The design of mega dairies in India: optimal facility allocation, and how big do you want to go?

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Please ask during the presentation
So long losers!
I’m off to India to live like a Goddess…
A mega dairy in India – in brief

• Design & management of a large-scale dairy farm require OR tools.

• In this study a combined model:
  • queuing-network, robust 6σ design,
  • simulation and optimization was developed

• Design criteria were:
  • 10,000 cows in milking,
  • intensive farming while maximized animal welfare,
  • year-round indoors, no grazing, open-large cowsheds, dry manure bedding,
  • no cubicle housing, maximizing cow resting time and worker convenience.

  All design criteria were met.

• We modeled eight farming aspects:
  * cow traffic,
  * vet treatment,
  * cow cooling,
  * workers' transportation
  * milking parlors,
  * manure handling,
  * feed-center operation,
  * a problematic junction,

  and their interrelations.
Project Aim – to design a mega dairy

- 10,000 cows in milking
- Three rotary milking parlors
- Two veterinary hospitals
- One animal-feed center
- Cow-manure handling & biogas production
- Cow cooling centers
- Calves, heifers, replacement
- Workers’ traffic and facilities
Figure 1. The mega dairy’s five traffic circles
Design tool 1. Robust 6σ design

The under-study farm milks $290 \times 12 \times 3 \times 365 \times 3 = 11,431,800$ milkings per a year.

<table>
<thead>
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<th>standard deviation</th>
<th>Percent variation (%)</th>
<th>Missed milkings per year (no sigma shift)</th>
<th>Missed milkings per year (1.5σ shift)</th>
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</table>
Design tool 2. closed queuing network

Figure 6. The flow of the cows throughout the treatments at the parlor’s pens
Design tool 3. Simulation model
A deterministic design problem:

Minimizes: \[ F(\mu_y(X)) \]
subject to: \[ g_i(\mu_y(X)) \leq 0 \]
\[ X_L \leq \mu_X \leq X_U. \]

A probabilistic design problem:

Minimizes: \[ F(\mu_y(X), \sigma_y(X)) \]
subject to: \[ g_i(\mu_y(X), \sigma_y(X)) \leq 0 \]
\[ X_L + n\sigma X \leq \mu_X \leq X_U - n\sigma X \]
\[ \mu_y - n\sigma_y \geq \text{Lower specification limit} \]
\[ \mu_y + n\sigma_y \leq \text{Upper specification limit} \]
\[ n=6 \]
The complexity

- several facilities making up a large farm
- mutual interaction
- numerous animal-related parameters
- number of multidisciplinary fields,

- Regular design – each facility separately
- Static design (Excel) and simulation
- **no proof of optimum solution**

- animal friendly
- environment friendly
- convenient for humans
- economically feasible
- **Social aspects - local community**
- sustainability

AgResearch

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A mega dairy subsystems = 7 models

Seven simulation models were built

- Milking parlor cow flow (model 1)
- In-parlor treatment cow flow (model 2)
- Cow traffic to the milking parlor and cooling sheds (model 3)
- Junction flow near the milking parlor (model 4)
- Manure scraping (flow?) (model 5)
- Feed-distribution flow (model 6)
- Worker traffic flow (model 7)
A model of mega dairy as a one single system

- Optimization - maximizing capacity of each facility
- Queuing network links all the facilities into one single system
- Reliability – Quality over Time
- Robust (6 sigma) design
A mega dairy in India - results

Farming area 1. Milking parlor

Based on the model, the decision were:

- 80-stalls rotary parlor
- Rotary speed 7.5 sec / cow
A mega dairy in India - results

Farming area 2.

Cow treatment

Based on the model, the decision were:

- 102 stalls for fast treatments in the parlor after milking: fertility, hooves, lameness, drying
- Other treatments – send the cow to the hospital
- Queue length:
A mega dairy in India - results

Farming area 3. Cow traffic

Based on the model, the decision were:

- the walking time to and from the parlor should not exceed 20 min
- Otherwise the natural lying time is suppressed
- Cow’s Time-Budget
- Walking distance and lane width were design

The influence of walking time on the availability of lie down time during one 8-h shift with milking
A mega dairy in India - results
Farming area 3. Cow traffic

Cow traffic simulation program objects and user interface; the influence of walking time on the availability of cow reclining time
A mega dairy in India - results

Farming area 3.
The Junction

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Farming area 3.
The Junction

Model suggests:

- Junction crossing time
- 10 min. or less from the parlor
- 5 min. or less from the cooling shed.
- Otherwise – the successive group is being delayed
- Consequently, a 80m buffer was designed and the junction was relocated accordingly
A mega dairy in India - results
Farming area 5.
Manure scraping

Model suggests:

- two tractor shovels are sufficient for the entire farm.
- (before the model- four shovels)
- Tractor utilization is rather high, 0.92–0.95
- The 36 cowsheds can be cleaned within 1 shift
- (before the model two shifts)

Manure-scraping simulation program objects and user interface
A mega dairy in India - results

Farming area 6. Cow-feed processing and distribution center

Model suggests:

• Two mixers and two wagons are required to finish 42 rounds within 16.25 h per day (two 8-h shifts).
• (before the model –

  three shifts, four wagon and three mixers)
A mega dairy in India - results

Farming area 7.

Labor traffic

Model suggests:

• one single bus carrying 50 passengers seems to be sufficient.
• The bus utilization was 0.28.
• Average transfer time for a worker was 0.34 h each way.
• (before the model – three busses)
Figure 7. Validation – queuing vs. regression models.
Conclusions (1)

Innovative aspects:

- (statistic CAD drawing, Excel, each components separately) **failed** to handle the mutual interaction between several facilities.
- A design concept for a mega dairy was developed.
- The model incorporates:
  - cow traffic,
  - milking parlors,
  - vet treatment,
  - manure handling,
  - cow cooling,
  - feed-center operation,
  - workers' transportation
  - A problematic junction, and their interrelations

Systems engineering

- **Design all components as one single system**

Aiming at:

- animal friendly
- environment friendly
- convenient for humans
- economically feasible
- Social aspects - local community
- sustainability

Simulation & Optimization
Conclusions (2)

• The model found bottle-necks

• The model maximized production capacity in terms of cows throughput in the milking parlor

• The simulation suggested “optimal solution”.

• The model recommendations were discussed with and were accepted by the farm managers and designers.

• In further research other aspects should be incorporate:
  • Local community interaction: social issues, animal care tradition
  • Environment
  • Branding and social networks
Open questions
How does a mega-dairy influence the local rural community?:

• Roads and water infrastructure
• Land price, and local feed supply and price
• Local tradition concerning animal care
• Odour smell, water contamination,
• Social – are the workers are locals?
• Branding and social networks?
• How big do you want to go?
• Environment, Sustainability?

Book – copy, to contribute a chapter -
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