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How to estimate the effect of increasing rejects in stock preparation for side stream applications – Outcome from process models

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Outline

1. Why do modern mills need process modelling tools?
2. Use of process models
3. Towards a framework for process modelling in paper mills
4. Design and structure of process models
5. Modelling and validation of increased rejects in deinking flotation

Influencing processes in paper mills

- Influencing the production
  - Automatic controls
  - Manual inputs by operators

Manual entries are affected by decisions of the mill operators

Decisions are based on process data from DCS's and in most cases on additional laboratory data.

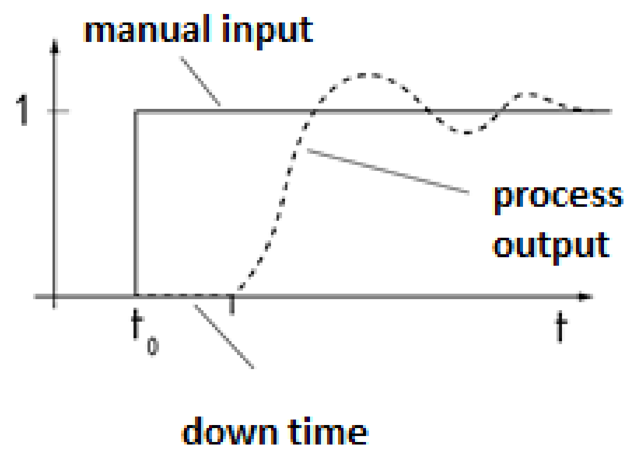
http://www.papierundtechnik.de/pt/live/fachartikel/pspic/bild1/7/Abb_4_PLT_4344dcaa64e87.jpg

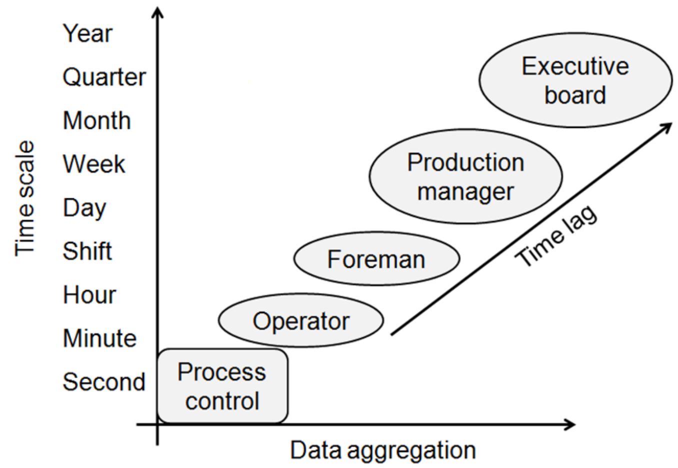
Skipping time lags – Advantages of process models

▪ Both manual inputs and the process of data aggregation cause a time lag in paper mills.

<u>Advantages of process models:</u>

- Prediction of both process and quality parameters
- Supporting sustainability indicator calculation
- Assessment of sidestream applications





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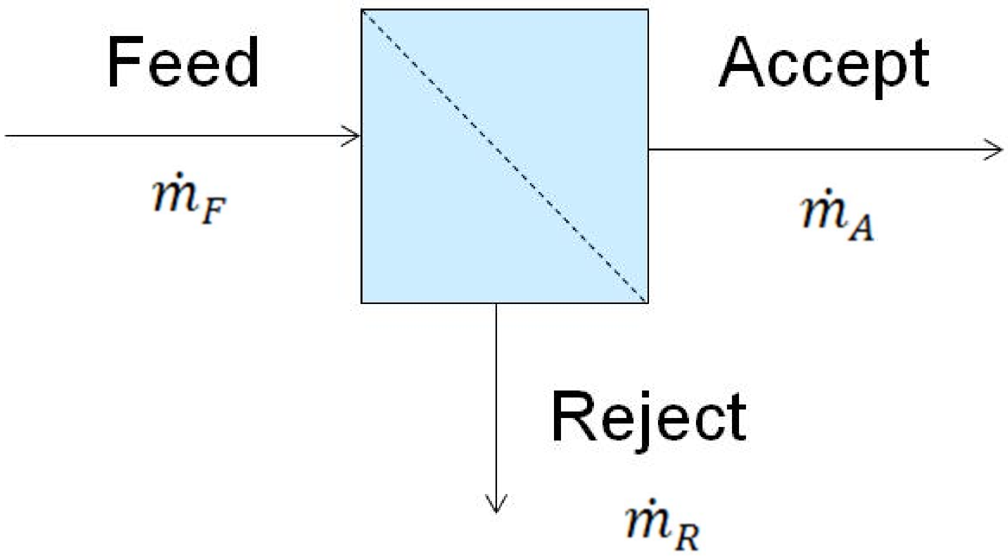
Use of process modelling tools

- Forecast on effects of:
  - Changes in composition of feed material,
  - Changes in reject rates,
  - Changes in the interconnection of process elements,
  - Changes in the resource consumption of different processes.

State of the art – Process modelling tools

- Balancing of mass flows within a separation process and definition of reject rates



$$\dot{m}_F = \dot{m}_R + \dot{m}_A$$

$$RR_m = \frac{\dot{m}_R}{\dot{m}_F}$$

Basic data structure of the models (1)

Components	Symbol
Long Fibre Fraction	LF
Short Fibre Fraction	SF
Fibre Fines	FS
Minerals	ASH
Large Stickies (> 1 mm)	ADH_L
Medium Size Stickies (0.5…1 mm)	ADH_M
Small Stickies (< 0.5 mm)	ADH_S
Specific dirt spec area for particles < 100 µm	SPEC_S
Specific dirt spex area for particles > 100 µm	SPEC_L

Basic data structure of the models (2)

Pulp quality properties	Symbol
Schopper Riegler Value	SR
Water Retention Value	WRV
ERIC Value	ERIC
Brightness	R457

Ressource data	Symbol
Energy consumption	EC
Process water consumption	PWC
Fresh water consumption	FWC

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Processes to be modelled within REFFIBRE

- Modelling of processes of relevance for the industrial partners which have an impact on both the value chain and the properties of the paper produced

Coarse Screening	Separation of coarse contaminants, staples and flakes
Fine Screening	Separation of fine contaminants, macro stickies and dirt specks
Flotation deinking	Separation of organic & inorganic fines, ink and micro stickies

Dispersing	Refining of dirt particles, highly energy-intensive process

Modelling of the single separation element (1)

- Measured:
  - Volumetric flow rate [l/min]
  - Consistency [%]

→ Mass flow rate [kg/min]

- Two main parameters used for calculations and modeling:

$$RR_V = \frac{\dot{V}_R}{\dot{V}_F}$$

Fines/ ash separation

$$RR_m = \frac{c_R * \dot{V}_R}{c_F * \dot{V}_F} = \frac{\dot{m}_R}{\dot{m}_F}$$

fibre/ sticky separation

Modelling of the single separation element (2)

- Material flows in paper mills are a heterogenous mixture of components $w_{i,X}$.
- Components behave differently in separation devices → Definition of the component-specific separation efficiency

$$E_R = \frac{w_{i,R} * \dot{m}_R}{w_{i,F} * \dot{m}_F}$$

- Calculation of the device-specific screening index α for each component

$$E_R = {RR_m}^{\alpha}$$

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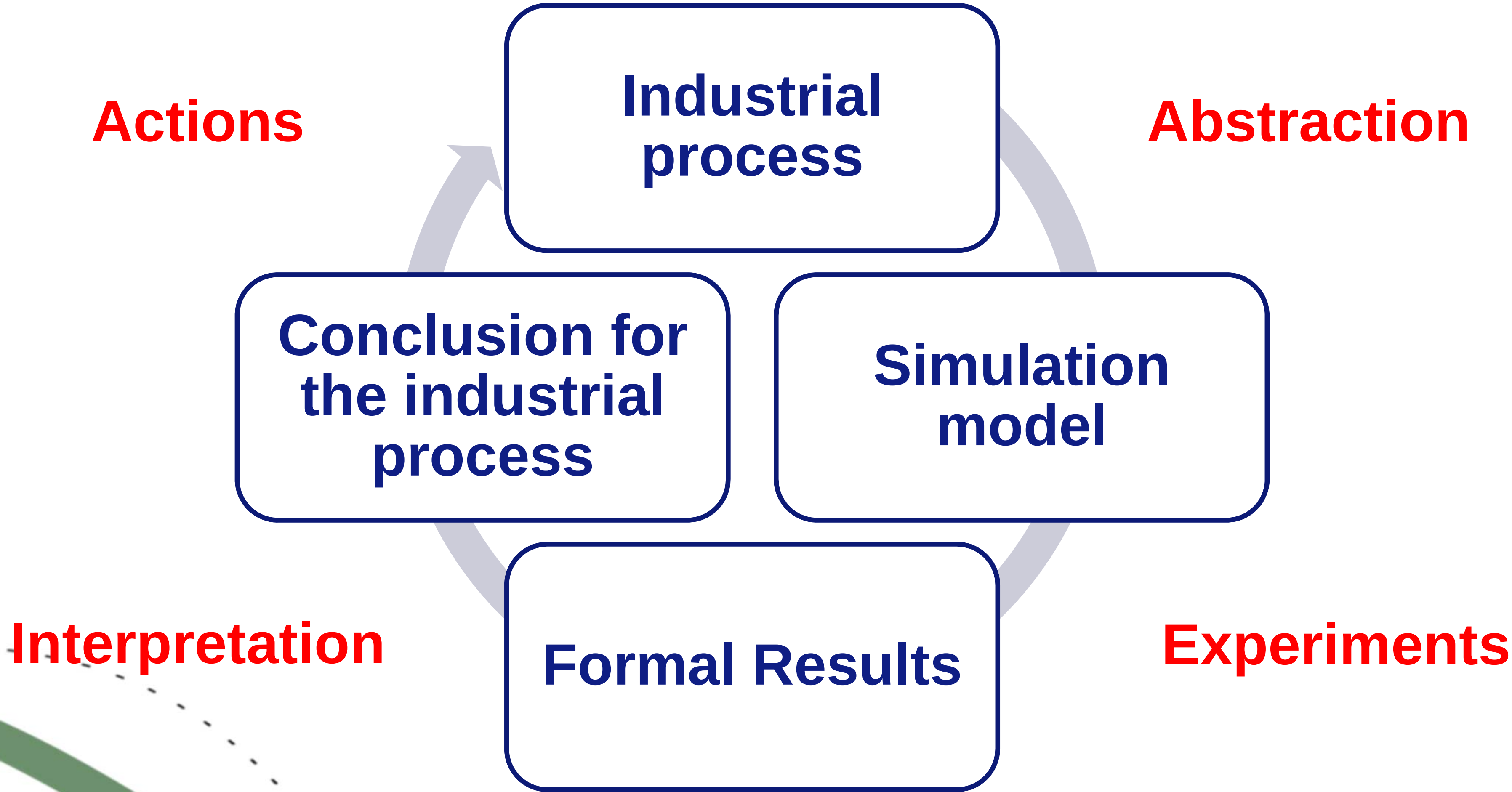
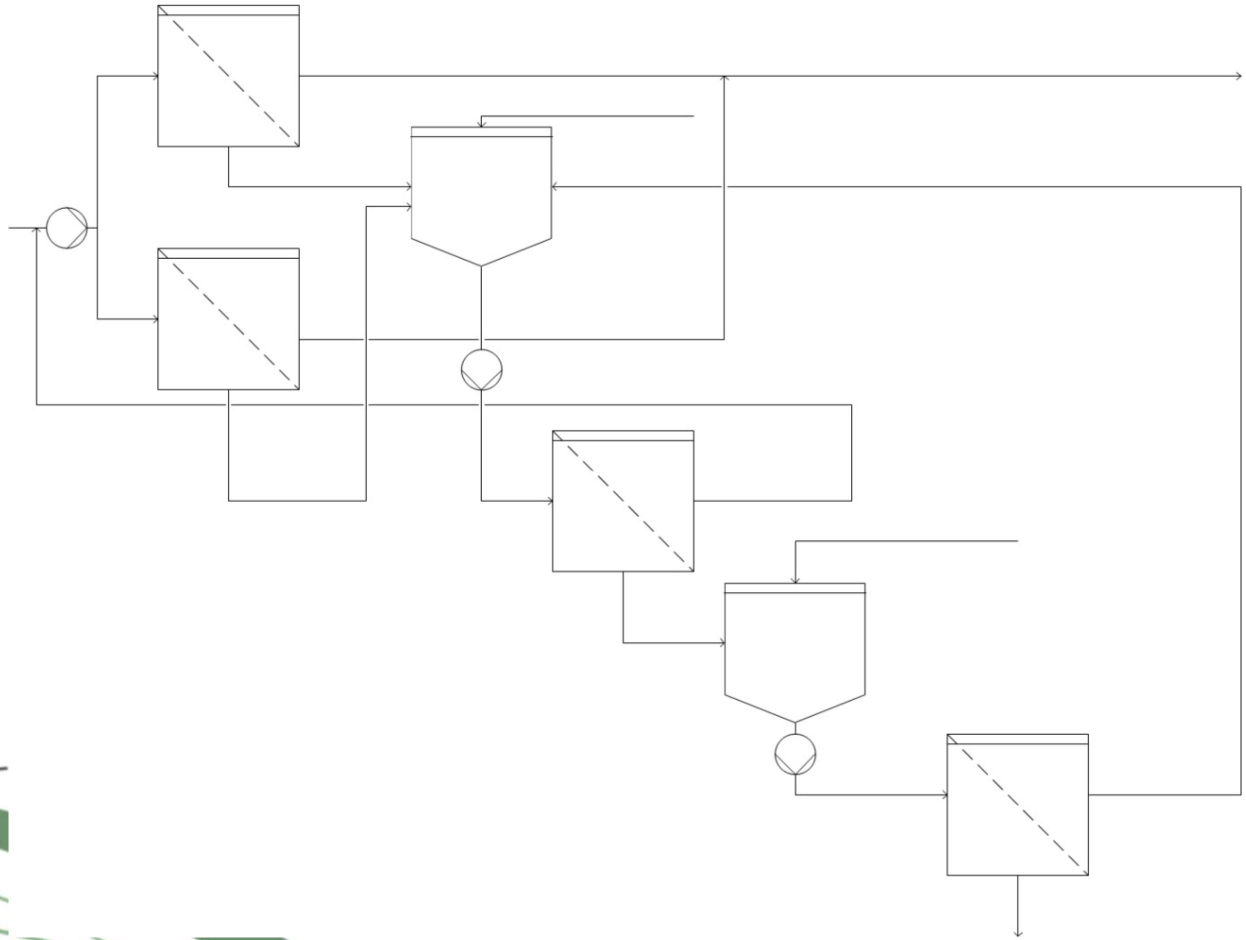
The Process of Modelling



Abstraction of a separation process



- Material flow balances according to VDI 3925 for all components entering and exiting processes and process units.
- Calculation of quality properties by usage of the material composition.
- Balacing ressource consumption and emissions for a total process.

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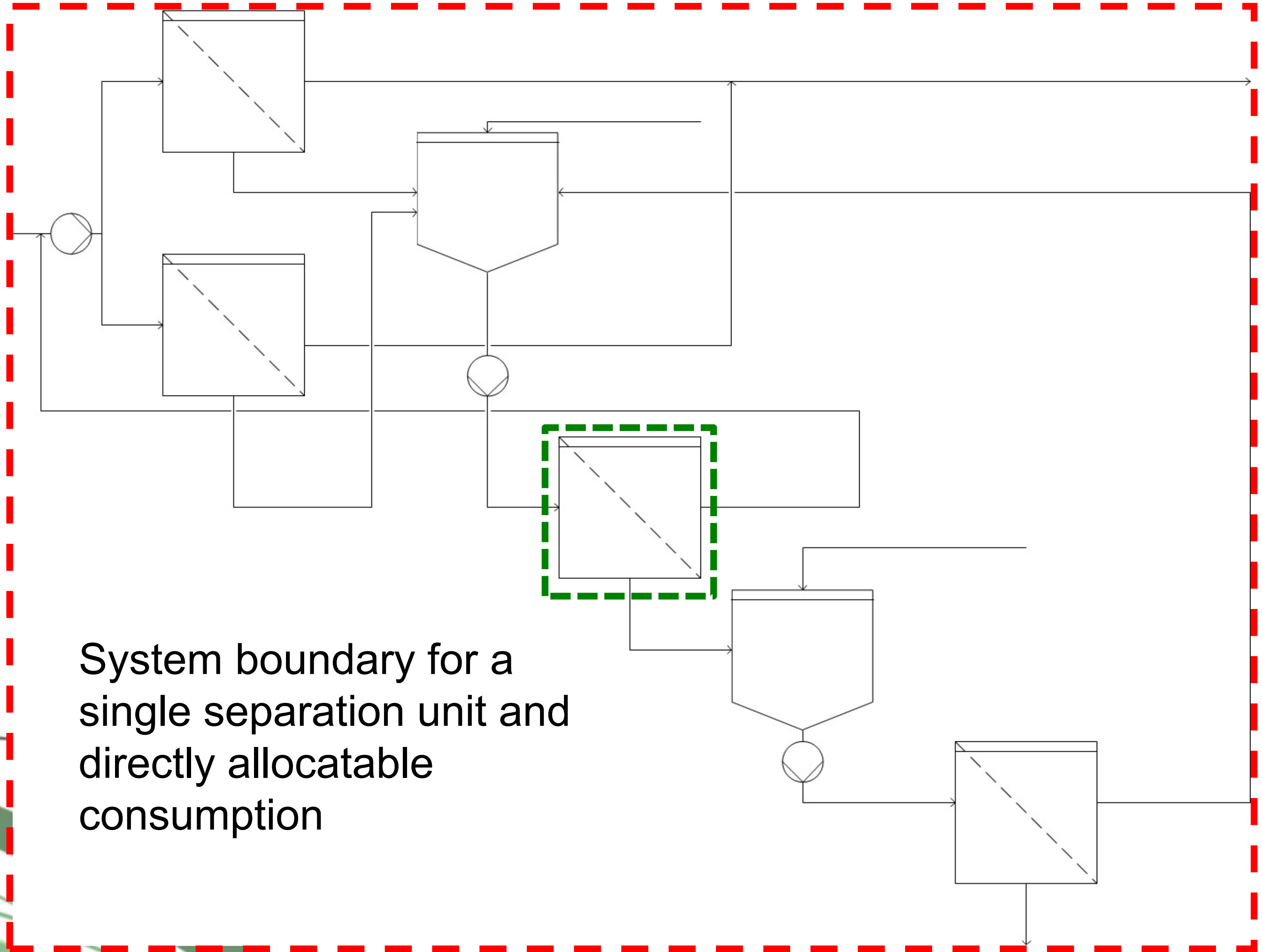
Definition of system boundaries



System boundary for accounting resource consumption within a process and for non-allocatable consumption

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		Input Material properties	Output Material Properties	
Parameter	Unit	Stage 1	Accepts	Rejects
volumetric flow rate	l/min	7600,00	8672,82	107,18
consistency	%	3,56	3,09	2,04
mass flow rate	kg/min	270,56	268,37	2,19
Haindl-McNett				
long fibres (sieve 30)	%	18,16	18,13	22,12
long fibres (sieve 30)	kg/min	49,13	48,66	0,48
short fibres (sieves 50+100)	%	32,89	32,91	31,81
short fibres (sieves 50+100)	kg/min	88,99	88,32	0,70
fines (sieve 200+P200)	%	48,94	49,20	46,07
P200	kg/min	132,41	132,04	1,01
Ash				
525°C	%	27,07	27,09	24,79
	kg/min	73,24	72,70	0,54
Stickies				
total	mm2/kg	4049	741	412779
small	mm2/kg	223	59	20279
medium	mm2/kg	509	62	55260
large	mm2/kg	3317	616	334318
Optical charactistics				
specific dirt spec area >100 µm	mm2/min	6000000	5554996	445004
Y		52	52	52
R457	%	49	49	49
ERIC	ppm	552	552	552
Water retention				
Schopper-Riegler-value SR		56,80	60,16	46,91
Water-retention-value WRV		112,78	115,22	112,89

Design of the models

Separation device specific data				
	Unit	S1	S2	S3
Mass reject rate	%	0,17	0,25	0,15
Spec. Screening Index Long Fibres		1,00	0,96	0,93
Spec. Screening Index Short Fibres		1,01	1,01	1,00

Resource consumption & Resouce-efficiency indicators								
Energy	Unit	MIX1	S1	RT1	S2	S3	SEP1	Total
feed pump	kW	3,97	67,50	0,00	12,73	0,00	0,00	84,20
screen rotor	kW	0,00	63,75	0,00	31,45	19,00	0,00	114,20
agitator	kW	0,00	0,00	6,38	0,00	0,00	0,00	6,38
other	kW	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Water								
Fresh water consumption	l/min	0,00	8,00	3,00	8,00	100,00	0,00	119,00
Process water consumption	l/min	1500,00		1180,00				2680,00
Process water consumption	l/min							
Emissions								
Carbon footprint	kg CO2							
Raw materials & waste								
Yield	%	0,00	83,00	0,00	75,00	85,00	0,00	99,19
Economic								
Profitability	%							

Workflow

Sampling

Laboratory tests

Calculation and modeling

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Calculation of quality parameters and resource consumption

$$SR = f(long\ fibre\ content\ \%, short\ fibre\ content\ \%, fines\ content\ \%)$$

$$WRV = f(long\ fibre\ content\ \%, short\ fibre\ content\ \%, fines\ content\ \%)$$

$$ERIC, R457, Y = f(RR_m)$$

$$Energy\ consumption = f(\Delta p, \dot{V})$$

$$Water\ consumption = f(\dot{V})$$

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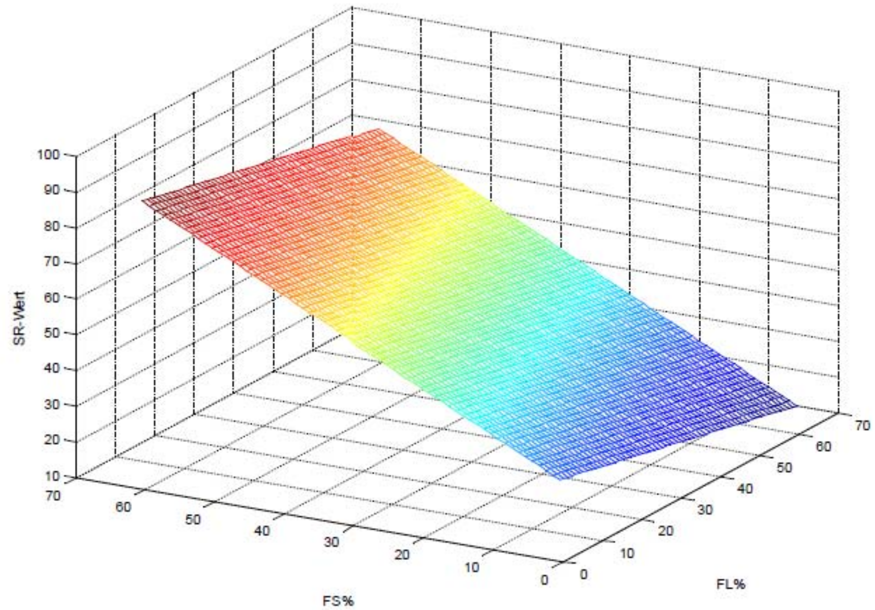
Modelling of drainage properties

- Drainage properties Schopper-Riegler and WRV can be modelled by solving an **overdetermined equation system** derived from the data collected for the different processes in the project partners mills.

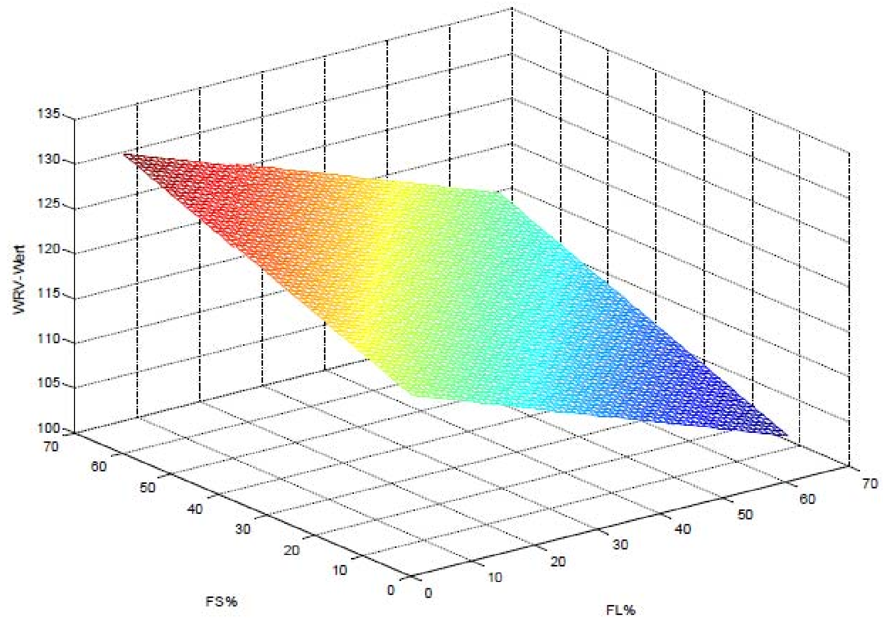
- As $\dot{m}_{LF} + \dot{m}_{SF} + \dot{m}_{FS} = 100\%$, the equation is given as the following and the parameters h and k can be calculated:

$$\begin{pmatrix} \dot{m}_{LF,F,S1} & \dot{m}_{FS,F,S1} \\ \dot{m}_{LF,A,S1} & \dot{m}_{FS,A,S1} \\ \dot{m}_{LF,F,S2} & \dot{m}_{FS,F,S2} \\ \dot{m}_{LF,A,S2} & \dot{m}_{FS,A,S2} \\ \dot{m}_{LF,F,S3} & \dot{m}_{FS,F,S3} \\ \dot{m}_{LF,A,S3} & \dot{m}_{FS,A,S3} \end{pmatrix} \begin{pmatrix} h \\ k \end{pmatrix} = \begin{pmatrix} SR_{F,S1} \\ SR_{A,S1} \\ SR_{F,S2} \\ SR_{A,S2} \\ SR_{F,S3} \\ SR_{A,S3} \end{pmatrix}$$

Visualization of the modelled drainage properties



Schopper Riegler



Water Retention Value

Modelling of optical properties

- The models can handle the following optical properties:
  - **Brightness** Y
  - **Whiteness** R457
  - **Effective residual ink concentration** ERIC

- The changes of optical properties in screening processes are assumed to remain constant, as they are small. Nevertheless, there are significant changes in the properties in deinking flotation.

$$Y_{A,i} = a * \exp^{b*\sum_{1}^{i} \frac{\dot{m}_{R,i}}{\dot{m}_F}} \qquad ERIC_{A,i} = d * \exp^{-g*\sum_{1}^{i} \frac{\dot{m}_{R,i}}{\dot{m}_F}}$$

Law of mixture for tanks

- Tanks are used as buffers and temporary storages in stock preparation. Additionally, pulp streams are mixed and diluted with different kinds of process water (clear/cloudy filtrate, filtrates originating from disc filters or double-wire presses).

- **Components** follow the mixing rules:

$$\sum_i \dot{m}_{in,i} = \dot{m}_{out} \qquad \sum_i \dot{V}_{in,i} = \dot{V}_{out}$$

- The mixture of pulp streams with different **optical and drainage properties** can be modelled by:

$$Y_{out} = \sum_{1}^{i} Y_{in,i} * \frac{\dot{m}_{in,i}}{\dot{m}_{out}}$$

Case Study - Increased rejects in flotation deinking (1)

- Increasing the amount of rejects in flotation deinking results in
  - Higher brightness levels due to ink removal,
  - Reduction of both organic and inorganic fines.
- Also valuable material such as fibres are lost.

- Therefore, a precise forecast of yield and the resulting product qualities becomes necessary.

- As deinking rejects can be used for side stream applications the composition of the rejects becomes more important than before.

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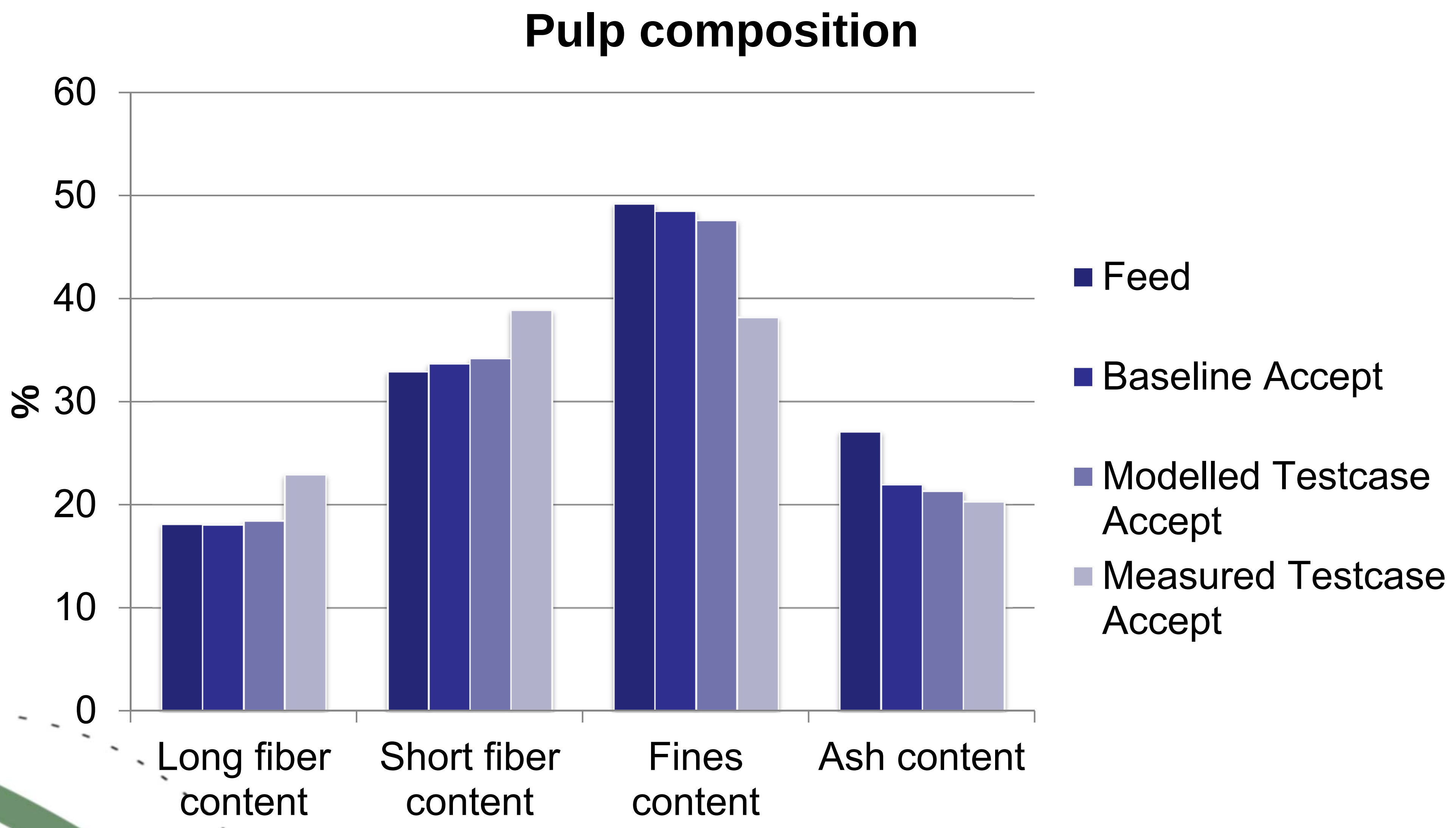

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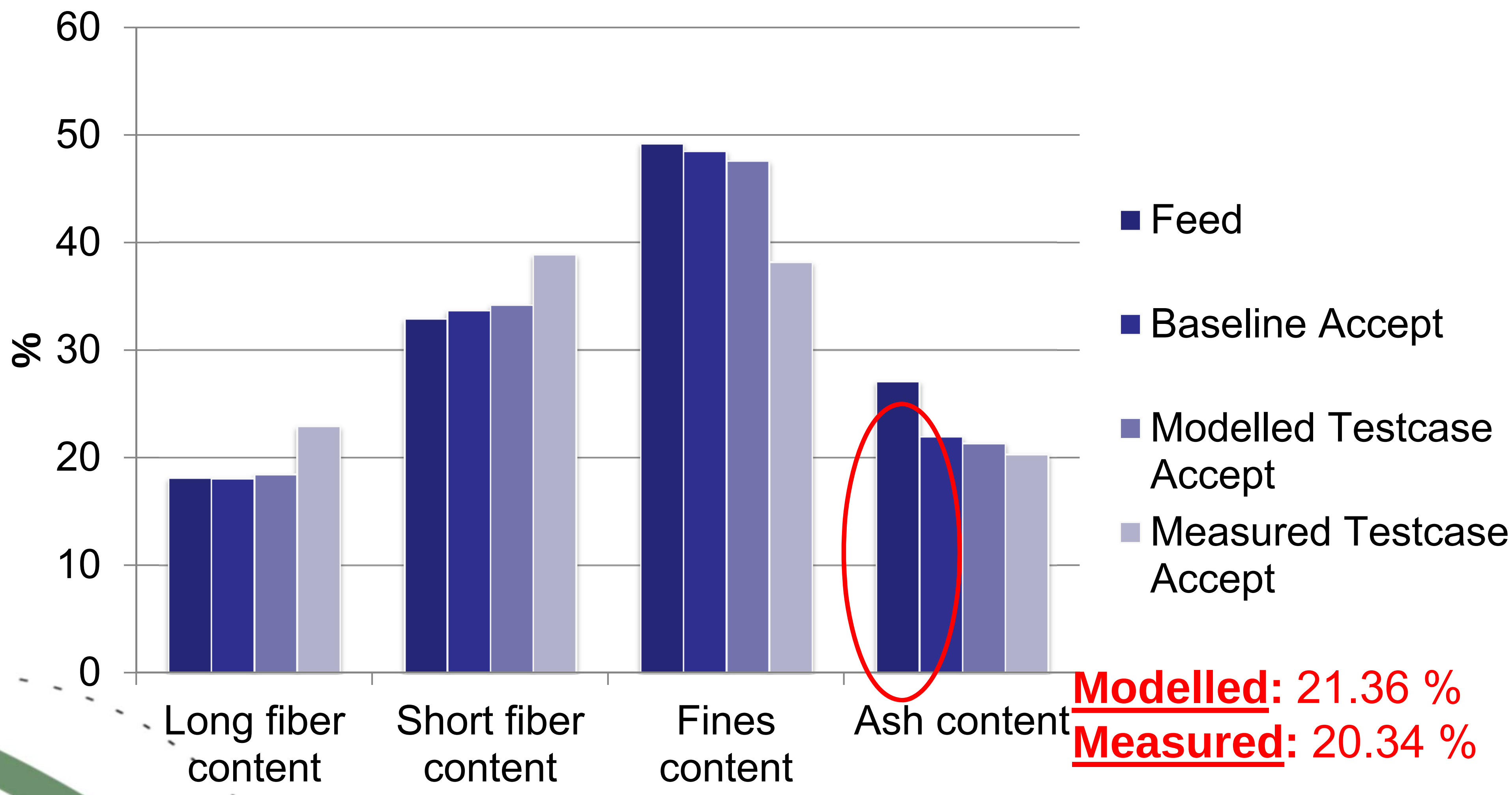
Pulp composition



Modelled: 21.36 %
Measured: 20.34 %

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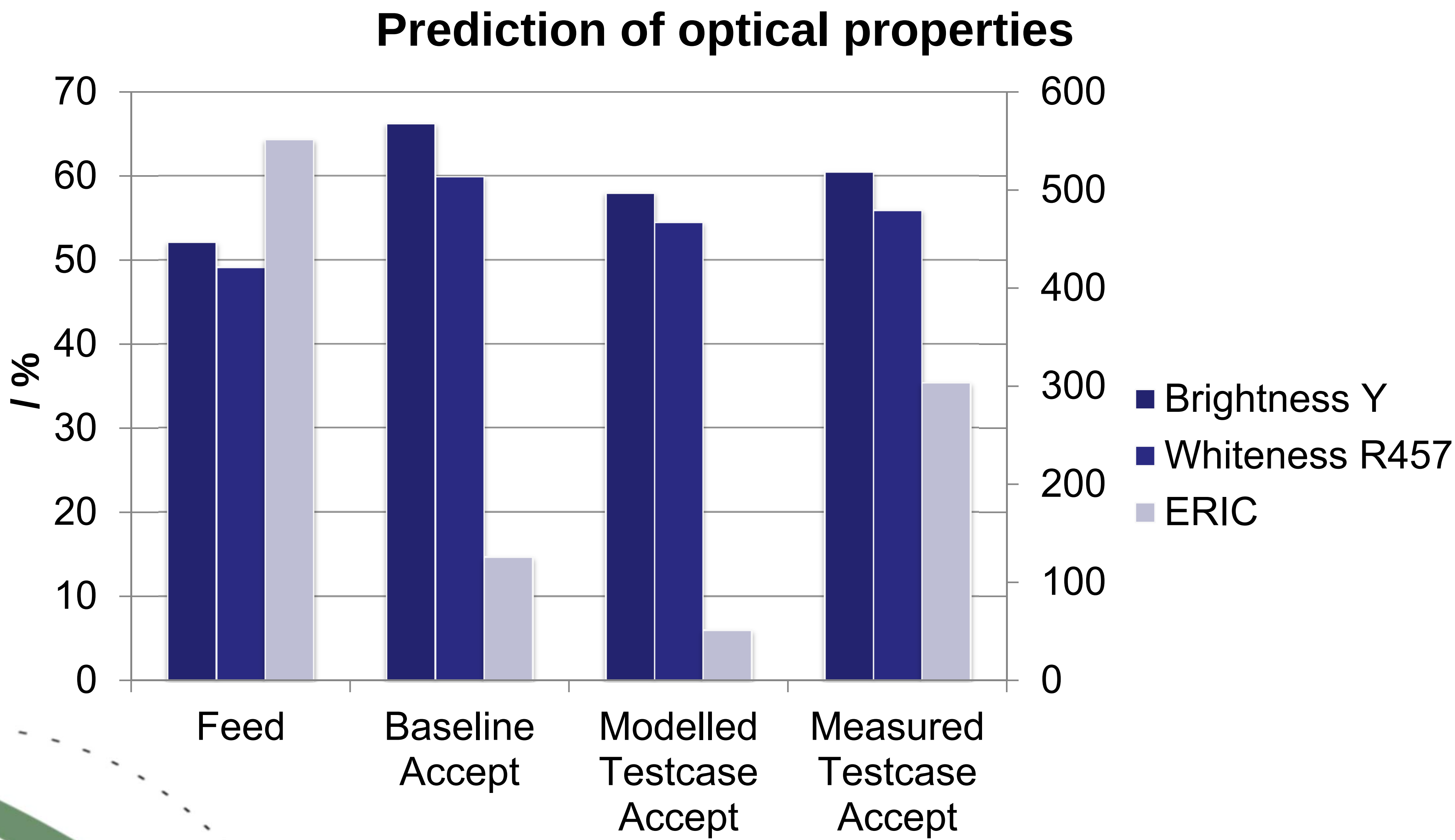


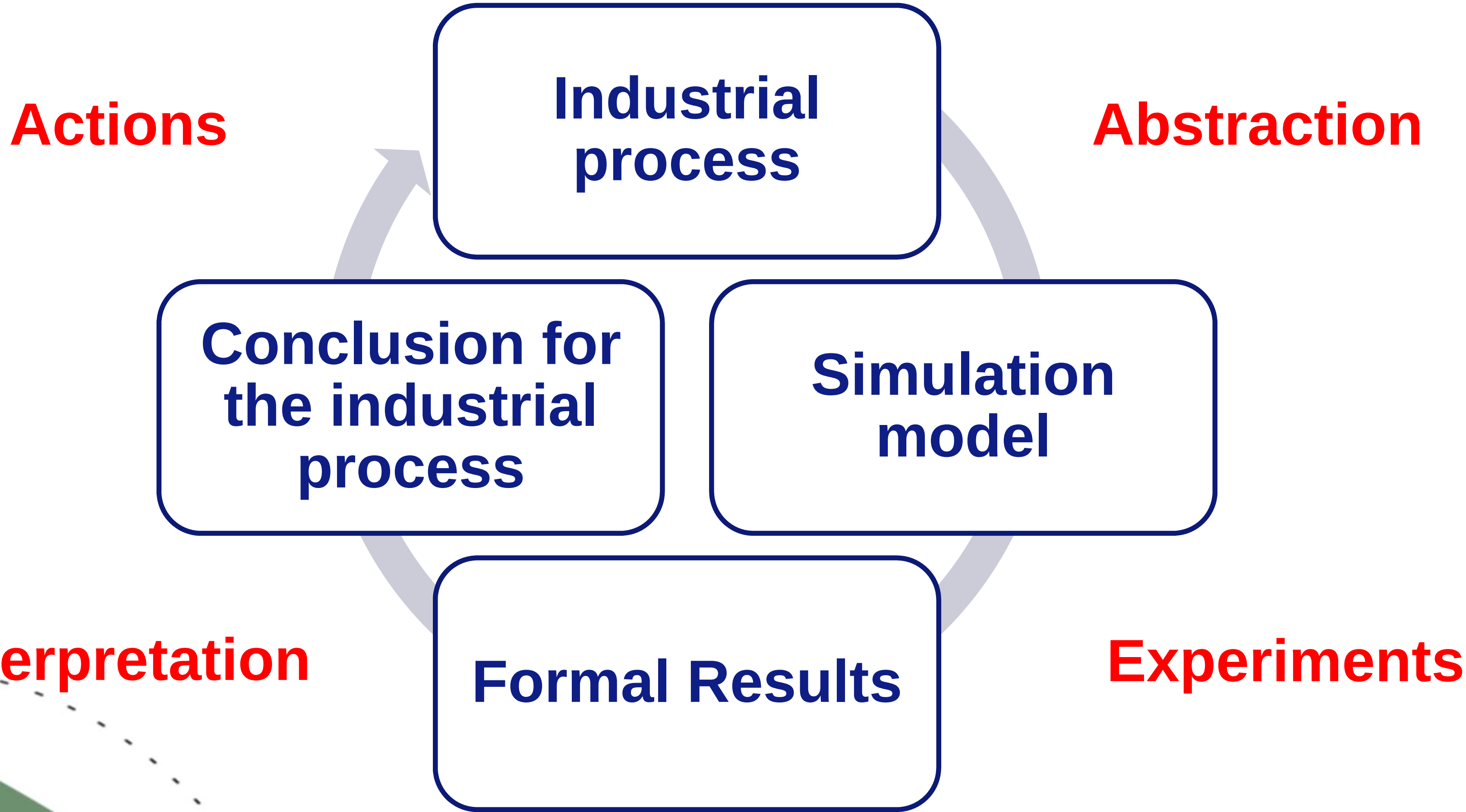
Interpretation

- Flotation model gives a good forecast on pulp composition and ash content.
- It lacks in predicting the precise fiber composition but gives a good indication.

- Optical properties can be predicted precisely.

- As energy consumption and process water consumption are only balanced and modelled for selected process, the modelled values have to be multiplied with a mill-specific factor in order to take consumers outside the system boundaries into account.

The Process of Modelling



Conclusions

- Existing process models can be extended in such a way that they can handle the indicators necessary for life cycle assessment calculations and predicting paper properties.
- There is a need to have an easy tool for companies to skip the time lag in the process chains.
- REFFIBRE project is helping by
  - Modelling the fiber flows within paper mills and predicting pulp properties,
  - Reducing the time lag between the implementation of a change within the process chain and the prediction of the outcome pulp properties
  - Integrating the modelling in a common tool

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Acknowledgement

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