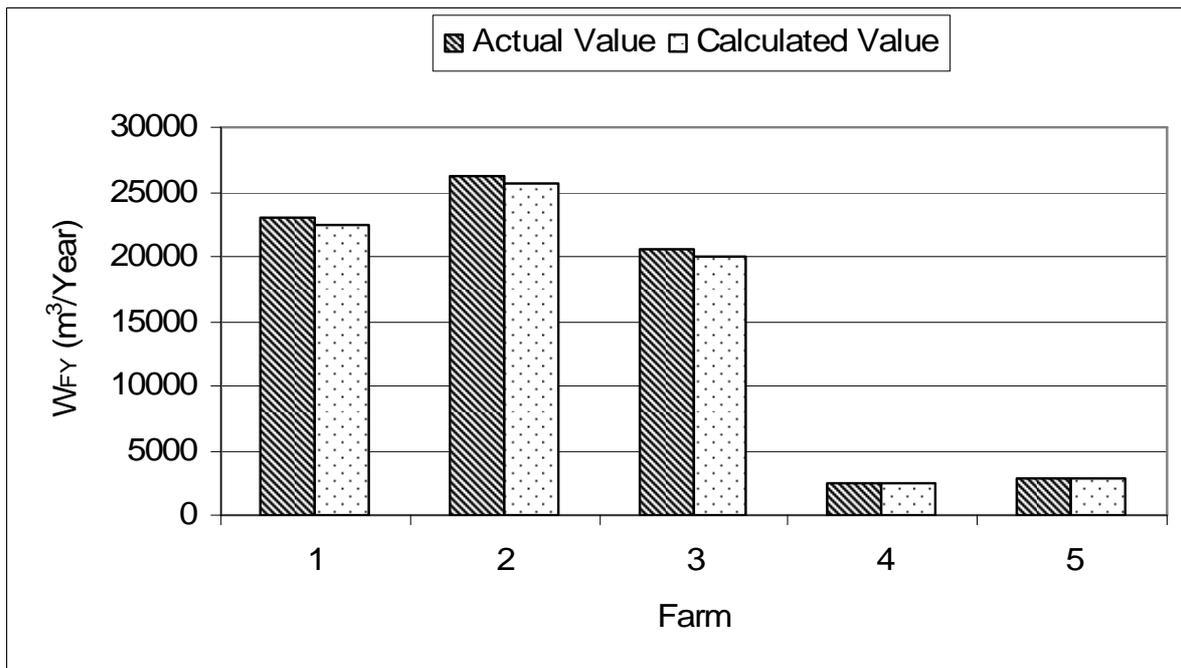


Figure 4.37: Water consumption of the different dairy farms (SAMER et al., 2008d)

4.2.9 Electricity Sub-Model

Input Data Windows

The Electricity Sub-Model requires 18 input data (Figure 4.38) of the four essential systems, which are: milking, cooling, manure handling, and night lighting systems. However, the designer/user can initialize other systems (Figure 4.39) in case that the farm encompasses other systems which consume electricity. In general, the required data are mainly the operating duration, rate of electricity consumption, and number of the same systems on farm.

Electricity Consumption and Sources Sub-Model

Milking System

Milking System Electricity Consumption per Hour	4,5	kWh
Number of Milking per Day	3	
Milking Duration	5	h
Number of Milking Systems in the Farm	1	

Manure Handling System

Manure Handling System Electricity Consumption per Hour	0	kW
Daily Operating Duration of Manure Handling system	0	h/Day
Number of Manure Handling Systems in Farm	0	

Cooling System

Total Number of Cooling Fans	37	
Electricity Consumption of One Cooling Fan	0,4	kW
Electricity Consumption of Cooling System Pump	0,5	kW
Daily Operating Duration of Cooling System	10	h/Day
Yearly Operating Duration of Cooling System	6	Months/Year
Number of Cooling Systems in Farm	2	

Night Lighting

Number of Lamps under One Cowshed/House	80	
Number of Houses in Farm	2	
Number of Lamps in Other Locations (Alley, Office,...)	40	
Electricity Consumption of One Lamp	60	W
Night Lighting Duration	10	h/Day

Buttons: Initialize other Systems, Initialize Supply, Calculate, Save Inputs, Close

Wizard: << Previous, Next >>

Figure 4.38: Input data window of electricity sub-model

On the other hand, the designer should initialize an electricity supply (Figure 4.40) either governmental supply or electric generators. This step requires 4 or 5 input data according to the initialized supply.

Output Data Window

The output data (Figure 4.41) are mainly the annual consumption of each system, farm total consumption per year, and the costs.

Validation and Evaluation

Data of 5 dairy farms were used to make the validation and evaluation of Electricity Sub-Model. The statistical analyses of the actual and calculated values showed that COV was 4.2% ($\sigma = 0.10$) for electricity consumption of the different dairy farms (Figure 4.42). The calculated accuracy of this sub-model is 98.7%.

Electricity Consumption and Sources Sub-Model (other Systems)

System (1)

Electricity Consumption per Hour of System 1 kWh

Daily Operating Duration of System 1 h/Day

Number of Systems 1 in Farm

System (2)

Electricity Consumption per Hour of System 2 kWh

Daily Operating Duration of System 2 h/Day

Number of Systems 2 in Farm

System (3)

Electricity Consumption per Hour of System 3 kWh

Daily Operating Duration of System 3 h/Day

Number of Systems 3 in Farm

System (4)

Electricity Consumption per Hour of System 4 kWh

Daily Operating Duration of System 4 h/Day

Number of Systems 4 in Farm

System (5)

Electricity Consumption per Hour of System 5 kWh

Daily Operating Duration of System 5 h/Day

Number of Systems 5 in Farm

System (6)

Electricity Consumption per Hour of System 6 kWh

Daily Operating Duration of System 6 h/Day

Number of Systems 6 in Farm

System (7)

Electricity Consumption per Hour of System 7 kWh

Daily Operating Duration of System 7 h/Day

Number of Systems 7 in Farm

Add New System

Click over this button every time you want to add a new system ...

Add New System

Ok **Cancel**

Figure 4.39: Input data window for initializing other systems

Electricity Supply

Electricity Supply

Governmental Generators

Price of 1 kWh of Electricity Governmental Supply Currency/kWh

Fixed Costs of Farm Electricity Consumption from Governmental Supply Currency/Year

Lifetime of Governmental Supply Circuit Year

Fixed Costs of One Electric Generator Currency/Year

Variable Costs of One Electric Generator Currency/Year

Number of Electric Generators

Lifetime of Electric Generator Year

Ok **Cancel**

Figure 4.40: Input data window for initializing electricity supply

Farmstead Layout Sub-Model outputs

Electricity Consumption and Sources Sub-Model

Item	Result
Milking System Electricity Consumption per Year	24637,5 kWh
Cooling System Electricity Consumption per Year	55080 kWh
Manure Handling System Electricity Consumption per Year	0 kWh
Lighting System Electricity Consumption per Year	43800 kWh
Electricity Consumption per Year of System 1	0 kWh
Electricity Consumption per Year of System 2	0 kWh
Electricity Consumption per Year of System 3	0 kWh
Electricity Consumption per Year of System 4	0 kWh
Electricity Consumption per Year of System 5	0 kWh
Electricity Consumption per Year of System 6	0 kWh
Electricity Consumption per Year of System 7	0 kWh
Farm Total Electricity Consumption per Year	123517,5 kWh
Variable Costs of Farm Electricity Consumption from Governmental Supply	30879,38 Currency/Year
Capital Investment of Farm Electricity Consumption from Governmental Supply	5000 Currency
Total Costs of Farm Electricity Consumption from Governmental Supply	31379,38 Currency/Year
Power of Electric Generator	0 kW
Capital Investment of Farm Electricity Consumption Using Generators	0 Currency
Total of fixed costs of the generators	0 Currency/Year
Total of variable costs of the generators	0 Currency/Year
Total Costs of the generators	0 Currency/Year

OK

Figure 4.41: Output data window of electricity sub-model

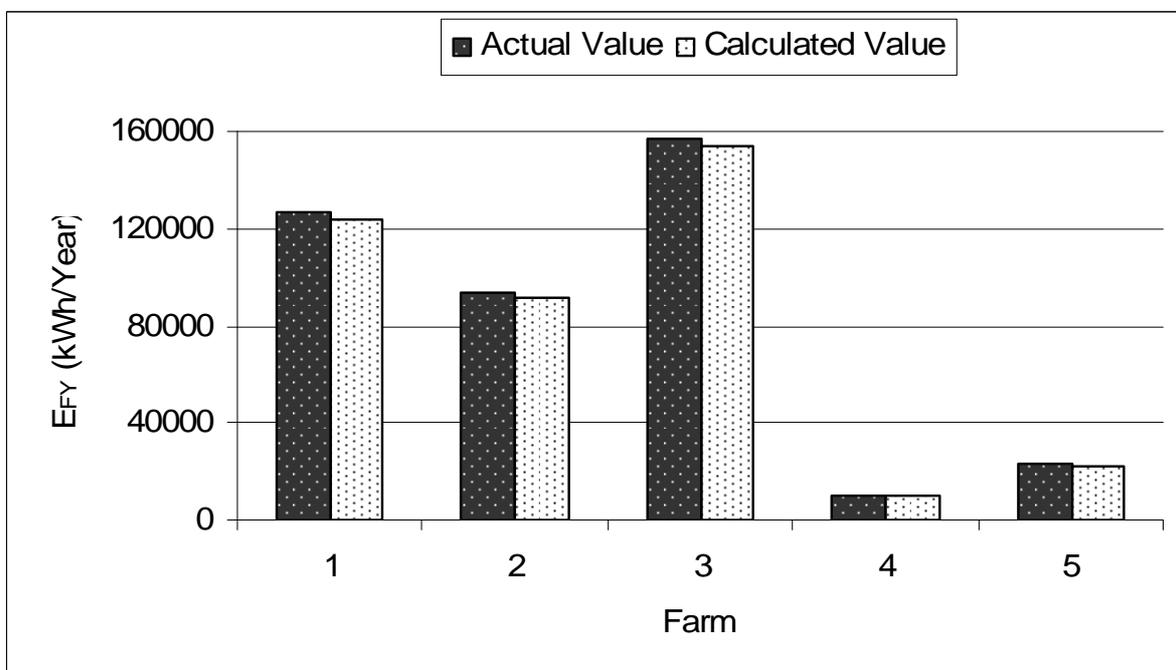


Figure 4.42: Electricity consumption of the different dairy farms (SAMER et al., 2008d)

4.3 Costs Calculation Model

The Costs Calculation Model requires 55 input data; thereof a multitude will be automatically transferred from the different sub-models, where each sub-model has made the costs calculation of the facility that it is responsible for. On the other hand, the model computes and displays 44 output data concerning the annual costs and the capital investment of the different facilities and the whole dairy farm. Therefore, the model has been divided into two parts: Annual Costs, and Capital Investment.

Input Data Windows

The input data window for annual costs calculation (Figure 4.43) requires 38 input data concerning five main categories, which are: technology costs, cow costs, land costs, costs of operating supply items (water and electricity), and construction costs (manure storage, forage storage, milking center, and cow buildings).

Category	Input Field	Unit	
Cow Costs	Price of One Heifer	2000 Currency/Cow	
	Number of Years (Seasons) per Cow (3 - 6)	5 Year	
	Number of Cows in Farm	480 Cow(s)	
	Variable Costs of One Cow	15000 Currency/Year	
	Project Lifetime (≈ 20 years)	20 Year	
	Farm Total Area	3,6 ha	
	Price of One Hectare	5000 Currency/ha	
	Variable Costs of Land	100 Currency/Year	
	Electricity Supply	<input checked="" type="radio"/> Governmental	
		<input type="radio"/> Generators	
Electricity Costs	Fixed Costs of Farm Electricity Consumption from Governmental Supply	500 Currency/Year	
	Variable Costs of Farm Electricity Consumption from Governmental Supply	343,22 Currency/Year	
Water Supply	<input checked="" type="radio"/> Governmental		
	<input type="radio"/> Well		
Water Costs	Fixed Costs of Farm Water Consumption from Governmental Supply	47157 Currency/Year	
	Variable Costs of Farm Water Consumption from Governmental Supply	773,27 Currency/Year	
Feeding System	Fixed Costs of Feeding System	12000 Currency/Year	
	Variable Costs of Feeding System	9125 Currency/Year	
Cooling System	Fixed Costs of Cooling System	6351,6 Currency/Year	
	Variable Costs of Cooling System	250 Currency/Year	
Construction Costs	Fixed Costs of Milking System	100000 Currency/Year	
	Variable Costs of Milking System	0 Currency/Year	
	Fixed Costs of Manure Handling System	0 Currency/Year	
	Variable Costs of Manure Handling System	0 Currency/Year	
	Fixed Costs of Manure Handling/Constructions	474,76 Currency/Year	
	Variable Costs of Manure Handling/Constructions	0 Currency/Year	
	Fixed Costs of Forage Storage Constructions	9353,6 Currency/Year	
	Variable Costs of Forage Storage Constructions	0 Currency/Year	
	Fixed Costs of the Cowshed	5072,1 Currency/Year	
	Variable Costs of the Cowshed	1000 Currency/Year	
Milking Center	Fixed Costs of Constructions of Milking Center	2728,5 Currency/Year	
	Variable Costs of Constructions of Milking Center	0 Currency/Year	
Concrete Base	Fixed Costs of Concrete Base	3678,6 Currency/Year	
	Variable Costs of Concrete Base	0 Currency/Year	
Cow Buildings	Number of Cow Buildings in Farm	2	
Other Costs	Other Fixed Costs	0 Currency/Year	
	Other Variable Costs	0 Currency/Year	
	Interest Payments	0 Currency/Year	
	Salaries of Workers	25000 Currency/Year	
Taxes	Taxes	10000 Currency/Year	

Figure 4.43: Input data window for annual costs calculation

On the other hand, the input data window for capital investments calculation (Figure 4.44) requires 17 input data concerning of the different dairy farm facilities.

Conversely, the model can be used to estimate the current farm price in order to sell it or to enroll it into the bourse. This process can be made by making market price survey of the different required prices, and then inserting them into the expert system with the design parameters of the already built facilities. Subsequently, the expert system will compute the current capital investment of the already existing farm.



Figure 4.44: Input data window for capital investments calculation

Output Data Windows

The output data window of annual costs calculation (Figure 4.45) displays 38 output data concerning the annual costs of the different farm facilities, and then the annual costs of the whole dairy farm. Furthermore, the model computes and displays the total costs per one cow. On other hand, the output data window of capital investments calculation (Figure 4.46) displays 6 output data concerning the capital investment of cow buildings and whole dairy farm. In addition, the system computes and displays the capital investment per one cow.

Costs Calculation Model: Annual Costs	
Item	Result
Total Price of Cows	960000 Currency
Fixed Costs of Cows	192000 Currency/Year
Variable Costs of Cows	7200000 Currency/Year
Total Costs of Cows	7392000 Currency/Year
Land Price	18000 Currency
Fixed Costs of Land	900 Currency/Year
Total Costs of Land	1000 Currency/Year
Total Costs of Farm Electricity Consumption from Governmental Supply	0 Currency/Year
Total Costs of the generators	0 Currency/Year
Total Costs of Farm Water Consumption from Governmental Supply	0 Currency/Year
Total Costs of Well	0 Currency/Year
Fixed Costs of Operating Supply Items	0 Currency/Year
Variable Costs of Operating Supply Items	0 Currency/Year
Total Costs of Operating Supply Items	0 Currency/Year
Fixed Costs of Technology	118351,66 Currency/Year
Variable Costs of Technology	250 Currency/Year
Total Costs of Technology	118601,66 Currency/Year
Total Costs of Manure Handling/Constructions	474,76 Currency/Year
Total Costs of Forage Storage Constructions	9353,62 Currency/Year
Fixed Costs of Milking Center Constructions	2728,56 Currency/Year
Variable Costs of Milking Center Constructions	0 Currency/Year
Total Costs of Milking Center Constructions	2728,56 Currency/Year
Total Costs of Concrete Base	3678,62 Currency/Year
Total Costs of the Shed	6072,11 Currency/Year
Fixed Costs of the Building	8750,73 Currency/Year
Variable Costs of the Building	1000 Currency/Year
Total Costs of the Building	9750,73 Currency/Year
Fixed Costs of All Cow Buildings	8752,73 Currency/Year
Variable Costs of All Cow Buildings	1002 Currency/Year
Total Costs of All Cow Buildings	9754,73 Currency/Year
Fixed Costs of Farm Constructions	21309,67 Currency/Year
Variable Costs of Farm Constructions	21309,67 Currency/Year
Total Costs of Farm Constructions	22311,67 Currency/Year
Fixed Costs of the Farm	332561,33 Currency/Year
Variable Costs of the Farm	7236352 Currency/Year
Other Total Costs	0 Currency/Year
Total Costs of the Farm	7568913,33 Currency/Year
Total Costs per Cow	15768,5694375Currency/Year.Cow

Figure 4.45: Output data window of annual costs calculation

Costs Calculation Model: Capital Investment	
Item	Result
Capital Investment of Building	73572 Currency
Capital Investment of All Cow Buildings	147144 Currency
Capital Investment of Milking Center Constructions	156013 Currency
Capital Investment of Operating Supply Items	12732,79 Currency
Capital Investment of the Farm	1699215,07 Currency
Capital Investment per Cow	3540,03139583333Currency/Cow

Figure 4.46: Output data window of capital investments calculation

The Design Model is the mentor of the different sub-models which receive a multitude of data from the Design Model. Conversely, the Costs Calculation Model receives a multitude of data from all of the sub-models and from the Design Model. Hence, the Costs Calculation Model is the computing unit where all the costs calculated by the sub-models will be congregated and processed in order to compute the farm costs and capital investment, annual costs per cow, and capital investment per cow.

5 DISCUSSION

According to the calculated values of the system's accuracy (98.6%) and the coefficients of variation which range between 3% and 7%, it can be concluded that the developed expert system can be used successfully for planning and designing dairy cow farms in hot climates.

5.1 Hybrid System

Simulation models, which quantitatively mimic the behavior of a particular system, are not capable of directly explaining and justifying their output and hence are not well suited as stand-alone decision support systems for the user.

Conversely, expert systems are knowledge-based systems that use the factual knowledge, procedural rules, assumptions, and heuristics to perform a specific task. Nevertheless, they tend to lack quantitative precision since they are not designed to efficiently carry out numeric simulations.

The combination of simulation models and expert systems are known as hybrid systems. The advantages of hybrid systems: simulations can provide the quantitative information for expert systems; expert systems provide missing parameters for simulation models; expert systems can provide the best selection of inputs to a simulation model; expert systems can select the appropriate simulation model to be used; and expert systems can interpret the simulation's output (GREER et al., 1994).

This concept has been exploited to develop an expert system for planning and designing dairy farms, where a simulation model had been developed for each dairy farm facility and then the resulting simulation models had been integrated into an expert system. Furthermore, an electronic spark map (decision tree) had been developed for each simulation model and the resulting spark maps are considered as heuristics of the expert system.

5.2 Structured Induction

Knowledge acquisition has been identified as the 'bottleneck' in the expert system development process. Structured induction offers a method for acquiring and formalizing knowledge. Induction is the opposite of deduction, a more familiar process whereby general knowledge is applied to a specific problem to predict an outcome. Induction takes specific examples, and develops general knowledge which is consistent with those examples. From such a set of examples, rules representing underlying knowledge can be derived, and structured into a decision tree, later known as spark map. The decision tree can then be developed into a functional knowledge base for an expert system. Structured induction takes a sample set of scenarios and applies a mathematical algorithm to them. The output is a spark map, optimized according to a predetermined criterion, with descriptive characteristics at each branch node and a decision at each terminal node. A spark map expresses the knowledge contained in the example set in an ordered and efficient structure. Since many decision trees are possible for a given set of examples, optimization must be employed to get the most efficient tree possible; this was achieved using actual values acquired from several dairy farms and comparing them with the values calculated by the expert system. Knowledge acquisition and formalization using structured induction in which an induction algorithm was used to derive rules. This perception is contingent to that stated by BRONER et al. (1990). Sensitive parameters, dependent variables, and constant values of a developed algorithm were structured to be used as input/output data of the relevant spark map and later to configure its interface.

Induction structures the declarative data to minimize some measure of uncertainty in the decision tree structure. Induction is a very powerful tool for expert system development. It should however be regarded as one of many strategies for knowledge acquisition. Personal dialogue between domain experts and the knowledge engineer is a critical part of the process, whether or not induction is used. When applied with a little common sense on the part of the knowledge engineer, induction can provide structured knowledge representing true expertise. Therefore, contacts were made with the experts of the Cattle Information System of Egypt (CISE) in order to emulate their expertise thought and using it in developing the structured induction of the expert system.

5.3 Coupling Method

The positivistic approach to knowledge engineering attempts to duplicate thought processes of domain experts in order to arrive at conclusions while the normative approach attempts to duplicate the conclusions of domain experts without consideration of their thought processes. These contrasting approaches require developing a coupling method as a transition phase between the two approaches. The developed electronic spark maps are considered as a transition phase between the simulation models (normative approach) and the expert system (positivistic approach). This is also in agreement with BATCHELOR et al. (1992) that employing the normative approach often require restructuring the problem solving process by substituting for the expert's established ideal in a way that result in relatively the same prescriptive conclusions as the expert. Simulation systems provide a means of substituting mathematical models which incorporate established research principles and the knowledge of many experts for the established ideal of the expert. Furthermore, the positivistic approach is usually employed when a problem solving process is systematic and objective; and when the solution process can be represented as a decision tree.

The electronic spark map represents the coupling of symbolic (qualitative) and numerical (quantitative) reasoning, where coupling concept is contingent to that developed by ENGEL et al. (1990) using blackboards, but instead using blackboards the developed expert system for planning and designing dairy farms in hot climates uses electronic spark maps. Hence, this expert system is a deep coupled system, since it explicitly represents the process's function, inputs and outputs, and usage constraints and limitations. Knowledge of each process is integrated with other information and is used directly by the knowledge-based system component during problem solving.

The more experienced an expert is, the more likely he is to describe his knowledge on a 'pattern recognition' or 'heuristic' level, rather than as a precise set of considerations. One way to overcome such difficulties is to reduce the scope of the system by limiting the scope to well defined areas, i.e. dividing the system/farm into precise elements/facilities which can be fully described by the knowledge representation scheme or the spark map which allows the system to interface with

numerical and/or purely algorithmic subroutines. Another simultaneous method should be deployed, which in most cases is perfectly legitimate, involves continual operator input in the form of decisions as to how the program should proceed, i.e. selecting a course of actions.

5.4 Programming Concepts

The expert system had been configured using two programming concepts. The first is the spark mapping of individual sub-models and integrating each simulation model into the relevant spark map, i.e. using the structured systems analysis and design method which addresses technological aspects of system development by breaking down system development into smaller parts (sub-models), each part consists of a sequence of stages, each stage consists of a number of steps, and each step consists of a number of tasks. The second programming concept is the use of C# programming language which is the object-oriented technique to buffer the expert system from the details to individual processes.

5.5 Computer Software

Expert Systems are special computer software applications that are capable of carrying out reasoning and analysis functions in narrowly defined subject areas at proficiency levels approaching that of a human expert. The advantage of expert systems is that once developed they can raise the performance of the average worker/designer to the level of an expert.

The use of expert systems is appropriate and necessary to solve pieces of a larger problem. Often, pieces of the problem might be solved best using an algorithmic approach. Typically, this concept had been adopted while developing DFD.

The developed expert system for planning and designing dairy farms in hot climates is a computer program with a set of inequation (constraints), If-Then rules and equations (algorithm) that analyses data supplied by the user/designer, and recommends one or more courses of user action. The expert system provides

mathematical analysis of the planning and designing procedures, which agrees with GIARRATANO and RILEY (2005).

5.6 Dairy Farms Designer Characteristics

Expert Systems currently offer the most promise for immediate applications solving computer programs that achieve a high level of performance in some specialized problem domain considered to be difficult and requiring specialized knowledge and skill. According to the validation and evaluation process, DFD showed high level of performance in planning and designing dairy farms in hot climates. However, DFD has the following characteristics:

- heuristic: it employ judgmental as well as formal reasoning in solving problems;
- transparent: it has the ability to explain and justify its line of reasoning;
- flexible: domain-specific knowledge is generally separate from domain-independent inference procedures, thus knowledge updating is made considerably easier than in conventional programming.

On the other hand, DFD can be used for planning and designing dairy farms which houses not only Holstein-Friesian but also Brown Swiss, Guernsey, Ayrshire, Jersey, and Milking Shorthorn. This process can be carried out by adjusting the housing dimensions according to body dimensions of the breed under consideration. Furthermore, this expert system can be used for planning and designing dairy farms for housing buffaloes, which are also housed in corrals system in hot climates, taking into consideration the engineering parameters of buffalo housing.

However, if the farm manger decides to adjust the project activity because of the instability of market prices, as the crisis of Egyptian dairy farms which took place at the end of 1990s and in the beginning of the third millennium; the designed dairy farms by DFD can be then used for housing beef cattle, and a number of the milking systems can be sold and then exported. Simultaneously, the farm can encompass

both activities as a transition phase to resume to the main activity. Subsequent to the crisis-end, the main project activity can be resumed to dairy milk production.

5.7 Ubiquity and Verification

The ubiquity of software systems, in all aspects of public and private institutions, means that the environments that have been created need to be critically examined as they have been developed and deployed. Therefore, thorough system validation and verification had been performed in order to reveal and uproot system errors and to verify system accuracy. This procedure is contingent to that stated by THOMSON and SCHMOLDT (2001).

5.8 End User

A potential drawback exists when providing access to sophisticated software. Such technology may increase considerably the power of users to make or influence decisions that were formerly beyond the limits of their knowledge and experience. Very powerful software packages allow users to perform all manner of inappropriate statistical tests on data without full knowledge of what they are doing. While current statistical software manuals contain a great deal of information regarding model specification and assumptions, they cannot replace a well-founded understanding of basic statistics by the experimenter (THOMSON and SCHMOLDT, 2001). Therefore, this expert system is addressed to dairy farm designers as end users with high academic training, i.e. awarded at least Bachelor degree.

5.9 How Does DFD Affect the Society?

DFD has three effects on the society, which are: economical effect, educational effect, and scientific effect. This wide scope of its effects on the society illustrates the importance of developing such computer tools for agricultural applications.

5.9.1 Economical Effect

As a result of the global food crisis, which negatively affects the developing countries, the Middle East and North Africa (MENA) region has adopted a new strategy to increase the self-produced agricultural products. Among these products, milk and meat are gaining high importance; therefore one key issue is to establish new dairy farms. According to the Five-Year Plans for the National Economy of Egypt, the government -in cooperation with the investors- is intending to establish new dairy farms in order to cover the increasing public requirements of milk and meat. Therefore, several studies -in this field- have been funded by the Cultural Affairs & Missions Sector of the Ministry of Higher Education & Scientific Research in Egypt, and one of them is this study where its results (expert system for planning and designing dairy farms in hot climates) will be one of the axes of the planned economical developments.

5.9.2 Educational Effect

The developed expert system (DFD) can also be used as a computer-based training (CBT), which is a type of education in which the student learns by executing special training programs on a computer. Consequently, DFD can be integrated with the applications of planning and designing dairy farms so that students can practice using the application as they learn.

Increasing users' decision-making power beyond their former knowledge and experience can also have positive impacts. In particular, when systems are largely based on existing publications typically involve knowledge delivery. The developed expert system illustrates this effect.

5.9.3 Scientific Effect

Eleven simulation models had been developed in order to form the knowledge-base of the expert system, these simulation models form the scientific contents of the expert system and represent the recent advancement in the field of planning and designing dairy farms in hot climates.

6 PROSPECTIVE

Expert systems will not be static devices; they will be under continual development and improvement. As new knowledge is discovered, this information will need to be incorporated into the knowledge base, calling for a continuing commitment of Expert Systems developers. Expert Systems derive their power from knowledge rather than from a single powerful technique. "In the knowledge is the power" is the key concept of expert systems developers. Therefore, further refinements are under consideration in order to improve DFD expert system, based on to suggestions noted in the preliminary evaluation that will be made by the end users in the first year of system deployment, this leads to issue the second version of the expert system.

Several modules are planned to be held in cooperation with the Cattle Information System of Egypt (CISE) in order to allegorize the expert system and to elaborate its utilization. Furthermore, a questionnaire will be developed to be filled by the attendants who will be: farm designers, managers of several dairy farms, and CISE experts. The questionnaire will be exploited to improve the expert system; this step will lead to develop extra windows and context-helps for the drop down menus, which results in minimizing the academic level pre-requirements of the end users.

After the refinement, the expert system is intended to be submitted to an international agricultural engineering society in order to be revised and issued as a product of the association.

It is planned to issue a new version every year taking into consideration the comments, suggestions, and notes of the end users which will be asked to fill a questionnaire specially developed for each newly issued version.

Furthermore, it is intended to develop new sub-models for other dairy farm facilities which have been recently appeared, such as biogas plants.

The recent advances, in the designs and plans of the housing system in hot climates and the farm facilities, will be taken into consideration to be integrated into the expert system after getting the required permissions from the copy right holders.

7 SUMMARY

Planning and designing dairy farm facilities is a sophisticated work where a multitude of procedures should be carried out which requires time and efforts; moreover, making mistakes is also possible. Therefore, it is necessary to develop computer tools that have the ability to pre-process the data so as to produce value-added information, in order to accelerate analyses and to improve decision-making.

Eleven simulation models were developed to plan and design several dairy farm facilities. Subsequently, an electronic spark map (decision tree) was developed for each simulation model, and then the simulation models were integrated into the relevant spark maps. Afterwards, C# language (C Sharp), which is an object-oriented programming language, was used to develop an expert system via the simulation models and the electronic spark maps. The developed expert system is able to plan and design several dairy farm facilities, e.g. housing system (corrals system), shade structure and roof material, concrete base, cooling system, milking parlor, forage storage, and manure handling system. Subsequently, it plans the farmstead layout, and it leads to implement the technologies, equipments, and machines required for performing several farm operations. Furthermore, it studies water and electricity requirements of the planned dairy farm and the available sources on site. Moreover, it calculates the capital investment and the fixed, variable, and total costs.

Data of 6 dairy farms were used to carry out the expert system validation and evaluation. The differences between the actual and calculated values were determined and the standard deviations were calculated. The coefficients of variation range between 3% and 7%. The required input data are 358 thereof a multitude will be recommended by the expert system itself; consequently, it computes and displays 372 output data with the ability of saving and retrieving data. Besides, the system's accuracy had been calculated using the actual and calculated values of the different outputs and it was found 98.6%. However, the system's syntax includes 22106 lines.

It can be concluded that the developed expert system can be used successfully for planning and designing dairy cow farms in hot climates.

8 ZUSAMMENFASSUNG

Die Planung und Gestaltung von Milchviehbetrieben in heißen Klimaten ist sehr komplex. Die dabei durchzuführenden Berechnungen sind nicht nur sehr zeit- und arbeitsaufwändig, sie können außerdem auch eine Fehlerquelle darstellen. Ziel der vorliegenden Arbeit ist deshalb die Entwicklung eines Computer-Tools zur Planung und Gestaltung von Milchviehbetrieben in heißen Klimaten. Dabei sollen die erfassten Daten so aufbereitet werden, dass sie den Anwender bei seiner Entscheidungsfindung optimal unterstützen.

Zur Planung und Gestaltung unterschiedlicher Milchviehbetriebe wurden insgesamt elf Simulationsmodelle entwickelt. Neun Modelle simulieren die Funktionsbereiche bzw. Funktionselemente, ein Modell erarbeitet die Zuordnung der Funktionsbereiche (Funktionsprogramm) und ein weiteres dient der Kostenkalkulation. Für jedes Simulationsmodell wurde ein elektronischer Entscheidungsbaum erstellt und jeweils das Simulationsmodell in den jeweiligen Entscheidungsbaum integriert.

Mit Hilfe der objektorientierten Programmierungssprache C# (C Sharp) wurde ein Expertensystem entwickelt, welches die Simulationsmodelle und die jeweiligen Entscheidungsbäume nutzt. Mit diesem Expertensystem können die verschiedenen Elemente eines Milchviehbetriebes, wie beispielsweise die Bauhülle, das Kühlsystem, der Melkstand sowie die Futter- und Güllelagerung, geplant und gestaltet werden. Das Expertensystem setzt dabei die implementierten Technologien um und erstellt anschließend einen Lageplan. Außerdem schätzt das Expertensystem den Strom- und Wasserverbrauch des geplanten Milchviehbetriebes und ermittelt die verschiedenen Anschlussmöglichkeiten. Darüber hinaus berechnet das Expertensystem den Kapitalbedarf für den gesamten Betrieb sowie die fixen und die variablen Kosten.

Für eine Planung sind maximal 358 Eingaben erforderlich. Dabei wird jedoch ein Großteil der Eingabedaten durch das Expertensystem mittels einer entsprechenden Voreinstellung vorgeschlagen. Nach einer Berechnung der eingegebenen Daten werden 372 Output-Daten ausgegeben. Die Output-Daten können anschließend gespeichert und später wieder abgerufen werden. Außerdem wurde die Genauigkeit

des Systems anhand der tatsächlichen und der berechneten Ausgabewerte überprüft. Dabei wurde eine 98,6%ige Genauigkeit festgestellt. Die Syntax des Expertensystems enthält 22106 Zeilen.

Grundlage für die abschließende Validierung und die Evaluierung des Expertensystems waren sechs bestehende Milchviehbetriebe in Ägypten. Dazu wurden die Unterschiede zwischen den tatsächlichen und den berechneten Werten ermittelt und die jeweiligen Standardabweichungen berechnet. Die Variationskoeffizienten liegen zwischen 3% und 7%.

Zusammenfassend kann festgestellt werden, dass das entwickelte Expertensystem für die Planung und Gestaltung von Milchviehbetrieben in heißen Klimaten geeignet ist und den Anwender bei seiner Entscheidungsfindung effektiv unterstützen kann.

9 REFERENCES

- Alfa Laval Agri (1996). Parlour Planning Guide. Ref. No. 11204-EN2/9604. Sweden, Lund: Alfa Laval Agri.
- Bartali E (1999). Characteristics and performances of construction materials. In CIGR Handbook of Agricultural Engineering: Animal Production and Aquacultural Engineering, 3-29. E. Bartali, A. Jongebreur, and D. Moffitt, eds. St. Joseph, Michigan: ASAE.
- Batchelor W D; McClendon R W; Wetzstein M E (1992). Knowledge engineering approaches in developing expert simulation systems. Computers and Electronics in Agriculture, 7, 97-107
- Bicudo J R (2001). Odor Control by Aerobic Treatment Systems. Matresa Workshop IMAG, Wageningen, Netherlands.
- Bihler J (1999). Nutrient Transport and Separation Behavior during the Solid Separation from Liquid Manure, Dissertation, University of Hohenheim, p. 207.
- Blowey R (1994). Dairy Cow Housing, p. 305-337. In: C.M. Walther and D.R. Charles (eds.). Livestock Housing. CAB International, Wallingford, UK.
- Bramley A J; Dodd F H; Mein G A; Bramley J A (1992). Machine Milking and Lactation. Vermont, USA: Insight Books.
- Broner I; King J P; Nevo A (1990). Structured induction for agricultural expert systems knowledge acquisition. Computers and Electronics in Agriculture, 5, 87-99
- Brugger M; Dorsey B (2006). Water use and savings on a dairy farm. In: ASABE Annual International Meeting. Portland, Oregon: ASABE.
- Burton C H; Turner C (2003). Manure Management: Treatment Strategies for Sustainable Agriculture, p. 451. 2nd Edition. Bedford, UK: Silsoe Research Institute.
- C# (2005). Microsoft Visual Studio. Ver. 8.0.50727.42. Washington, D. C.: Microsoft Corporation.
- Doluschitz R (1990). Expert systems for management in dairy operations. Computers and Electronics in Agriculture, 5, 17-30
- Doluschitz R; Schmisser W E (1988). Expert systems: applications to agriculture and farm management. Computers and Electronics in Agriculture, 2, 173-182
- Elder J; Gribble T; Gribble D J (2001). Case study: Mallories Dairy, Silverton, Oregon. In: ASAE Annual International Meeting. Sacramento, California: ASAE Sacramento Convention Center.

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- Engel B A; Beasley D B; Barrett J R (1990). Integrating expert systems with conventional problem-solving techniques using blackboards. *Computers and Electronics in Agriculture*, 4, 287-301
- Georg H (2007). Green roofing against dairy cow summer heat stress (In German). *Landtechnik* 62 (5), 346
- Georges M; Haake K W; Bockisch F J (2005). Buildings for dairy cattle husbandry in arid and semi-arid areas (In German). *Landtechnik* 60 (5), 290
- Giarratano J C; Riley G (2005). *Expert Systems, Principles and Programming*. 4th ed. Boston, Australia: Thomson Course Technology.
- Godbout S; Marquis A; Fafard M; Picard A (2003). Analytical determination of internal forces in a cylindrical tank wall from soil, liquid, and vehicle loads. *Canadian Biosystems Engineering*, 45, 5.7-5.14
- Greer J E; Falk S; Greer K J; Bentham M J (1994). Explaining and justifying recommendations in an agriculture decision support system. *Computers and Electronics in Agriculture*, 11, 195-214
- Harner J P; Smith J F; Brook M; Murphy J P (1999). *Sprinkler Systems for Dairy Cows at a Lane Feeding*. Kansas, USA: Kansas State University, Extension Service.
- Hatem M H (1993). *Theory of Structures and Agricultural Buildings and Environmental Control*. (In Arabic). Cairo, Egypt: Faculty of Agriculture, Cairo University.
- Hatem M H; Sadek R R; Samer M (2004a). Shed height effect on dairy cows microclimate. *Misr Journal of Agricultural Engineering*, 21 (2), 289 - 304
- Hatem M H; Sadek R R; Samer M (2004b). Cooling, shed height and shed orientation affecting dairy cows microclimate. *Misr Journal of Agricultural Engineering*, 21 (3), 714 - 726
- Hatem M H; Sadek R R; Samer M (2006). Effects of shed height and orientation on dairy cows` microclimate, cooling system efficiency and milk productivity. In Proc. 16th CIGR World Congress, 413-414. Düsseldorf, Germany: VDI Verlag.
- House H K; Huffman H E; Johnson J W (2000). Plastic and fabric covered arch-frame buildings. In Proc. Dairy Housing and Equipment Systems, 353-365, Ithaca, New York, USA: NRAES.
- Ikeguchi A; Okushima L (2001). Airflow patterns related to polluted air dispersion in open free-stall dairy houses with different roof shapes. *Transactions of the ASAE*, 44 (6), 1797-1805
- Jäkel K (2003). *Analyse der Elektroenergieanwendung und Einsparpotentiale am Beispiel sächsischer Milchviehanlagen*. (Analysis of the electrical energy input and

-
- saving potentials at the example of Saxon dairy farms.) Forschungsbericht Agrartechnik 414. Martin-Luther-Universität Halle/Saale.
- Jungbluth T (1995). The design of systems. In Proc. Animal Behavior and the Design of Livestock and Poultry Systems, 9-19. Ithaca, New York, USA: NRAES.
- Keown J F; Grant R J (1999). How to Reduce Heat Stress in Dairy Cattle. Missouri, USA: University of Missouri-Columbia.
- Kraatz S; Berg W (2007). Energy demand for milking dairy cows. In: ASABE Annual International Meeting. Minneapolis, Minnesota: ASABE.
- Lacroix R; Huijbers J; Tiemessen R; Lefebvre D; Marchand D; Wade K M (1998). Fuzzy set-based analytical tools for dairy herd improvement. Applied Engineering in Agriculture, 14 (1), 79-85
- Lindley J A; Whitaker J H (1996). Agricultural Buildings and Structures. St. Joseph, Michigan: ASAE.
- Martin J G (1998). Sitting large dairy facilities. In Proc. Fourth International Dairy Housing Conference, p. 201-208, ed. J. P. Chastain. ASAE, St. Joseph, Michigan, USA.
- Meyer M J; Smith J F; Harner J P; Shirley J E; Titgemeyer E C; Brouk M J (2002). Performance of lactating dairy cattle in three different cooling systems. Applied Engineering in Agriculture, 18 (3), 341-345
- Miller P; Marter J (2003). Bunker silo systems engineered for producer profit. In Proc. Fifth International Dairy Housing Conference. Texas: ASAE.
- Samer M; Grimm H; Hatem M; Doluschitz R; Jungbluth T (2008a). Mathematical modeling and spark mapping of dairy farmstead layout in hot climates. Misr Journal of Agricultural Engineering (in Press).
- Samer M; Grimm H; Hatem M; Doluschitz R; Jungbluth T (2008b). An expert system for planning and designing corral systems and their concrete constructions for dairy farms in hot climates. Submitted to Transactions of the ASABE on 12.03.2008.
- Samer M; Grimm H; Hatem M; Doluschitz R; Jungbluth T (2008c). An expert system for planning and designing milking parlor constructions. Submitted to Biosystems Engineering on 31.03.2008.
- Samer M; Grimm H; Hatem M; Doluschitz R; Jungbluth T (2008d). An expert system for planning and designing dairy farms in hot climates. Submitted to Computers and Electronics in Agriculture on 30.04.2008.
- Schmidt G H; Van Vleck L D; Hutjens M F (1988). Dairy Cattle Housing. In Principles of Dairy Science, p. 428-444. 2nd Edition. USA: Prentice Hall.

- Simon J (2006). Comparing investment costs and functions of different milking house arrangements (In German). *Landtechnik* 61(6), 392
- Smith J F; Armstrong D V; Gamroth M J; Harner III J (1998). Factors affecting milking parlor efficiency and operator walking distance. *Applied Engineering in Agriculture*, 14 (6), 643-647
- Spangler A M; Ray C D; Hamaker K (1989). Knowledge acquisition for expert system development. *Computers and Electronics in Agriculture*, 4, 23-32
- Steiner B; Thalmann C; Keck M (2007). Refurbishing solid concrete floor surfaces (In German). *Landtechnik* 62 (5), 348
- Thomson A J; Schmoltd D L (2001). Ethics in computer software design and development. *Computers and Electronics in Agriculture* 30, 85-102
- Tillie M (1999). Equipment and control. In *CIGR Handbook of Agricultural Engineering: Animal Production and Aquacultural Engineering*, 115-145. E. Bartali, A. Jongebreur, and D. Moffitt, eds. St. Joseph, Michigan: ASAE.
- Turner L W; Warner R C; Chastain J P (1997). *Micro-Sprinkler and Fan Cooling for Dairy Cows: Practical Design Considerations*. Kentucky, USA: University of Kentucky, Extension Service.
- Tyson J T (2000). *Farmstead Layout: Putting the Pieces Together*. Proceedings of Dairy Housing and Equipment Systems, p. 49-56, NRAES, Ithaca, New York.
- Yoder D C; Tyner J S; Balousek J D; Panuska J C; Buchanan J R; Kirsch K J; Lyon J P (2007). Conservation planning for construction sites. *Transactions of the ASABE* 50 (5), 1613-1618
- Zhang Q; Britton M G (2003). A micromechanics model for predicting dynamic loads during discharge in bulk solids storage structures. *Canadian Biosystems Engineering*, 45, 5.21 - 5.27

10 APPENDICES

Prerequisites for installing DFD:

- Hardware prerequisites: laptop or PC Pentium III, Processor at least 500 MHZ, HDD capacity at least 10 GB, RAM at least 64 MB, VGA Card at least 8 MB, and CD-ROM.
- Software prerequisites: operating system (Windows 98, Millennium, XP, and Vista), and Microsoft .NET Framework.

Figure A1: Prerequisites for installing DFD

Table A1: Actual data acquired for making the validation of design model

Symbol	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6
N _{CF}	480.00	600.00	700.00	100.00	25.00	72.00
N _{CH}	240.00	200.00	20.00	20.00	25.00	72.00
N _{CC}	12.00	10.00	20.00	20.00	25.00	12.00
N _{CFP}	1.00	1.00	1.00	1.00	1.50	1.00
L _{FB}	0.95	0.90	1.00	0.85	0.85	0.80
A _{AC}	25.00	20.00	22.00	20.00	20.00	22.50
Corrals Distribution	2 Sides of Corrals	2 Sides of Corrals	One Corral (Pie)	One Corral	One Corral	One Side of Corrals
W _{LB}	4.00	5.00	4.50	4.00	3.50	4.50
W _{FP}	2.50	2.00	0.00	0.00	0.00	2.00
W _{BB}	0.20	0.15	0.20	0.20	0.15	0.20
W _{RC}	0.20	0.15	0.00	0.00	0.00	0.20
L _{FP}	11.40	9.00	14.00	17.00	14.20	9.60
W _{FP}	2.50	2.00	2.00	2.00	2.00	2.00
L _{SH}	114.00	90.00	14.00	17.00	14.50	57.60
S _F	100.00	100.00	100.00	100.00	100.00	100.00
S _L	90.00	80.00	33.33	33.33	66.67	75.00
A _O	25.00	20.00	30.00	16.00	15.00	18.00
A _H	6456.96	4449.60	530.00	467.50	550.00	1879.49
A _{FS}	500.00	660.00	558.00	0.00	25.00	
A _{MC}	355.00	651.00	710.40	242.25	0.00	
A _M	0.00	40.70	0.00	0.00	0.00	
L _C	26.15	22.37	21.85	23.38	35.52	27.96
W _C	11.52	9.10	20.22	17.18	14.33	9.70
A _C	301.20	202.50	440.75	400.00	504.10	269.76
N _{HC}	20.00	20.00	1.00	1.00	1.00	6.00
W _{CB}	9.80	9.60	4.70	4.20	3.65	6.90
A _H	6485.76	4450.00	546.00	467.50	550.00	1877.76
W _H	56.30	50.00	21.00	17.00	14.20	32.60
L _H	115.20	90.00	26.00	27.50	38.50	57.60
H _C	8.20	7.50	5.00	4.50	5.00	7.80
A _{FP}	28.75	18.00	28.00	34.00	28.50	
R _A	0.10		0.06	0.09	0.06	0.07
N _{HF}	2.00	3.00	35.00	5.00	1.00	1.00
A _{IF}	13793.92	14720.50	19848.40	2595.75	590.00	
Structure Material	Steel	Steel	Steel	Steel	Steel	Steel
Orientation	EW	EW	Others	EW	EW	EW
Floor material	Concrete & Sand	Concrete & Sand	Concrete & Sand	Concrete & Sand	Concrete & Sand	Concrete & Sand
Roof Material	Reed Mats	Straw Mats	Straw Mats	Straw Mats	Reed Mats	Reed Mats
Climate Conditions	8 mm/year; 1.4 m/s; North & North West; 36.7 °C; 55%; 82%; 476 Cal/cm ² .day	35 mm/year; 3.1 m/s; North & North West; 28.1 °C; 74%; 78%; 457 Cal/cm ² .day	40 mm/year; 3.5 m/s; North & North West; 29.5 °C; 75%; 76%; 460 Cal/cm ² .day	19 mm/year; 2.3 m/s; North & North West; 28.1 °C; 70%; 78%; 459 Cal/cm ² .day	67 mm/year; 1.3 m/s; North & North West; 27.5 °C; 74%; 77%; 453 Cal/cm ² .day	40 mm/year; 3.5 m/s; North & North West; 29.5 °C; 75%; 76%; 460 Cal/cm ² .day

Table A2: Actual data acquired for making the validation of concrete base sub-model

Symbol	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6
Corrals Distribution	2 Sides of Corrals	2 Sides of Corrals	One Corral (Pie)	One Corral	One Corral	One Side of Corrals
L _{CB}	115.20	90.00	26.00	27.50	38.50	57.60
W _{LB}	4.00	5.00	4.50	4.00	3.50	4.50
W _{FP}	2.50	2.00	0.00	0.00	0.00	2.00
W _{RC}	0.20	0.15	0.00	0.00	0.00	0.20
W _{BB}	0.20	0.15	0.20	0.20	0.15	0.20
T _{LB}	0.25	0.20	0.18	0.20	0.18	0.22
T _{FP}	0.20	0.20	0.00	0.00	0.00	0.22
H _{BB}	0.50	0.50	0.45	0.50	0.48	0.50
H _{RC}	0.20	0.25	0.00	0.00	0.00	0.20
NØD/m	6Ø6/m	6Ø6/m	6Ø6/m	6Ø6/m	6Ø6/m	6Ø6/m
N _{IML}	6.00	6.00	6.00	6.00	6.00	6.00
N _G	1.00	1.00	1.00	1.00	1.00	1.00
L _{SI}	12.00	12.00	12.00	12.00	12.00	12.00
M _{IML}	0.67	0.67	0.67	0.67	0.67	0.67
P _G	25.00	30.00	20.00	11.50	14.50	28.00
P _C	0.30	0.35	0.30	0.21	0.24	0.33
P _S	60.00	70.00	58.00	47.00	49.50	69.00
C _{EC}	25.00	30.00	22.50	15.00	19.00	28.00
P _I	2800.00	3000.00	2750.00	1850.00	2150.00	2950.00
t _P	20.00	20.00	20.00	20.00	20.00	20.00
C _{VCB}	0.00	0.00	0.00	0.00	0.00	0.00
W _{CB}	9.80	9.60	4.70	4.20	3.65	6.90
V _{CB}	282.50	194.06	23.52	24.87	27.16	95.97
V _G	225.98	155.19	18.82	19.91	21.74	76.79
M _C	91415.77	62785.33	7609.95	8049.00	8789.50	31059.90
V _S	114.50	78.50	9.52	10.07	11.03	38.90
M _I	9.64	7.38	1.06	1.00	1.22	3.41
C _{ICB}	75000.00	60000.00	7050.00	4750.00	6293.76	28369.50

Table A3: Actual data acquired for making the validation of roof material and structure sub-model

Symbol	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6
A_{SH}	5875.84	3639.77	197.85	184.07	377.68	1442.50
L_{SH}	114.00	90.00	14.00	17.00	14.50	57.60
m	8.00	10.00	0.00	12.00	0.00	10.00
H_C	8.20	7.50	5.00	4.50	5.00	7.80
Corrals Distribution	2 Sides of Corrals	2 Sides of Corrals	One Corral (Pie)	One Corral	One Corral	One Side of Corrals
Roof Type	Compound 3 Parts	Open Ridge Roof	Horizontal Roof	Mono-Slope	Horizontal Roof	Compound 2 Parts
M	2.00	1.50	0.00	0.00	1.00	1.00
Sp	5.80	4.50	7.00	8.50	7.10	4.80
R	4.00	4.00	2.00	2.00	2.00	3.00
W_{CB}	9.80	9.60	4.70	4.20	3.65	6.90
W_{LB}	4.00	5.00	4.50	4.00	3.50	4.50
Roof Material	Reed Mats	Straw Mats	Straw Mats	Straw Mats	Reed Mats	Reed Mats
A_{RM}	9.00				4.00	9.00
A_{SM}		4.00	4.00	4.00		
P_{RM}	12.00				3.50	10.00
P_{SM}		5.00	4.00	3.50		
M_{RM}	3.00				1.00	3.00
M_{SM}		1.50	1.20	1.20		
P_{RCM}	8500.00	9500.00	200.00	171.00	332.50	1667.00
P_{ISC}	93000.00	71500.00	3250.00	3000.00	6250.00	23750.00
t_s	20.00	20.00	20.00	20.00	20.00	20.00
C_{VS}	1000.00	1000.00	100.00	100.00	50.00	180.00
α	5.00	5.70	0.00	7.00	0.00	5.70
W_R			14.00	11.00	26.00	
L_R	114.00	90.00	14.00	17.00	14.50	57.60
A_R						1500.00
W_S	47.67	39.34	14.17	10.86	24.11	23.10
L_S	114.00	90.00	14.00	17.00	14.50	57.60
N_P	21.00	21.00	3.00	3.00	3.00	13.00
N_{Pt}	84.00	84.00	6.00	6.00	6.00	39.00
H_C	8.20	7.50	5.00	4.50	5.00	7.80
H_{CS}	6.20	5.80		3.00		6.20
W_{WR}	21.00	20.10				
W_{LR}	21.00	20.00				12.50
W_{OR}		2.00				
W_{WS}	19.00	17.00				
W_{LS}	19.00	17.00				11.50
W_{MS}						11.50
W_{MR}	14.00					13.50
N_{RM}	704.00				95.00	167.00
N_{SM}		910.00	50.00	50.00		
P_{IRM}	8500.00				332.50	1667.00
P_{ISM}		4700.00	200.00	171.00		
C_{IS}	101500.00	76200.00	3450.00	3171.00	6582.50	25420.00

Table A4: Actual data acquired for making the validation of manure handling sub-model

Symbol	Farm 1	Farm 2	Farm 6
Ψ	0.75	0.80	0.75
N_{CF}	480.00	600.00	72.00
V_{MCM}	1.85	1.80	1.85
D_{MP}	4.00	4.00	3.00
V_M	90.00	120.00	10.45
H_{IT}	2.50	3.50	1.00
T_{TB}	0.30	0.25	0.20
T_{TW}	0.25	0.20	0.20
$N\emptyset D/m$	6 \emptyset 8/m	8 \emptyset 8/m	6 \emptyset 6/m
N_{IML}	6.00	8.00	6.00
N_G	2.00	2.00	1.00
L_{SI}	12.00	12.00	12.00
M_{IML}	0.89	0.89	0.67
P_I	2800.00	3000.00	2950.00
P_G	25.00	30.00	28.00
P_C	0.30	0.35	0.33
P_S	60.00	70.00	69.00
C_{EC}	25.00	30.00	28.00
t_P	20.00	20.00	20.00
C_{VMT}	0.00	0.00	0.00
V_{RS}	90.00	120.00	10.45
V_{IT}	100.00	126.00	11.50
R_{IT}	3.57	3.40	1.90
R_{ET}	3.82	3.60	2.10
A_{MT}	45.84	40.70	14.00
V_{CT}	28.50	25.80	5.25
V_G	22.70	20.75	4.18
M_C	9120.10	8516.50	1680.80
V_S	11.50	10.21	2.12
M_I	1.79	2.78	0.16
C_{IMT}	9750.00	13950.00	1465.00

Table A5: Actual data acquired for making the validation of milking parlor constructions sub-model

Symbol	Farm 1	Farm 2	Farm 3	Farm 4	Farm 6
Front Exit	Without	Without	Without	Without	Without
Parlor Size	2x12	2x10	2x20	2x4	2x6
Parlor Design	Parallel	Herringbone	Herringbone	Herringbone	Herringbone
L _{CP}	10.50	13.95	25.35	7.10	9.40
W _{CP}	2.50	4.00	4.50	3.50	3.50
L _{EA}	4.00	5.00	6.00	4.00	5.00
W _{EA}	1.00	1.00	1.00	1.00	1.00
L _{FEA}	0.00	0.00	0.00	0.00	0.00
W _{FEA}	0.00	0.00	0.00	0.00	0.00
W _P	2.60	2.00	2.50	2.00	2.00
D _p	1.24	1.10	1.10	0.85	1.07
L _{RA}	10.00	8.00	10.00	6.00	7.00
W _{RA}	1.00	1.00	1.00	1.00	1.00
m _{CY}	3.00	3.00	3.00	3.00	3.50
N _{CY}	24.00	20.00	40.00	8.00	12.00
A _{CCY}	2.50	2.80	3.00	2.50	2.80
A _{MR}	30.00	25.00	35.00	20.00	25.00
A _{MRP}	24.00	24.00	30.00	20.00	22.00
A _{PR}	12.00	12.00	15.00	10.00	10.00
T _{CL}	0.20	0.20	0.20	0.18	0.15
NØD/m	6Ø6/m	6Ø6/m	6Ø6/m	6Ø6/m	6Ø6/m
N _{I ML}	6.00	6.00	6.00	6.00	6.00
N _G	1.00	1.00	1.00	1.00	1.00
L _{SI}	12.00	12.00	12.00	12.00	12.00
M _{I ML}	0.67	0.67	0.67	0.67	0.67
P _I	2800.00	3000.00	2750.00	1850.00	2950.00
P _G	25.00	30.00	20.00	11.50	28.00
P _C	0.30	0.35	0.30	0.21	0.33
P _S	60.00	70.00	58.00	47.00	69.00
C _{EC}	25.00	30.00	22.50	15.00	28.00
P _R	40.00	42.00	40.00	35.00	41.00
t _P	20.00	20.00	20.00	20.00	20.00
C _{VCM}	0.00	0.00	0.00	0.00	0.00
L _{SH}	41.80	38.50	58.70	Closed Building (No Cowshed)	42.00
W _{SH}	10.50	12.00	12.50		11.50
m	45.00	0.00	40.00		30.00
H _S	10.00	8.00	10.00		8.50
Roof Type	Gable Roof	Horizontal	Gable Roof		Gable Roof
M	1.00	1.00	0.50		1.00
S _P	6.00	7.00	5.00		6.00
R	2.00	2.00	2.00		2.00
Roof Material	Isolated Aluminum	Polished Aluminum	Isolated Aluminum		Isolated Aluminum
A _R		462.00			504.00
P _{PA}		15.00			
P _{IA}	20.00		18.00	20.00	
M _{PA}		1.25			
M _{IA}	1.50		1.40	1.50	
P _{RCM}	10000.00	7000.00	14550.00		10080.00

P _{tSC}	12000.00	11250.00	15750.00		8950.00
t _s	20.00	20.00	20.00		20.00
C _{VS}	0.00	0.00	0.00		0.00
L _{PM}	24.50	27.00	41.50	17.00	21.25
W _{PM}	7.50	10.00	11.50	9.00	9.00
A _{PM}	183.75	270.00	477.25		
W _{MC}	8.00	10.00	11.50	9.00	9.00
L _{MC}	41.30	38.50	58.70	25.00	31.50
A _{CY}	60.00	56.00	120.00	20.00	34.00
V _{CCP}	84.50	101.90	174.30	51.06	56.32
V _G	68.30	81.80	140.20	41.10	45.10
M _C	26980.00	32530.00	55860.00	16375.00	17905.00
V _S	33.90	40.80	69.90	20.55	22.38
M _I	3.55	4.29	7.31	2.39	3.14
C _{ICM}	35000.00	45511.00	66135.50	14977.88	28497.70
A _{SH}		462.00			
W _R		12.00			
W _{WR}	5.80		6.75		6.00
W _{LR}	5.80		6.75		6.00
L _R	41.80	38.50	58.70		42.00
A _R		462.00			504.00
W _S	8.50	10.00	11.60		9.60
L _S	41.80	38.50	58.70		42.00
N _P	8.00	7.00	13.00		8.00
N _{Pt}	16.00	14.00	26.00		16.00
H _S	10.00	8.00	10.00		8.50
H _{SS}	8.00		7.75		7.00
P _{tPA}		7000.00			
P _{tIA}	10000.00		14550.00		10080.00
C _{IS}	22000.00	18250.00	30300.00		19030.00

Table A6: Actual data acquired for making the validation of forage storage structure constructions sub-model

Symbol	Farm 1	Farm 2	Farm 3	Farm 6
N_{CF}	480.00	600.00	700.00	72.00
V_{FSC}	10.00	10.00	10.00	10.00
V_{STC}	1.75	1.74	1.76	1.75
V_{HC}	0.35	0.36	0.34	0.35
V_{PC}	0.50	0.60	0.55	0.50
V_{GC}	0.65	0.55	0.60	0.65
V_{SC}	6.75	6.75	6.75	6.75
V_{IST}	850.00	1050.00	1235.00	126.00
V_{IHS}	150.00	220.00	240.00	25.00
L_{SH}	50.00	55.00	62.00	9.00
W_{SH}	10.00	12.00	9.00	6.00
m	20.00	0.00	0.00	0.00
Roof Type	Gable Roof	Horizontal Roof	Horizontal Roof	Horizontal Roof
M	1.00	0.50	1.00	0.00
S_p	10.00	5.00	6.00	4.50
R	2.00	2.00	2.00	2.00
Roof Material	Polished Aluminum	Polished Aluminum	Polished Aluminum	Polished Aluminum
A_R		660.00	558.00	54.00
P_{PA}	15.00	17.50	13.50	14.00
M_{PA}	1.20	1.15	1.25	1.20
P_{RCM}	8000.00	11550.00	7535.00	760.00
P_{ISC}	13500.00	15780.00	16885.00	2256.00
t_s	20.00	20.00	20.00	20.00
C_{VS}	0.00	0.00	0.00	0.00
V_{IPS}	240.00	350.00	390.00	36.00
V_{ISS}	3250.00	4000.00	4730.00	486.00
V_{IGS}	320.00	320.00	425.00	47.00
W_{HSP}	5.00	5.00	6.00	5.00
H_{WHS}	2.00	2.00	2.00	2.00
N_{HSP}	15.00	18.00	18.00	6.00
T_{SW}	0.20	0.20	0.20	0.20
T_{SB}	0.20	0.20	0.25	0.20
NØD/m	6Ø6/m	6Ø6/m	6Ø6/m	6Ø6/m
N_{IML}	6.00	6.00	6.00	6.00
N_G	1.00	1.00	1.00	1.00
L_{SI}	12.00	12.00	12.00	12.00
M_{IML}	0.67	0.67	0.67	0.67
P_I	2800.00	3000.00	2750.00	2950.00
P_G	25.00	30.00	20.00	28.00
P_C	0.30	0.35	0.30	0.33
P_S	60.00	70.00	58.00	69.00
C_{EC}	25.00	30.00	22.50	28.00
C_{VCH}	0.00	0.00	0.00	0.00
t_P	20.00	20.00	20.00	20.00
V_{IST}	850.00	1050.00	1235.00	126.00
V_{IHS}	150.00	220.00	240.00	25.00
V_{IPS}	240.00	350.00	390.00	36.00
V_{IGS}	320.00	320.00	425.00	47.00
V_{ISS}	3250.00	4000.00	4730.00	486.00
V_{IFS}			7020.00	720.00
A_{SH}		660.00	558.00	54.00

α	11.31	0.00	0.00	0.00
W_R		12.00	9.00	6.00
L_R	50.00	55.00	62.00	9.00
W_{WR}	5.00			
W_{LR}	5.00			
A_R		660.00	558.00	54.00
W_S	8.00	11.00	7.00	6.00
L_S	50.00	55.00	62.00	9.00
N_P	6.00		11.00	3.00
N_{Pt}	12.00		22.00	6.00
H_S	4.00	3.65	5.00	4.50
H_{SS}	3.00			
P_{tPA}	8000.00	11550.00	7535.00	760.00
C_{IS}	21500.00	27330.00	24420.00	3016.00
V_{tHF}	3810.00	4670.00	5550.00	569.00
L_{HS}	25.50	26.00	26.00	9.50
V_{CHS}	600.30	732.00	972.50	100.90
V_G	479.20	585.00	776.00	80.59
M_C	193221.00	235795.00	313099.00	32492.90
V_S	240.00	292.50	389.00	40.35
M_I	24.17	29.49	33.35	3.82
C_{ICH}	166331.89	230210.00	245357.00	30218.93

Table A7: Actual data acquired for making the validation of farmstead layout sub-model

Symbol	Farm 1	Farm 2	Farm 4	Farm 6
d_{X1F}	10.00	25.00	25.00	15.00
D_{X1}	115.20	9.00	27.50	57.60
d_{X12}	10.00	14.00	5.50	32.00
D_{X2}	50.00	90.00	9.50	2.10
d_{X23}		30.00	5.50	
D_{X3}		20.00	27.50	
d_{X34}			2.00	
D_{X4}			4.00	
d_{XnF}	15.00	10.00	13.00	7.00
d_{Y1F}	10.00	12.00	4.00	3.00
D_{Y1}	56.30	55.00	25.50	3.00
d_{Y12}	30.00	54.20	5.50	25.50
D_{Y2}	56.30	7.20	17.00	32.60
d_{Y23}	12.00	54.10	10.00	37.50
D_{Y3}	8.00	55.00	17.00	6.00
d_{Y34}			7.00	
d_{YnF}	5.00	14.00	5.00	9.50
X_F	200.40	198.23	119.64	113.82
Y_F	178.00	252.00	91.20	117.35
A_{IFA}	3.57	5.00	1.09	1.34
P_F	757.00	900.46	421.68	462.34

Table A8: Actual data acquired for making the validation of cooling system sub-model

Symbol	Farm 1	Farm 2	Farm 3	Farm 6
L _{CO}	112.00	90.00	14.00	57.60
Q _{MS}	0.40	0.42	0.00	0.42
P _{rMS}	175.00	176.00	0.00	176.00
N _{CLC}	2.00	2.00	2.00	1.00
t _{CS}	5.00	10.00	5.00	4.00
S _{CF}	6.00	5.00	7.00	6.00
P _{CF}	600.00	680.00	630.00	645.00
P _{CP}	4500.00	4950.00	0.00	4865.00
P _{CPL}	1.50	1.75	0.00	1.65
L _{CML}	6.00	7.30	0.00	5.50
P _{CML}	4.50	5.20	0.00	4.75
L _{CSL}	12.00	10.50	0.00	11.00
P _{CSL}	6.00	6.80	0.00	6.50
S _M	6.00	5.00	0.00	6.00
C _{ECS}	2000.00	1750.00	500.00	2250.00
P _M	2.50	2.85	0.00	2.75
P _A	550.00	580.00	0.00	575.00
P _{PG}	80.00	84.50	0.00	83.50
P _{IVF}	250.00	265.00	0.00	277.50
N _{CT}	2.00	2.00	0.00	2.00
P _{CT}	125.00	129.50	0.00	133.50
P _{FC}	1200.00	1370.00	0.00	1299.50
C _{VCS}	250.00	237.00	66.00	288.50
N _{ICF}	37.00	36.00	4.00	10.00
Q _{CP}	1.00	1.00	Just Cooling Fans without Microsprinklers	0.27
P _{ICP}	230.00	230.00		200.00
L _{ICP}	224.00	180.00		57.60
d _{CP}	18.00	18.00		11.00
N _M	37.00	36.00		10.00
C _{ICS}	32500.00	34972.00	3020.00	16322.77

Table A9: Actual data acquired for making the validation of water sub-model

Symbol	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6
W_{MSH}	65.00	60.00	121.00	28.00	No available info	35.00
D_{DMS}	15.00	15.00	13.50	10.50		4.50
N_{MSF}	1.00	1.00	1.00	1.00		1.00
N_M	37.00	36.00	Air Cooling Without Sprinkling. i.e. without microsprinklers and water	No Cooling System	No Cooling System	10.00
W_M	0.40	0.42				0.42
D_{HM}	20.00	15.00				20.00
D_{DOC}	10.00	8.00				9.00
D_{YOC}	6.00	5.00				6.00
N_{CSF}	2.00	3.00				1.00
W_{MHD}	6.00	5.00				No Flushing System
N_{MHF}	2.00	3.00				1.00
X_1	35.00	32.00	27.00	22.00	18.50	33.50
X_2	30.00	29.00	33.00	30.00	29.00	30.00
N_{CF}	480.00	600.00	700.00	100.00	25.00	72.00
W_{HS1}		3.00				
D_{DS1}		12.50				
N_{S1}		1.00				
Supply	Governmental	Governmental	Well	Governmental	Governmental	Governmental
P_{WG}	1.75	1.75		1.75	1.75	1.75
P_{MWS}	350.00	350.00		350.00	350.00	350.00
V_{CC}	5.00	5.00	5.00	4.00	4.00	5.00
P_{BWC}	200.00	180.00	220.00	155.00	150.00	195.00
t_{GW}	10.00	10.00		10.00	10.00	10.00
D_W			120.00			
C_{DPW}			18.00			
C_{MDW}			275.00			
P_{WF}			3800.00			
P_{WP}			42000.00			
C_{OWP}			4.00			
C_{OW}			55000.00			
t_w			20.00			
W_{FY}	23056.11	26288.52	20531.42	2432.20	493.65	2839.72
C_{VWG}	48230.37	52704.40		5259.49	1150.07	5950.81
V_{BW}					4.00	
N_{BWC}					1.00	5.00
P_{TWC}					150.00	
C_{IWG}					500.00	
Q_{WP}			7.50			
C_{IDW}			145332.75			

Table A10: Actual data acquired for making the validation of electricity sub-model

Symbol	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6
E_{MSH}	4.50	4.20	7.80	2.60	3 small mobile milking units	3.50
N_{MD}	3.00	3.00	3.00	3.00		3.00
D_M	5.00	5.00	4.50	3.50		1.50
N_{MSF}	1.00	1.00	1.00	1.00		1.00
N_{ICF}	37.00	36.00	4.00	No Cooling System	No Cooling System	10.00
E_{CF}	0.40	0.40	0.40			0.40
E_{CP}	0.50	0.50	0.00			0.50
D_{DOC}	10.00	8.00	10.00			9.00
D_{YOC}	6.00	5.00	6.00			6.00
N_{CSF}	2.00	3.00	35.00			1.00
N_{LC}	80.00	No Night Lighting	2.00			No Night Lighting
N_{HF}	2.00		35.00	1.00		
N_{LO}	40.00		12.00	15.00		
E_L	60.00		60.00	60.00		
D_{NL}	10.00		8.00	8.00		
E_{HS1}		3.20				
D_{DS1}		12.50				
N_{S1}		1.00				
Supply	Governmental	Governmental	Governmental	Governmental		Governmental
P_{EG}	0.25	0.25	0.25	0.25		0.25
C_{FEG}	500.00	500.00	500.00	500.00		500.00
t_{GC}	10.00	10.00	10.00	10.00		10.00
E_{FY}	126372.88	93261.20	157261.30	10205.70		23058.76
C_{VEG}	31343.22	22990.30	38565.33	2588.93		5739.69
C_{IEG}	5000.00	5000.00		5000.00		5000.00

Curriculum Vitae

Personal Data

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09/1982 – 06/1984	Lomita School, Los Angeles, California, USA
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06/1997	High School Certificate, Cairo, Egypt
09/1997 – 05/2001	Undergraduate Educations, Faculty of Agriculture, Cairo University, Cairo, Egypt
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10/2002 – 12/2004	Postgraduate Educations, Agricultural Engineering Department, Faculty of Agriculture, Cairo University, Cairo, Egypt
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Career

04/2002 – 02/2005	Demonstrator, Agricultural Engineering Department Faculty of Agriculture, Cairo University, Cairo, Egypt
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Stuttgart, on 25.08.2008

Mohamed Samer Mohamed

Declaration

Declaration according to the doctoral regulations on 01.04.2002; § 8.2.2

Herewith, I declare that I have completed the dissertation independently; only the given invention sources and the used resources which have been marked literally as references.

Stuttgart, on 25.08.2008

Mohamed Samer Mohamed

Erklärung

Erklärung gemäß Promotionsordnung vom 01.04.2002; § 8 Abs. 2 Ziff. 2

Hiermit erkläre ich, dass ich die Dissertation selbständig angefertigt habe, nur die angegebenen Quellen und Hilfsmittel benutzt und wörtlich oder inhaltlich übernommene Stellen als solche gekennzeichnet habe.

Stuttgart, den 25.08.2008

Mohamed Samer Mohamed