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Agricultural Engineering Institution

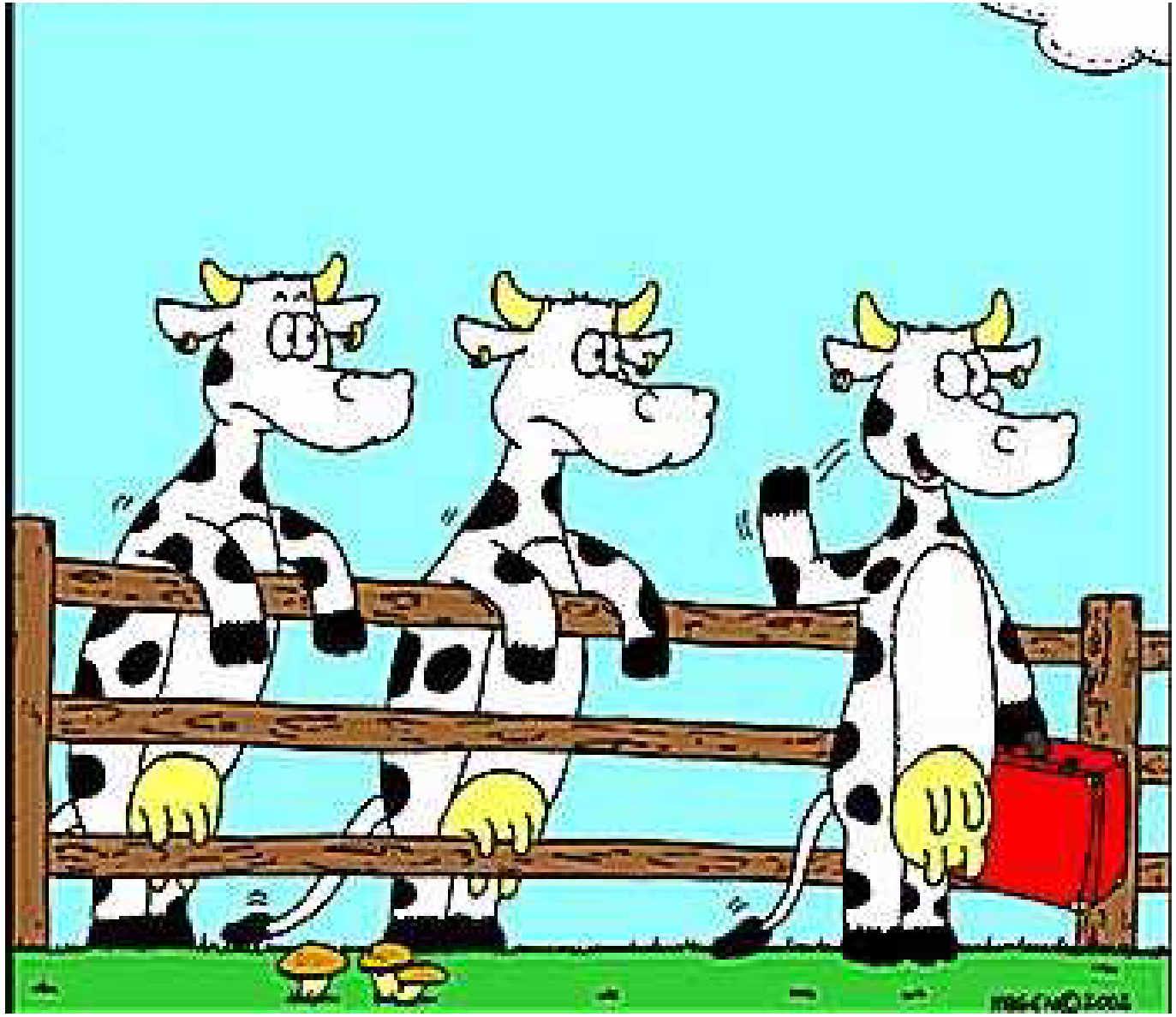
The design of mega dairies in India: optimal facility allocation, and how big do you want to go ?

Ilan Halachmi

ARO, The Volcani Centre, Bet Dagan. Israel

EAAP 2014 Copenhagen Denmark

Please ask during the presentation



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So long losers !
I'm off to India to live like a Goddess…

A mega dairy in India – in brief

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- 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

- <u>Design criteria were:</u>
  - 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.

<u>All design criteria were met.</u>

- <u>We modeled eight farming aspects:</u>

  * cow traffic,
  * vet treatment,
  * cow cooling,
  * workers' transportation
  * milking parlors,
  * manure handling,
  * feed-center operation,
  * a problematic junction,

  <u>and their interrelations.</u>

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

A mega dairy subsystems

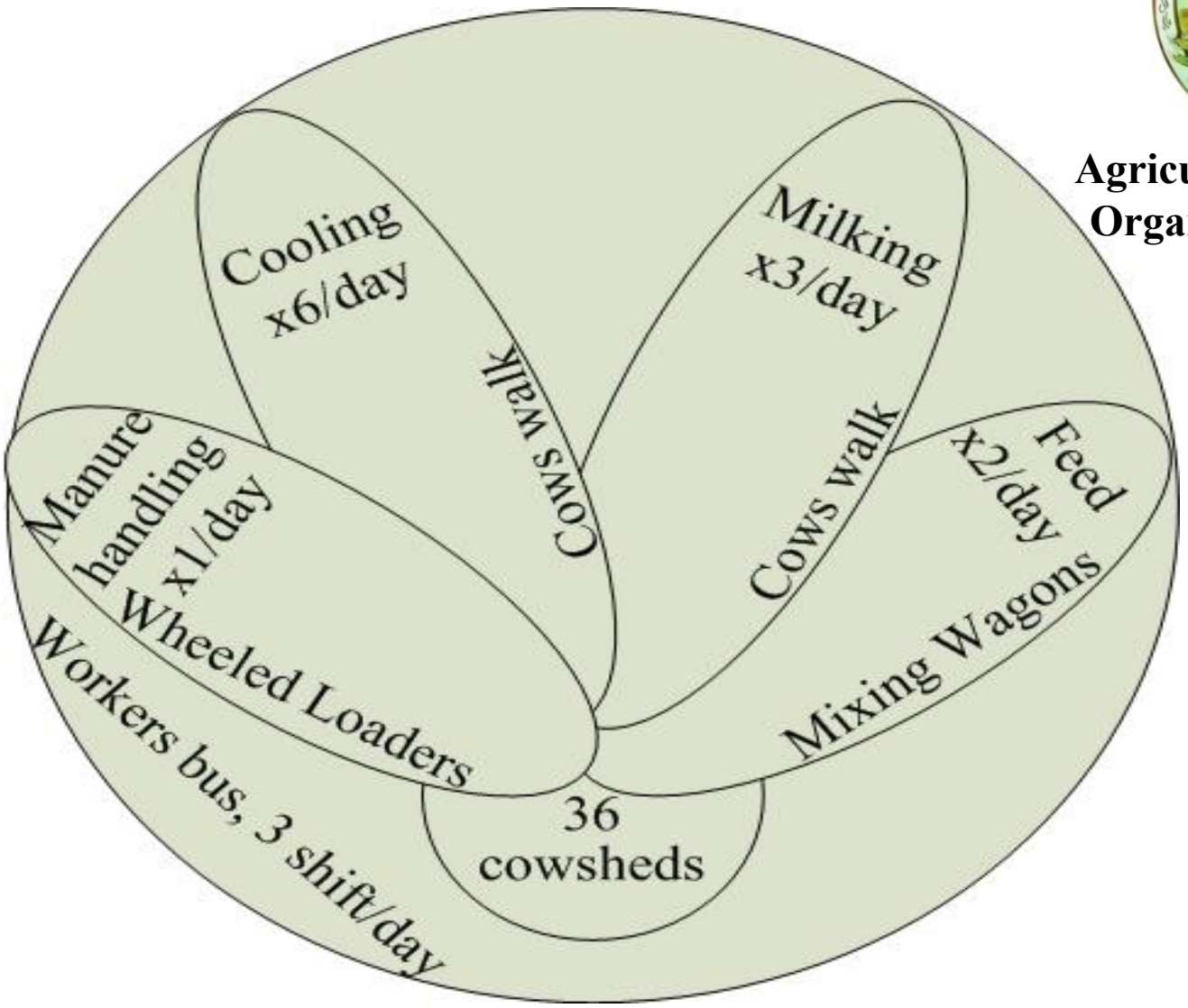

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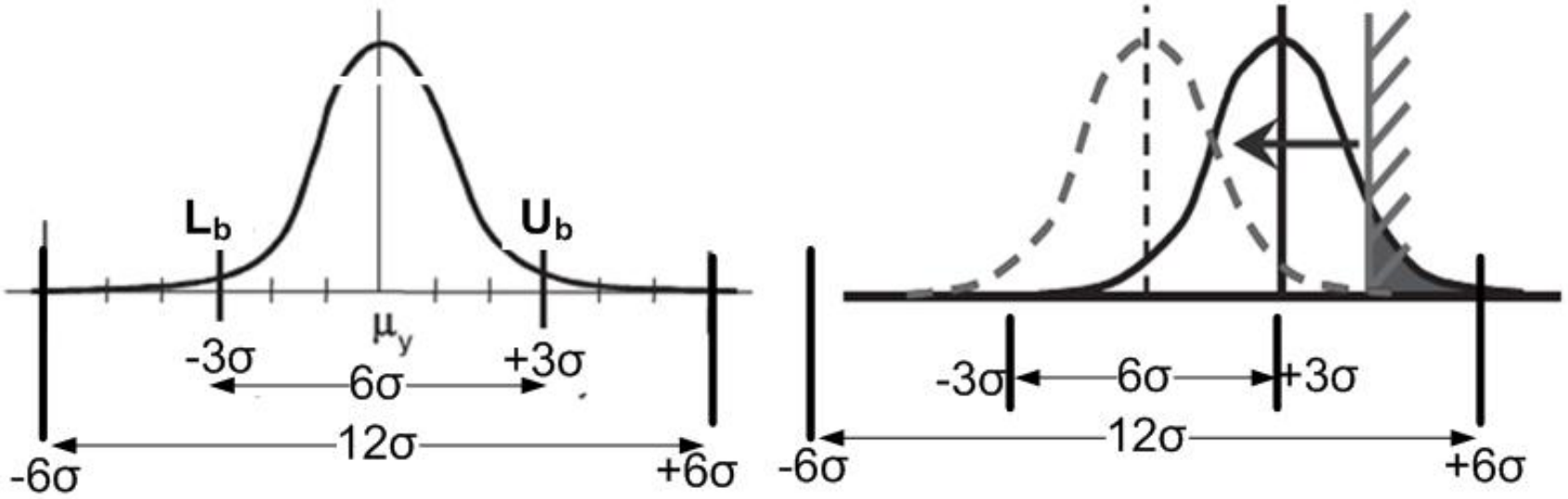
Figure 1. The mega dairy's five traffic circles

Design tool 1. Robust 6σ design

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



standard deviation	Percent variation (%)	Missed milkings per year (no sigma shift)	Missed milkings per year (1.5σ shift)
±1σ	**68.26**	**3628453**	**7975966**
±3σ	**99.73**	**30865**	**763678**
±4σ	**99.99**	**720**	**70877**
±5σ	**99.9999**	**6.5**	**2664**
±6σ	**99.999999**	**0.02**	**39**

Design tool 2.
closed queuing network

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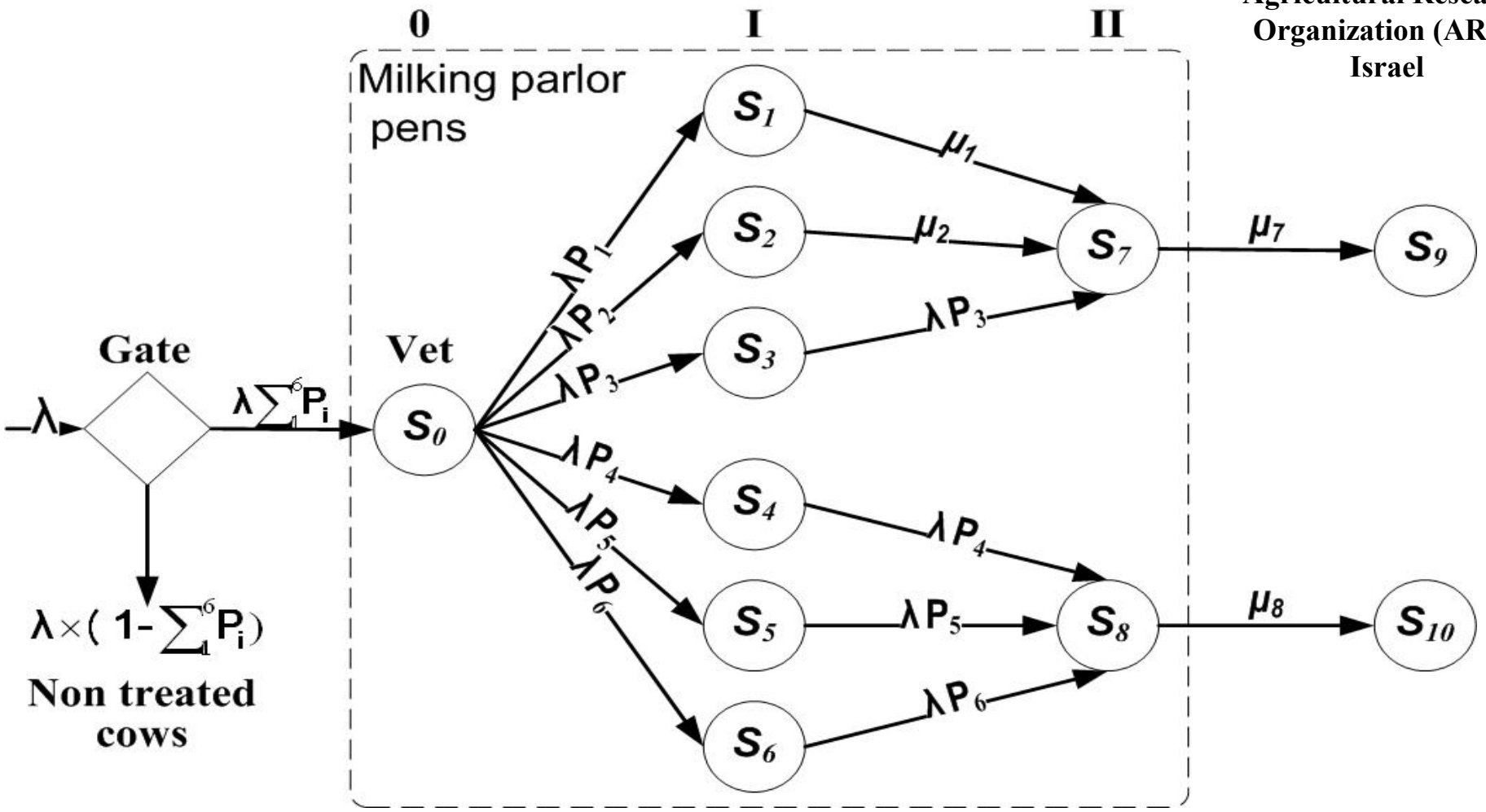
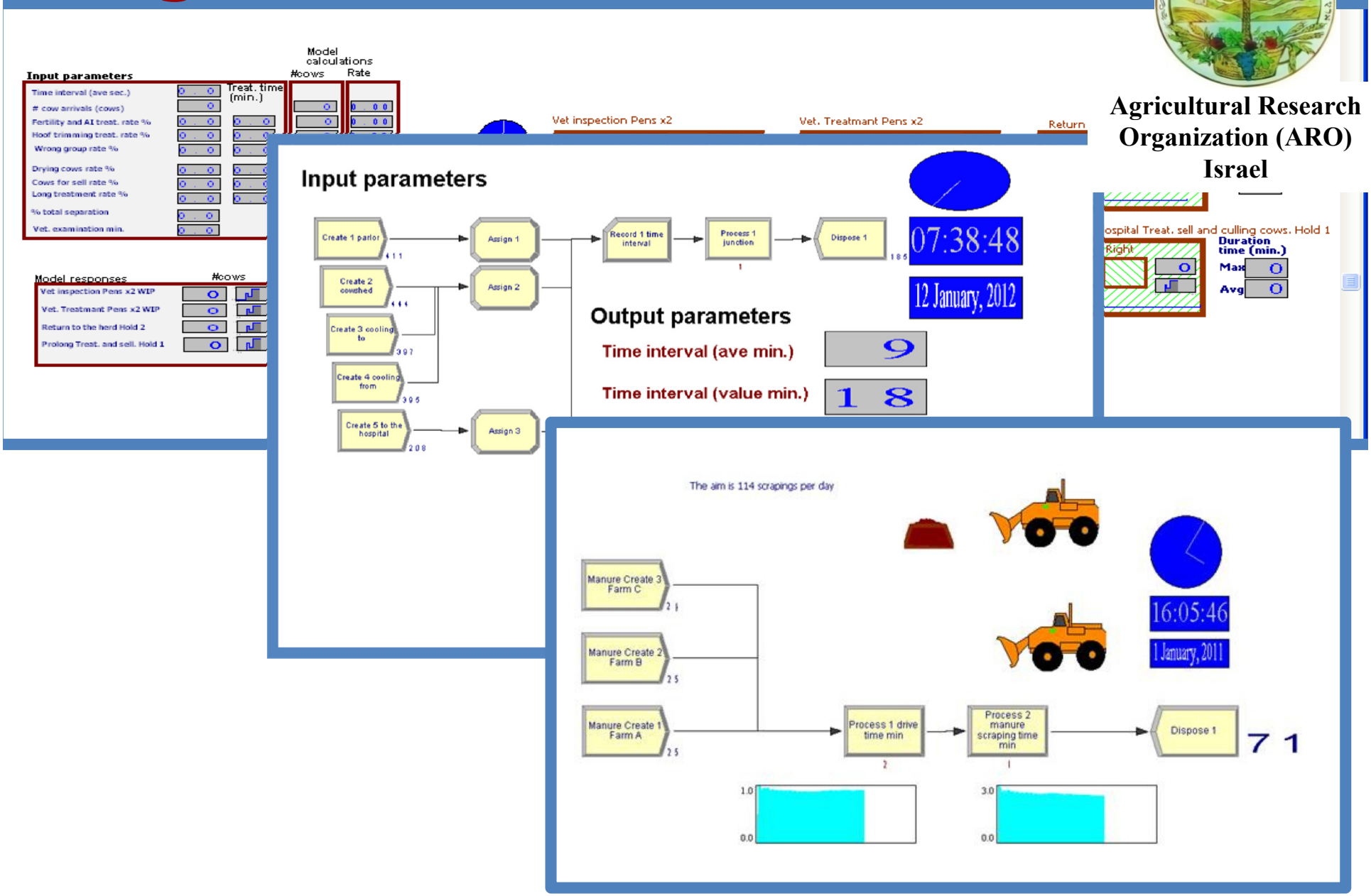


Figure 6. The flow of the cows throughout the treatments at the parlor's pens

Design tool 3. Simulation model



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Design tool 4. Optimization

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A deterministic design problem:

Minimizes: $F(\mu_y(X))$

subject to: $gi(\mu_y(X)) \leq 0$

$X_L \leq \mu_X \leq X_U$.

A probabilistic design problem:

Minimizes: $F(\mu_y(X), \sigma_y(X))$

subject to: $gi(\mu_y(X), \sigma_y(X)) \leq 0$

$X_L + n\sigma X \leq \mu X \leq X_U - n\sigma X$

$$\mu_y - n\sigma_y \geq \text{Lower specification limit}$$
$$\mu_y + n\sigma_y \leq \text{Upper specification limit}$$

n=6

The complexity

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

Systems engineering

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

Design all components as one single system

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

Simulation & Optimization

A mega dairy subsystems = 7 models

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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

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- 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

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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 :**

"Mommy wants you to know where your food comes from."

"I tried looking through rose-colored glasses, but that just made it worse."

A mega dairy in India - results

Farming area 3. Cow traffic

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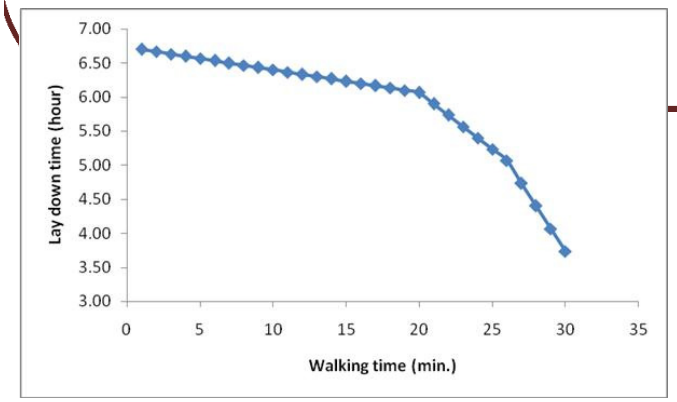
Based on the model, the decision were:

- **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

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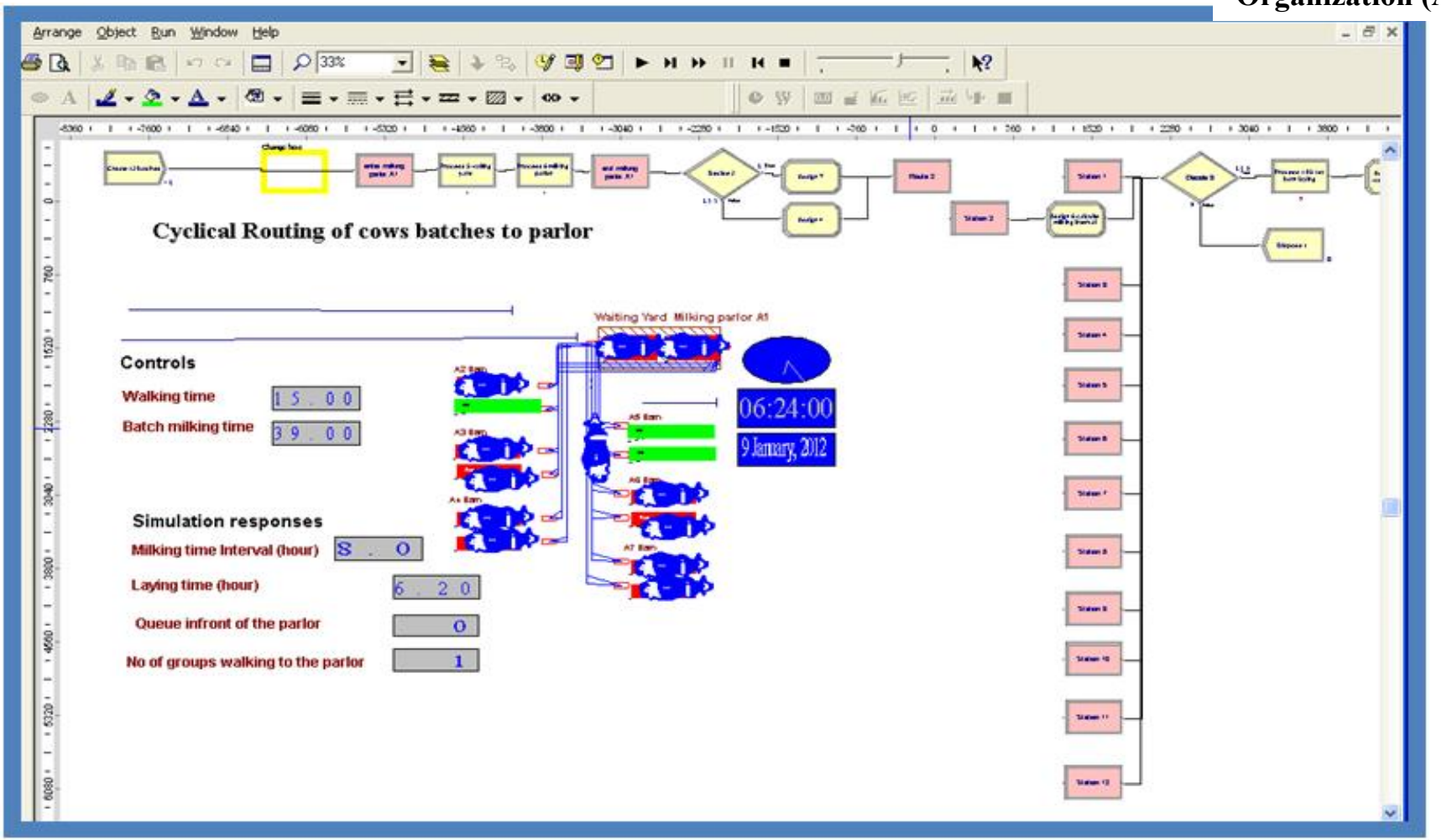
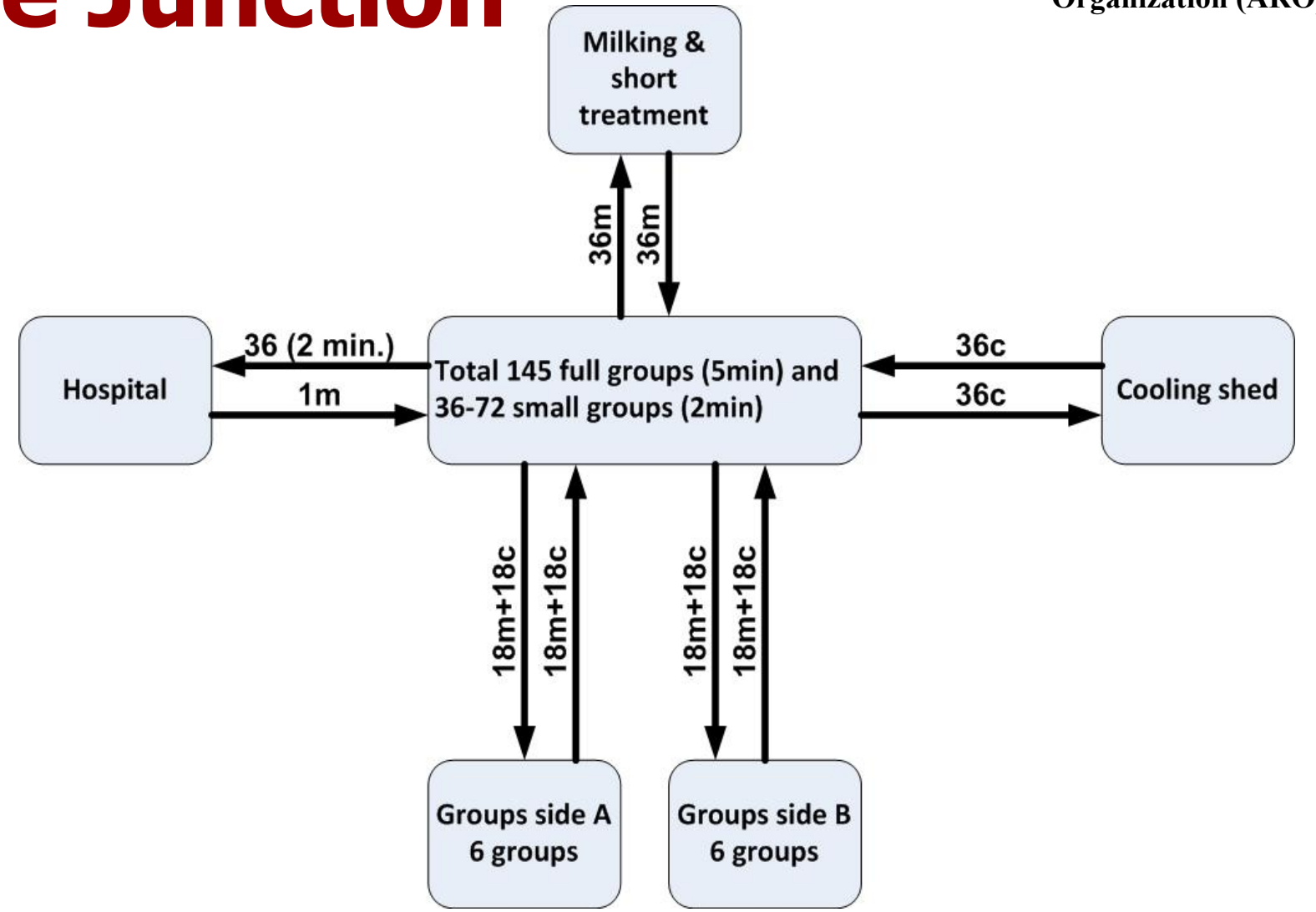


Cow traffic simulation program objects and user interface; the influence of walking time on the availability of cow reclining time

A mega dairy in India - results

Farming area 3.
The Junction



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Farming area 3. The Junction

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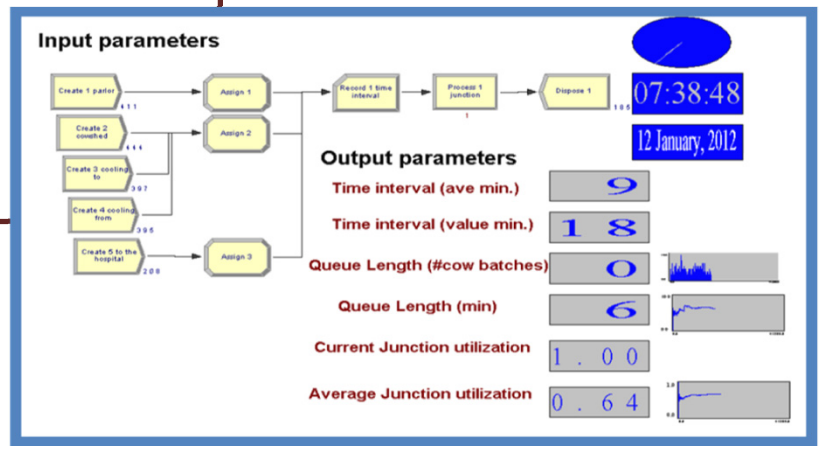
Model suggests:

- 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



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Farming area 5.
Manure scraping

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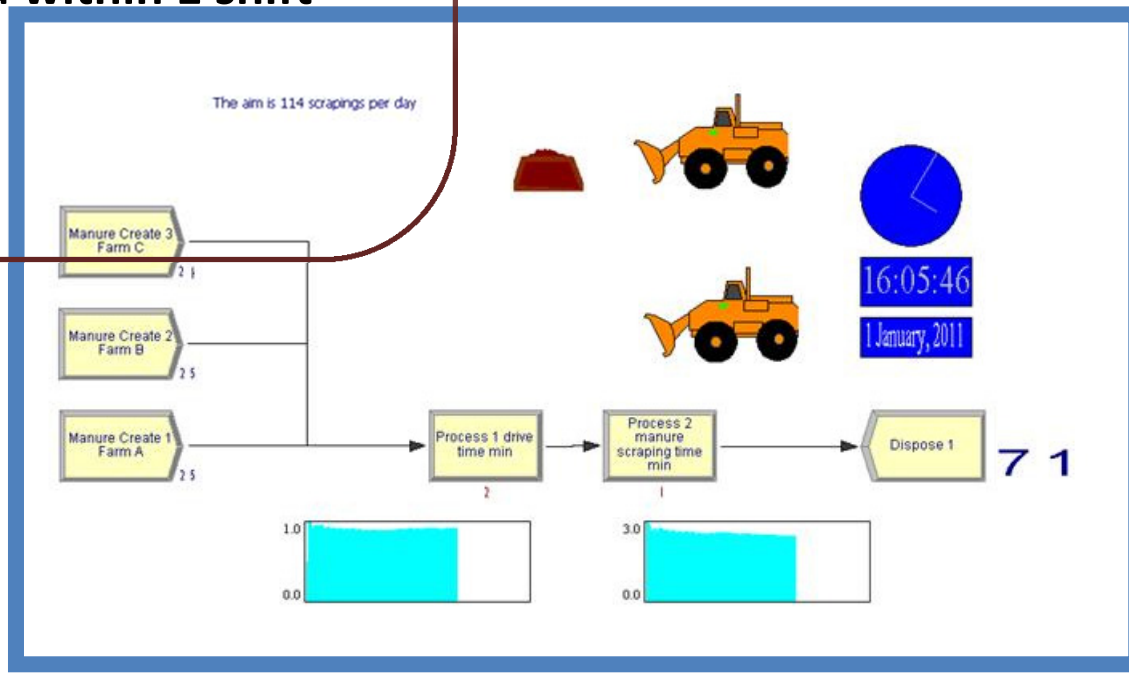
Model suggests:

- 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

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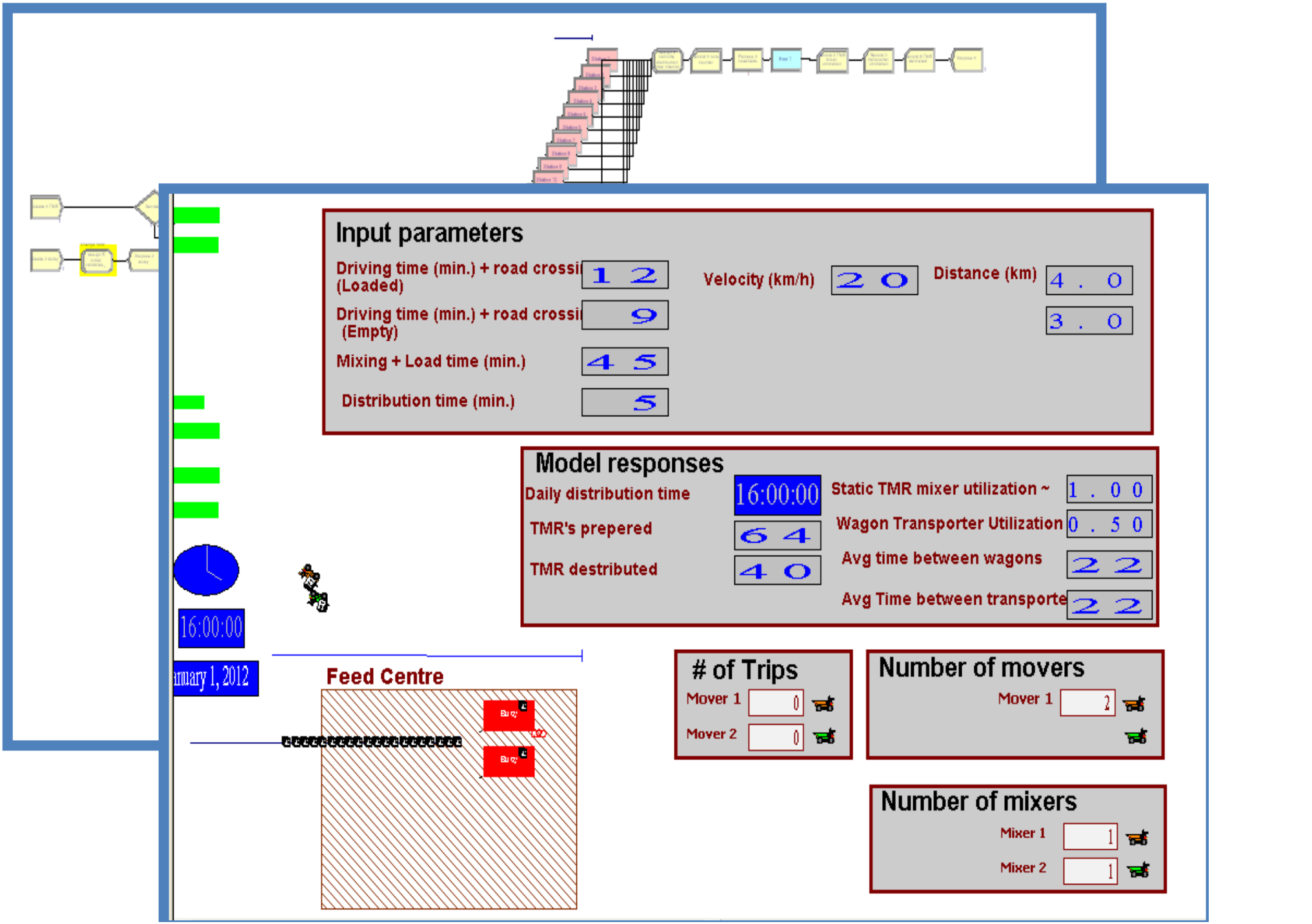
Farming area 6. Cow-feed processing and distribution center

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)


Input parameters
Driving time (min.) + road crossi (Loaded)
12
Velocity (km/h)
20
Distance (km)
4.0
Driving time (min.) + road crossi (Empty)
9
3.0
Mixing + Load time (min.)
45
Distribution time (min.)
5
Model responses
Daily distribution time
16:00:00
Static TMR mixer utilization ~
1.00
TMR's prepered
64
Wagon Transporter Utilization
0.50
TMR destributed
40
Avg time between wagons
22
Avg Time between transporte
22
16:00:00
Feed Centre
# of Trips
Mover 1
0
Mover 2
0
Number of movers
Mover 1
2
Number of mixers
Mixer 1
1
Mixer 2
1

A mega dairy in India - results

Farming area 7.
Labor traffic

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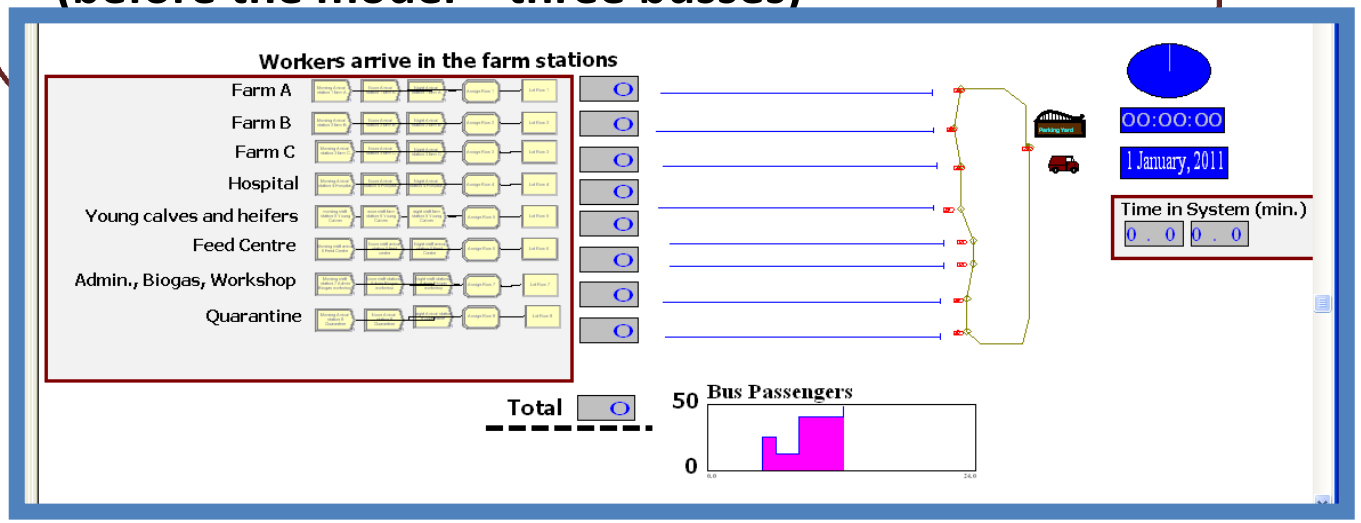
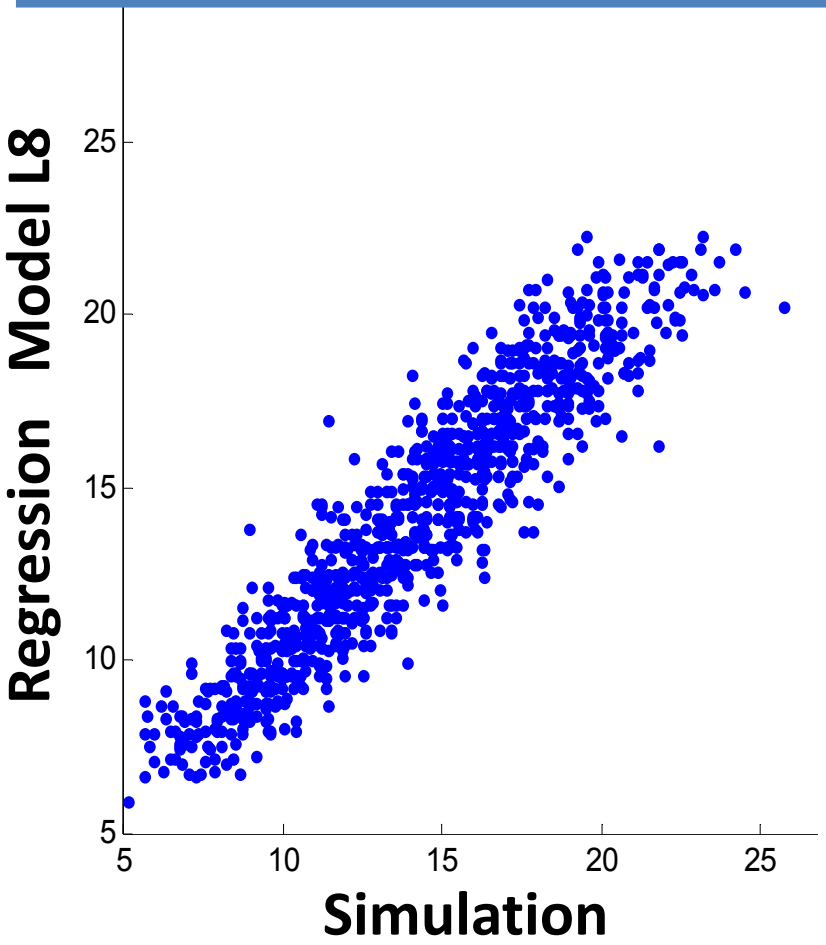
Model suggests:

- 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)



Labor traffic simulation program objects and user interface: layout view

Model Validation



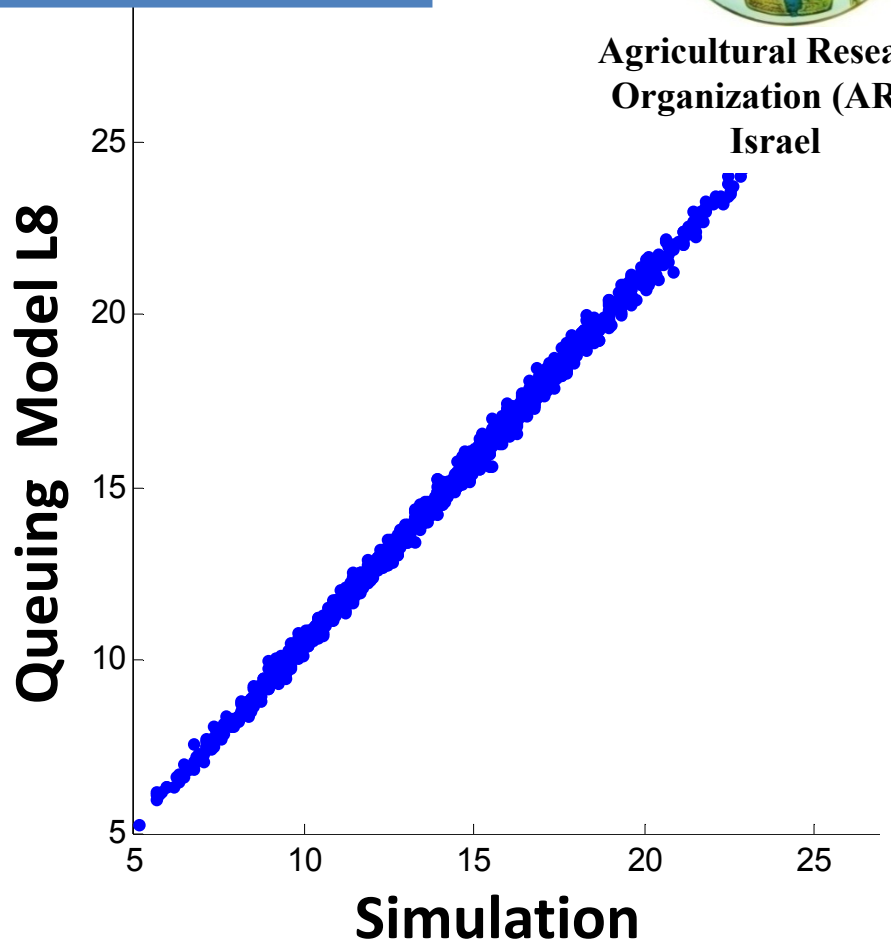


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Figure 7. Validation – queuing vs. regression models.

Conclusions (1)

Innovative aspects: **Systems engineering**

(statistic CAD drawing, Excel, each components separately)

failed to handle the mutua

Design all components as one single system

- A design concept for a mega
- The model incorporates:
  - cow traffic,
  - milking parlors,
  - vet treatment,
  - manure handling,
  - cow cooling,
  - feed-center operation,
  - workers' transportation
- A problematic junction, and their interrelations

Simulation & Optimization

Aiming at:

- animal fr
- environm
- convenient for humans
- economically feasible
- Social aspects - local community
- sustainability

Conclusions (2)

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- 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

<u>How does a mega-dairy influence the local rural community ?:</u>

- 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 ?

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Book – copy , to contribute a chapter -

halachmi@volcani.agri.gov.il Ilan Halachmi


Jim Thompson - Lyerly - Cow-Test - D18