Evaluating An Emergent Behaviour Algorithm for Energy Conservation in Lighting Systems Using JCSP

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Energy saving

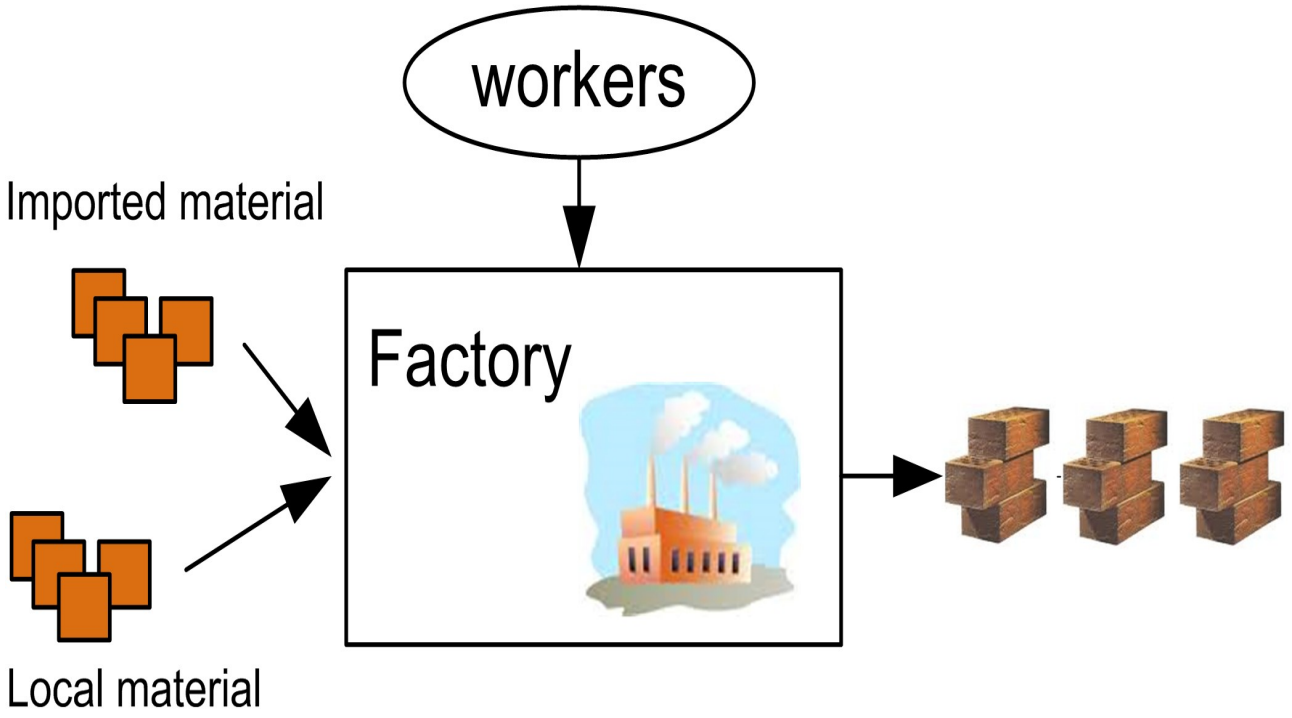
- Beneficial for the environment
- Saving money
- Helps reducing load peaks in the power system

Building automation system trends

- Pervasive
- Distributed
- Adaptive
- Performing “intelligent” behaviour

The Brick Factory

- Material
  - Cheap (limited),
  - expensive (not limited).
- Employees
- Manager



Challenges

- Is it possible to make this brick making company reliable, as long as there are employees to work?
- How to minimize the production cost by using available employees and material?

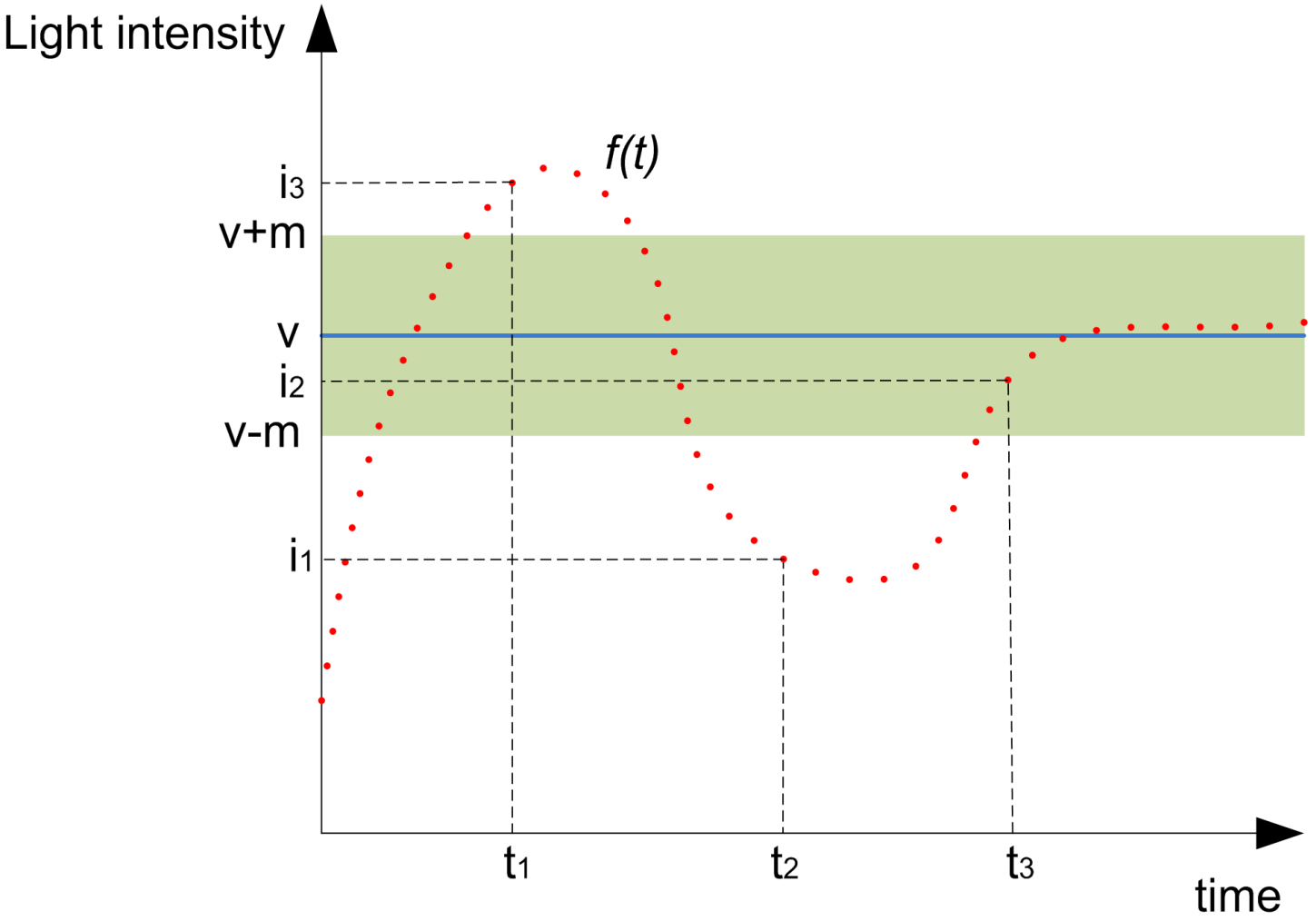
Lazy and Enthusiastic Employee algorithm

Request	Lazy employee	Enthusiastic employee
The overall production is to small	Waits and increases the workload only slightly	Starts working immediately at full speed
The overall production is to large	Stops working immediately	Waits and decrease the workload only slightly

Employees behaviour

- The first reaction is crucial
- Reduction of feedback loop problem
  - Various reaction
  - Various increase/decrease factor

Margin



Increase/decrease factor

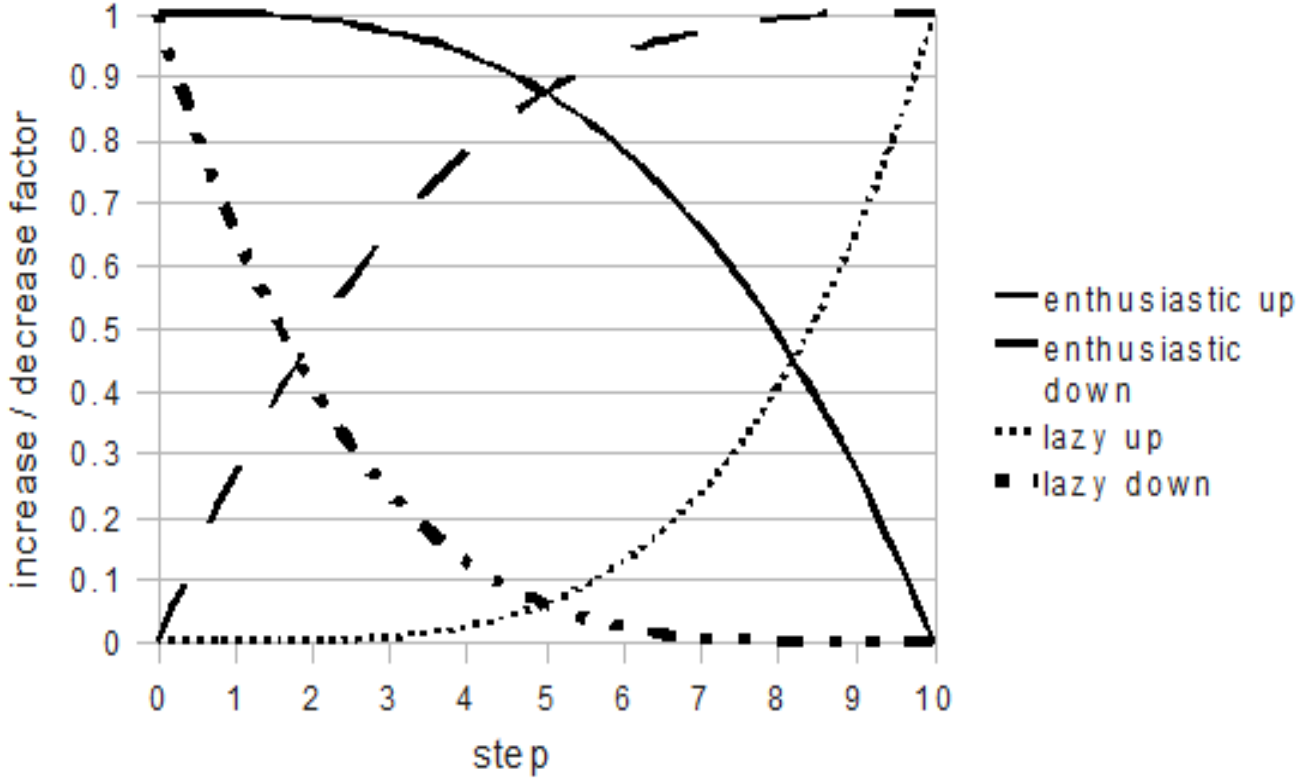
- Independent of the actual production rate
  - Constant (linear)
  - Variable (based on a curve)
- Dependent of the actual production rate
  - Distance-based

Constant factor

	Enthusiastic	Lazy
Increase	$g'_{a_1}(\Delta d) = 3,$	$g'_{b_1}(\Delta d) = 1,$
Decrease	$h'_{a_1}(\Delta d) = 1,$	$h'_{b_1}(\Delta d) = 3,$

Various factor

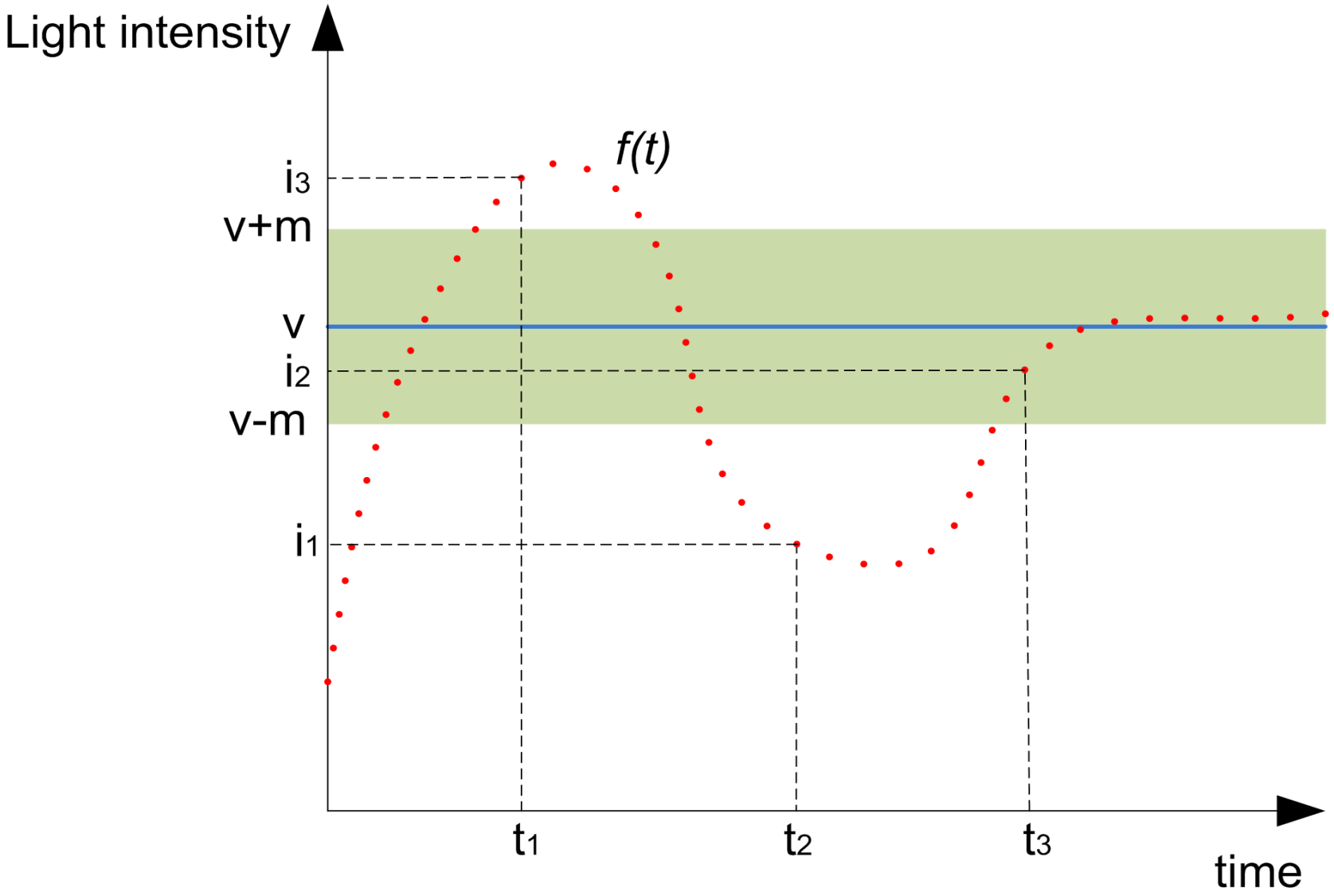
$$g'_{a_2}(step, \Delta d) = \Delta d \cdot (step^4/100)/100, \quad \text{where } step \in [0, 10],$$
$$h'_{a_2}(step, \Delta d) = \Delta d \cdot ((step - 10)^4/100)/100, \quad \text{where } step \in [0, 10],$$
$$g'_{b_2}(step, \Delta d) = \Delta d \cdot ((step - 10)^3/10 + 100)/100, \quad \text{where } step \in [0, 10],$$
$$h'_{b_2}(step, \Delta d) = \Delta d \cdot (100 - (step)^3/10)/100, \quad \text{where } step \in [0, 10].$$



Distance-dependent factor

$$
\begin{aligned}
g''_{a_4}(i,v) &= (1 - (|v-i|/v)) && v, i > 0, \\
h''_{a_4}(i,v) &= (|v-i|/v) && v, i > 0, \\
g''_{b_4}(i,v) &= (|v-i|/v) && v, i > 0, \\
h''_{b_4}(i,v) &= (1 - (|v-i|/v)) && v, i > 0.
\end{aligned}
$$

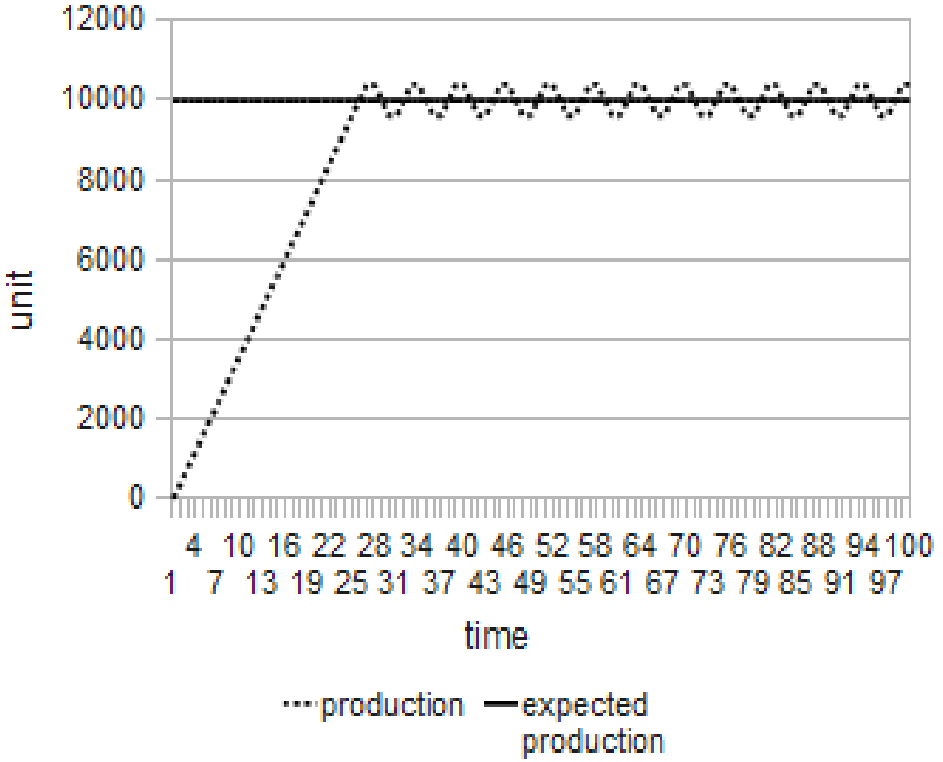
Margin

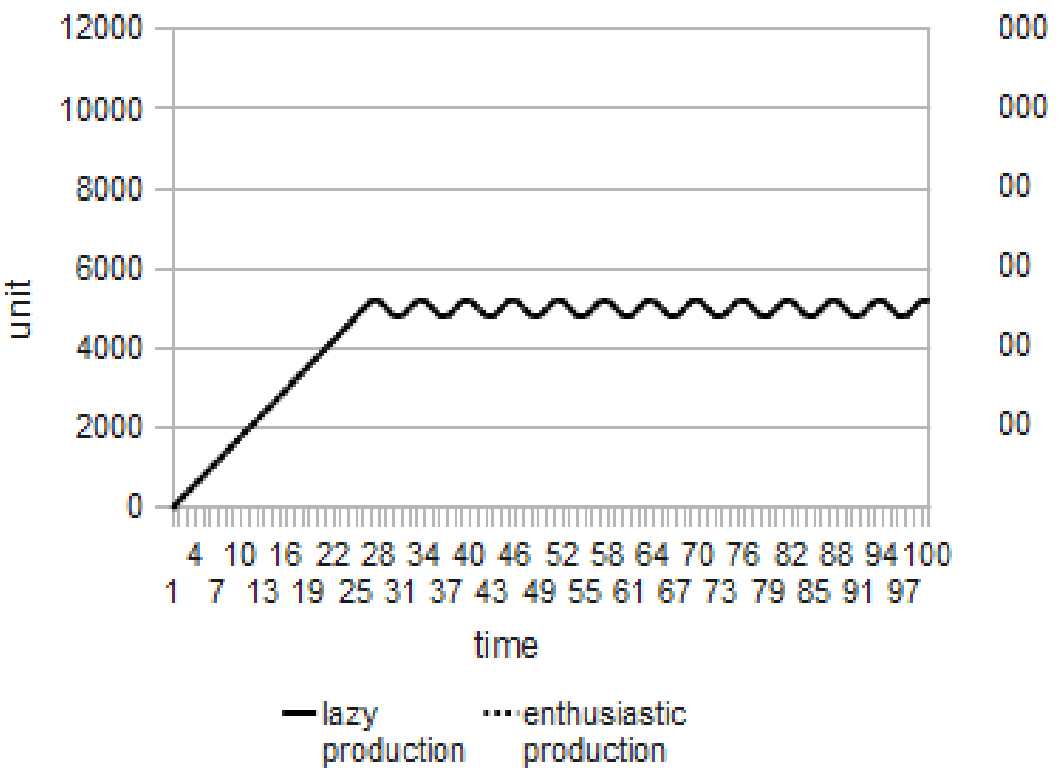


Experiment set-up

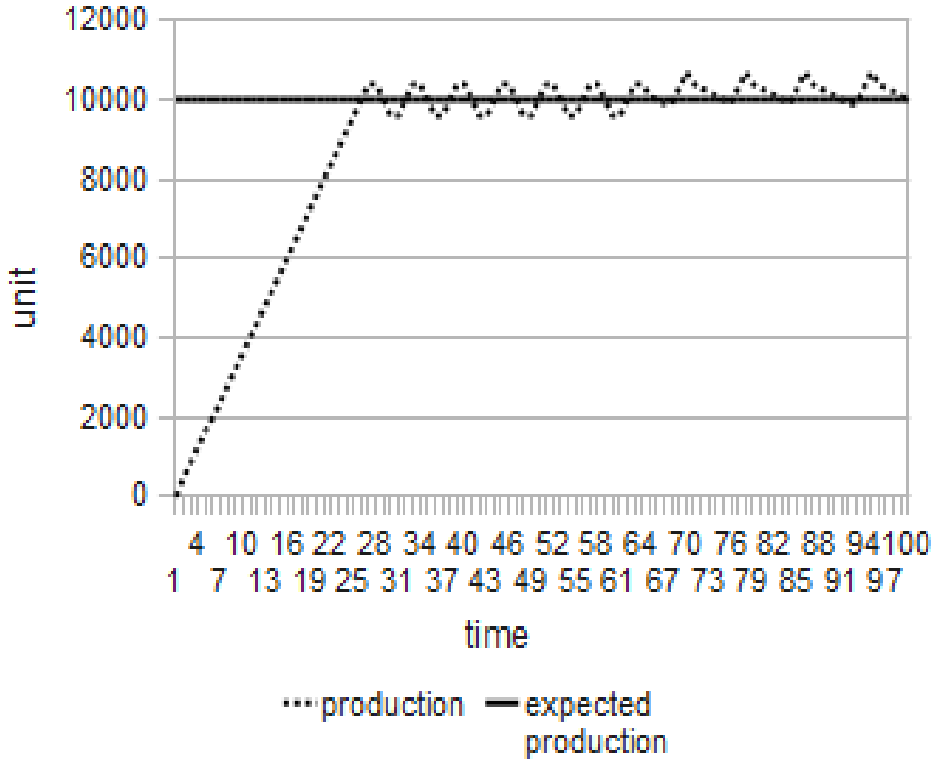
- 100 Lazy workers
- 100 Enthusiastic workers
- Ideal production 10,000 bricks/minute
- All start from 0 bricks/minute
- Default increase factor is 10 bricks/minute
- Cheap material 1$, expensive material 10$

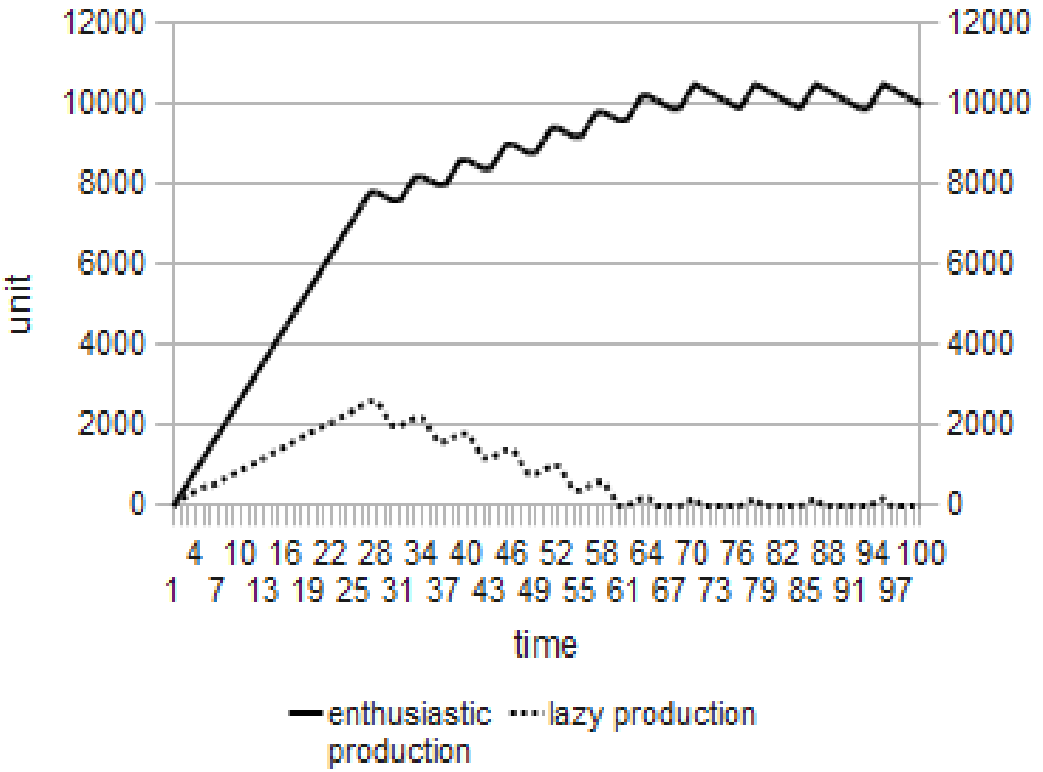
Reference data



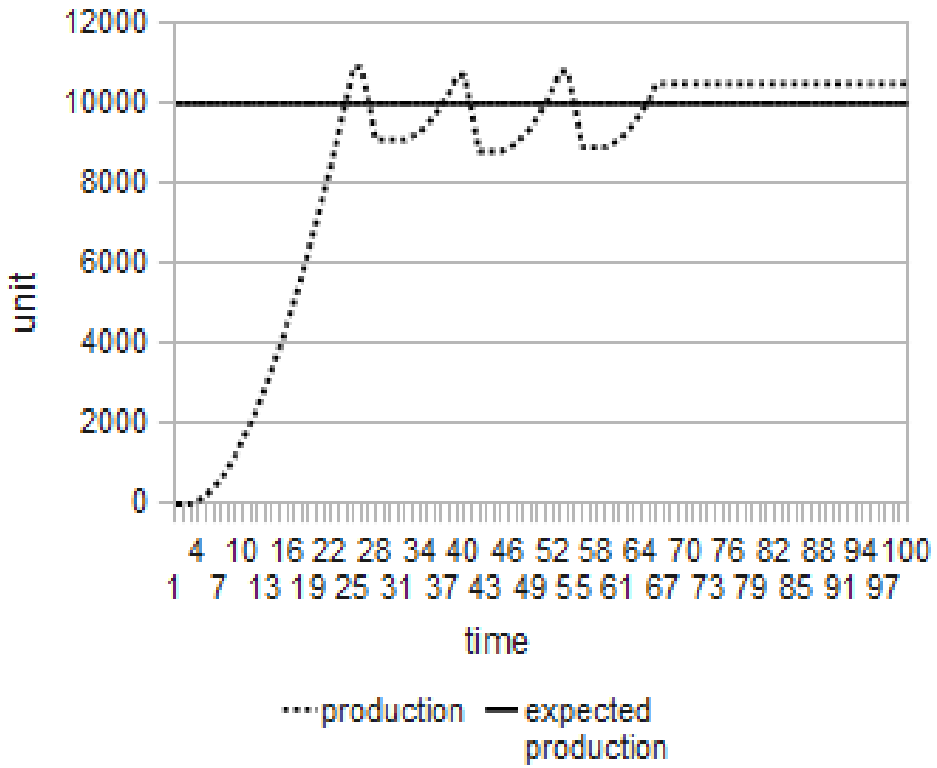


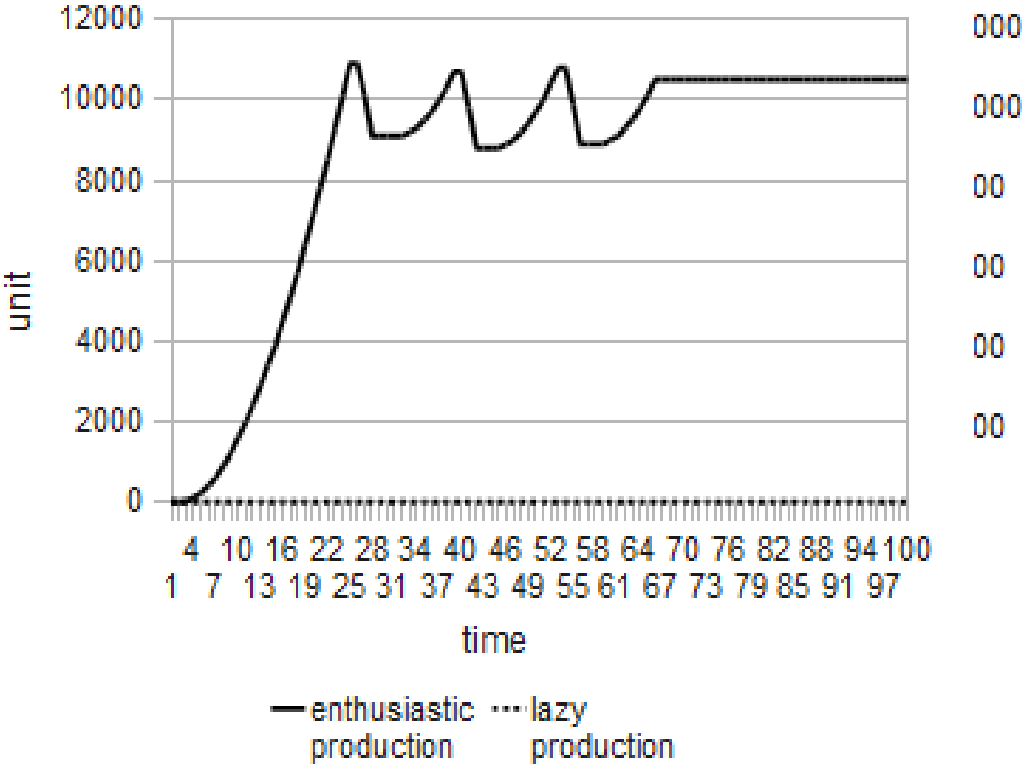
Constant factor





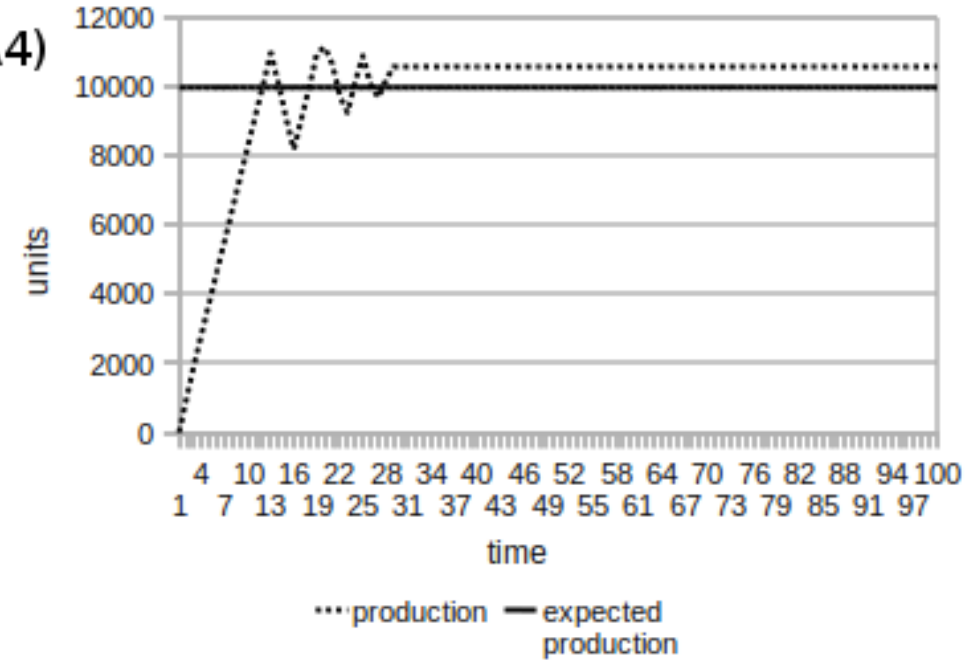
Various factor

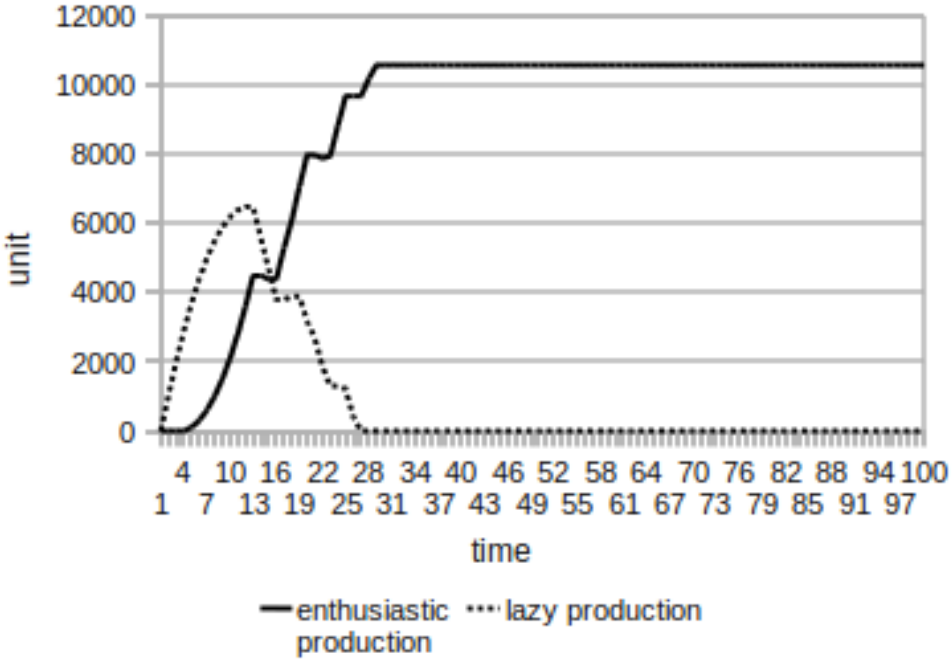




Distance-dependent factor

(A4)



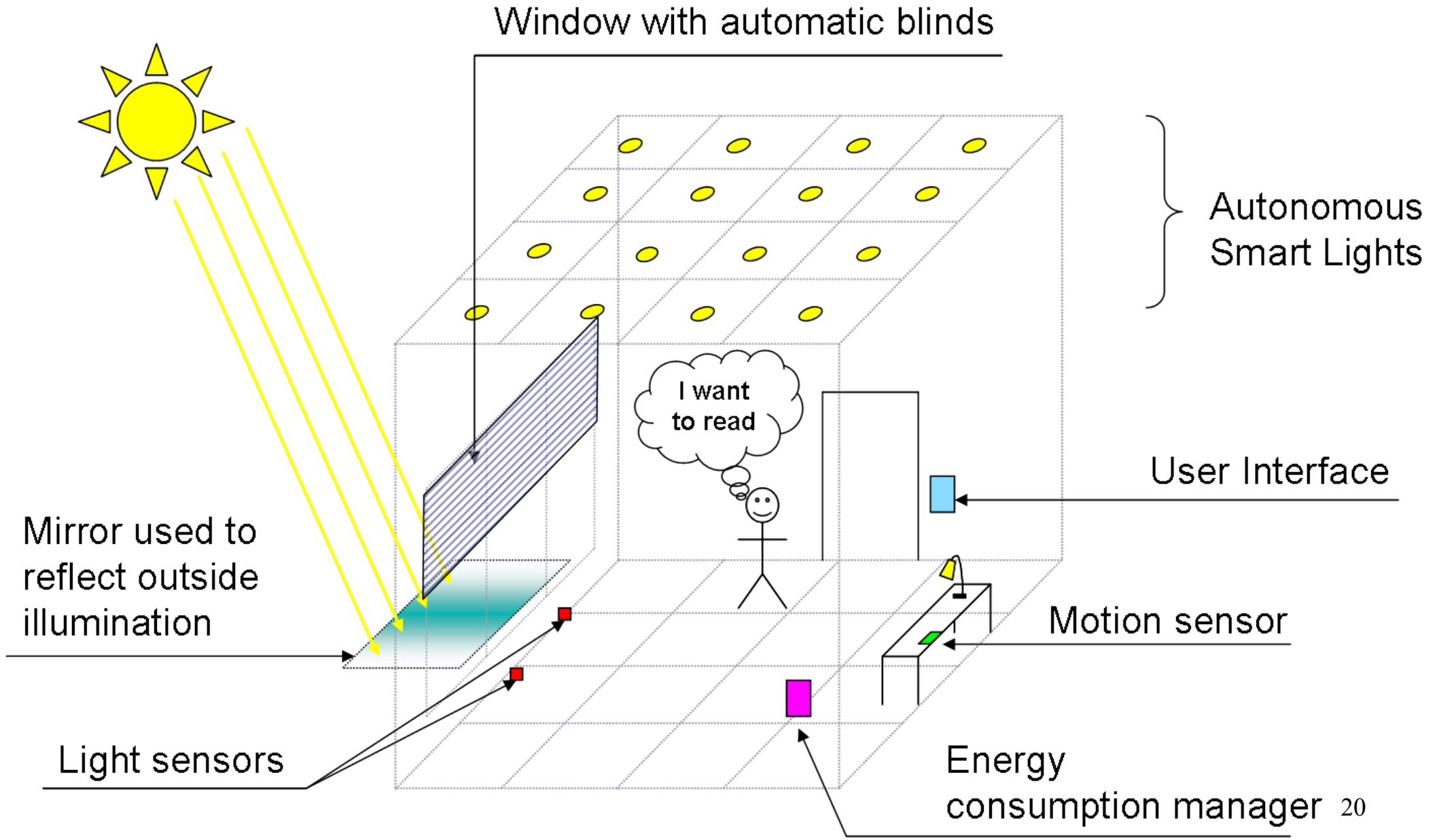


(B4)

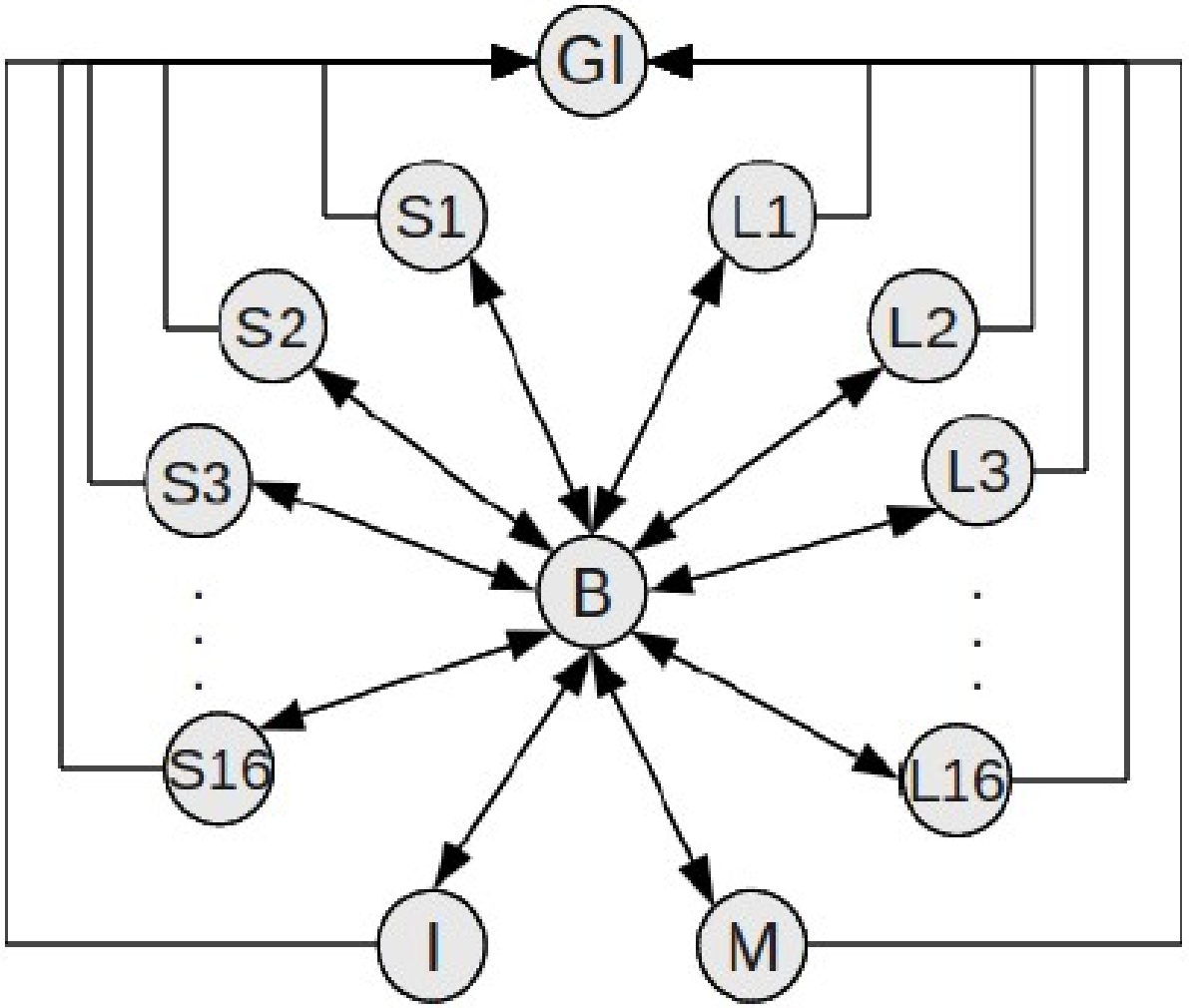
Results

Function used	Cheap bricks cost ($)	Expensive bricks cost ($)	Overall cost ($)	Factory reliability (%)
constant	798601	800520	1599121	72
various	84390	0	89390	84
no function	435400	4354000	4789400	76
distance dependent	891502	936440	1827942	94

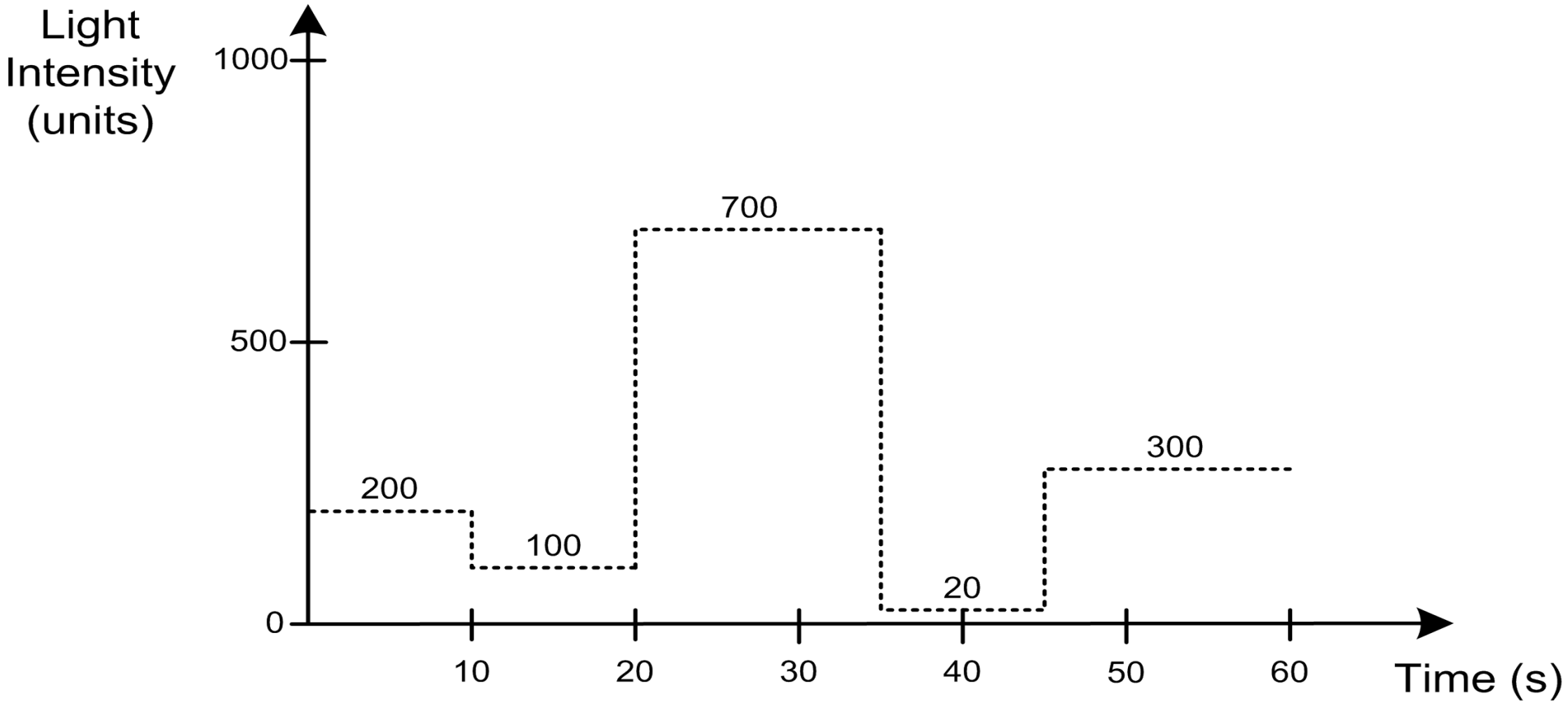
Scenario


Window with automatic blinds
Autonomous
Smart Lights
I want
to read
User Interface
Mirror used to
reflect outside
illumination
Motion sensor
Light sensors
Energy
consumption manager

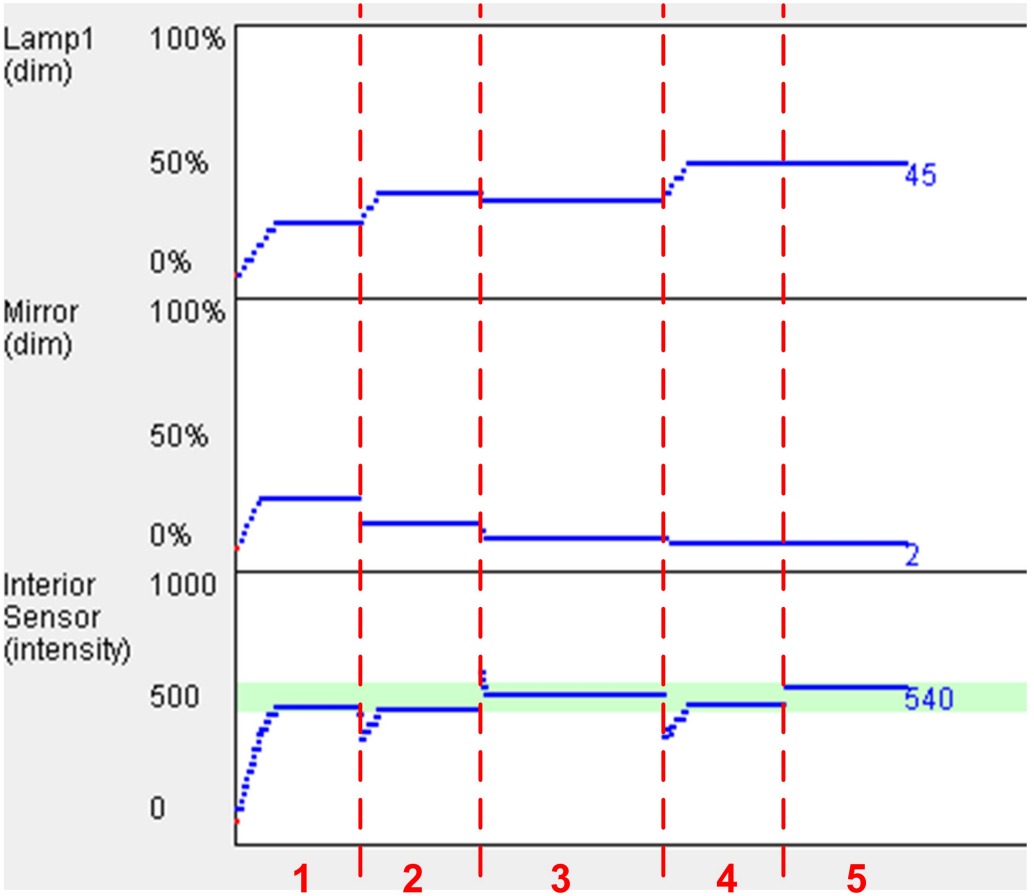
Implementation

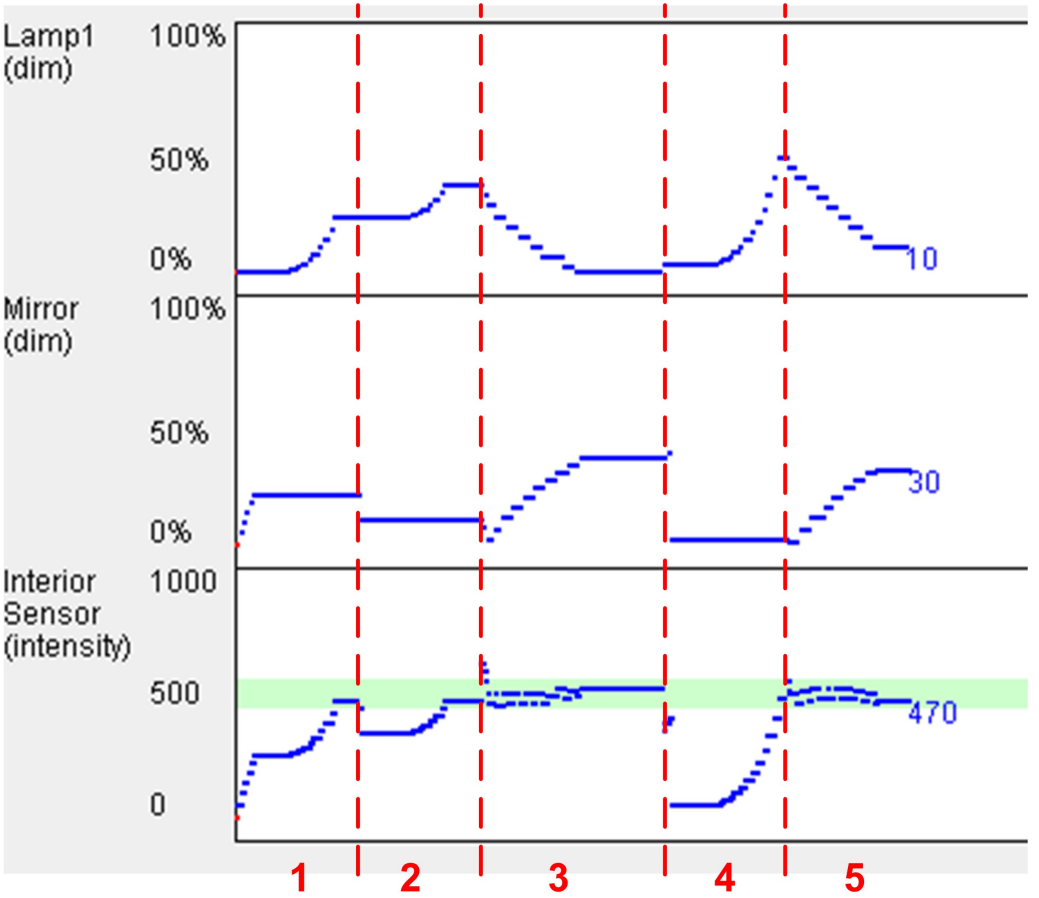


Input data


Light Intensity (units)
1000
500
0
200
100
700
20
300
10
20
30
40
50
60
Time (s)

Results


Lamp1
(dim)
100%
50%
0%
45
Mirror
(dim)
100%
50%
0%
2
Interior
Sensor
(intensity)
1000
500
0
540
1
2
3
4
5


Lamp1
(dim)
100%
50%
0%
10
Mirror
(dim)
100%
50%
0%
30
Interior
Sensor
(intensity)
1000
500
0
470
1
2
3
4
5

Energy usage

Algorithm	Energy usage (J)
No algorithm, all lamps 100% dim	86700
Dimming control, no algorithm	31428
L&EE Algorithm	16019

81,5 % energy savings!

Questions?