

# Big data in daily manufacturing operations

Ivo Adan

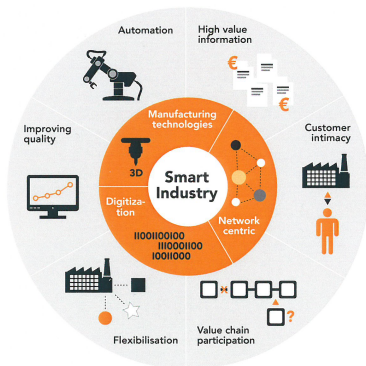
Joint work with

Tim Wilschut and Joep Stokkermans



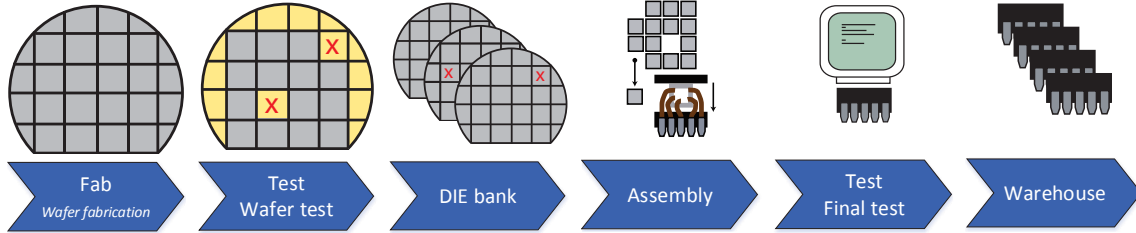
## Big Data and Smart Industry

- ICT and robotization are changing the manufacturing industry: **the fourth industrial revolution**
- **Internet of Things:** Products, machines, factories, warehouses, customers are able to exchange information!
- **Challenge:** Fully exploit this network to improve processes and to develop innovative products and services!
- **National initiative:** Smart Industry



- This project is example of **smart use of information**

## Semi-conductor manufacturing



- ▶ Furnace
- ▶ Implantation
- ▶ Deposition
- ▶ Stepper
- ▶ Etching
- ▶ Wetting

- ▶ Functional wafer test

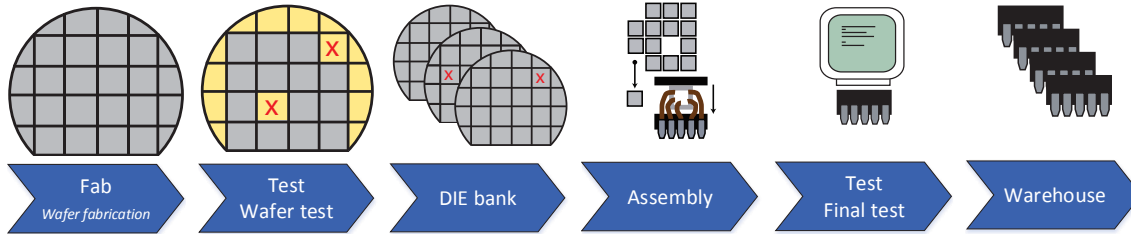
- ▶ Semi-finished goods on stock

- ▶ Grinding
- ▶ Sawing
- ▶ Die bonding
- ▶ Wire bonding
- ▶ Molding
- ▶ Trim & form

- ▶ Final testing

- ▶ Finished goods on stock

## Semi-conductor manufacturing



- ▶ Furnace
  - ▶ Implantation
  - ▶ Deposition
  - ▶ Stepper
  - ▶ Etching
  - ▶ Wetting
- ▶ Functional wafer test
- ▶ Semi-finished goods on stock
- ▶ Grinding
  - ▶ Sawing
  - ▶ Die bonding
  - ▶ Wire bonding
  - ▶ Molding
  - ▶ Trim & form
- ▶ Final testing
- ▶ Finished goods on stock

- Focus on die assembly (die bonding, wire bonding, molding)



## NXP Assembly Plant in Guandong China



- Advanced Warning and data Collection System (AWACS) collects 26 GB's of data/day (100 Oxford dictionaries!)
- Is it possible to increase Overall Equipment Efficiency (OEE) by exploiting Big Data?

## NXP Assembly Plant in Guandong China

- Production characteristics
  - High speed production: Thousands of products are produced per machine per hour
  - High volume production: Millions of products per day
- Due to scale of operations: Difficult to get a grasp of “What is happening?”
- Manually monitoring and processing data is labor intensive and inefficient
- **Develop software tool to give clues to basic operational questions like:**
  - How is production going?
  - Where is what attention required?
  - Which action has priority?
- To answer first two questions: Data should be filtered on dedicated metrics (OEE)
- To answer third question: Intelligent data mining is required (**Fluid flow simulation model**)

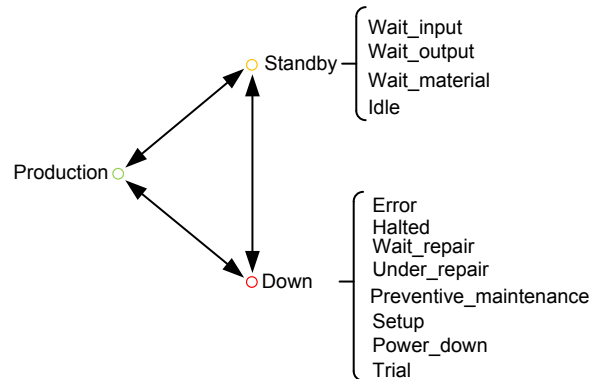
## Project objectives

In order to support factory maintenance teams in prioritizing their activities

- Design and develop data analysis software for every day use in manufacturing operations
- Investigate the suitability of a fluid simulation model to conduct “what if” analysis, such as
  - What can be gained in terms of throughput if certain machine errors are solved?

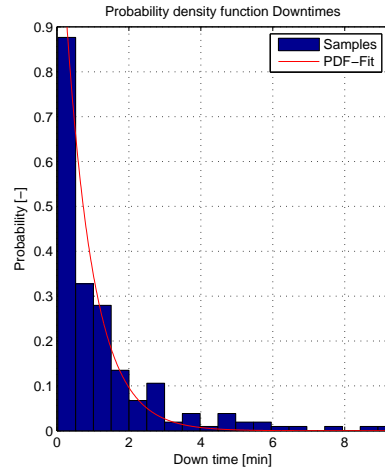
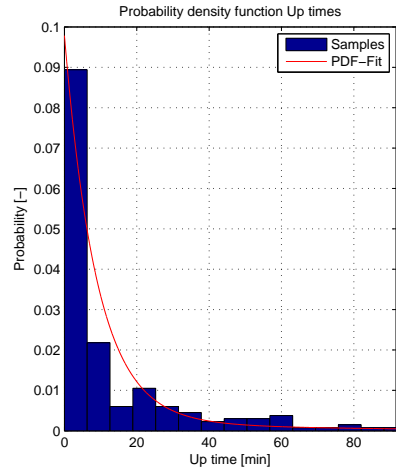
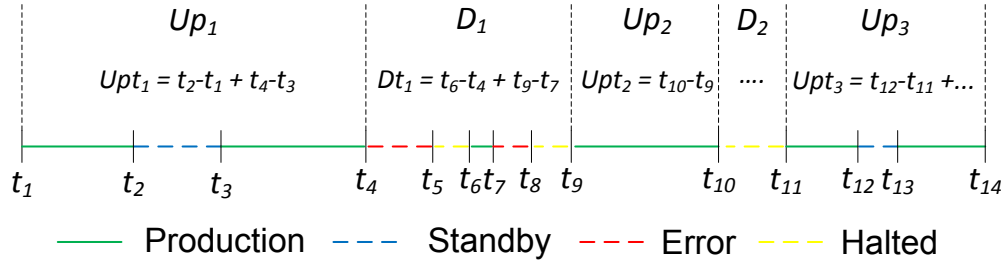
## Data collection

- AWACS collects state events of equipment with corresponding times stamps
- Machine states
  - **Production:** Machine is producing
  - **Standby:** Machine could be producing but is not
  - **Down:** Machine cannot produce





## Machine up and down times



## The software

**Three level** Graphical User Interface since “different management levels require different information”

- **Heads Up Display:** General overview of complete production floor
  - How is production going?
  - Where is attention required?

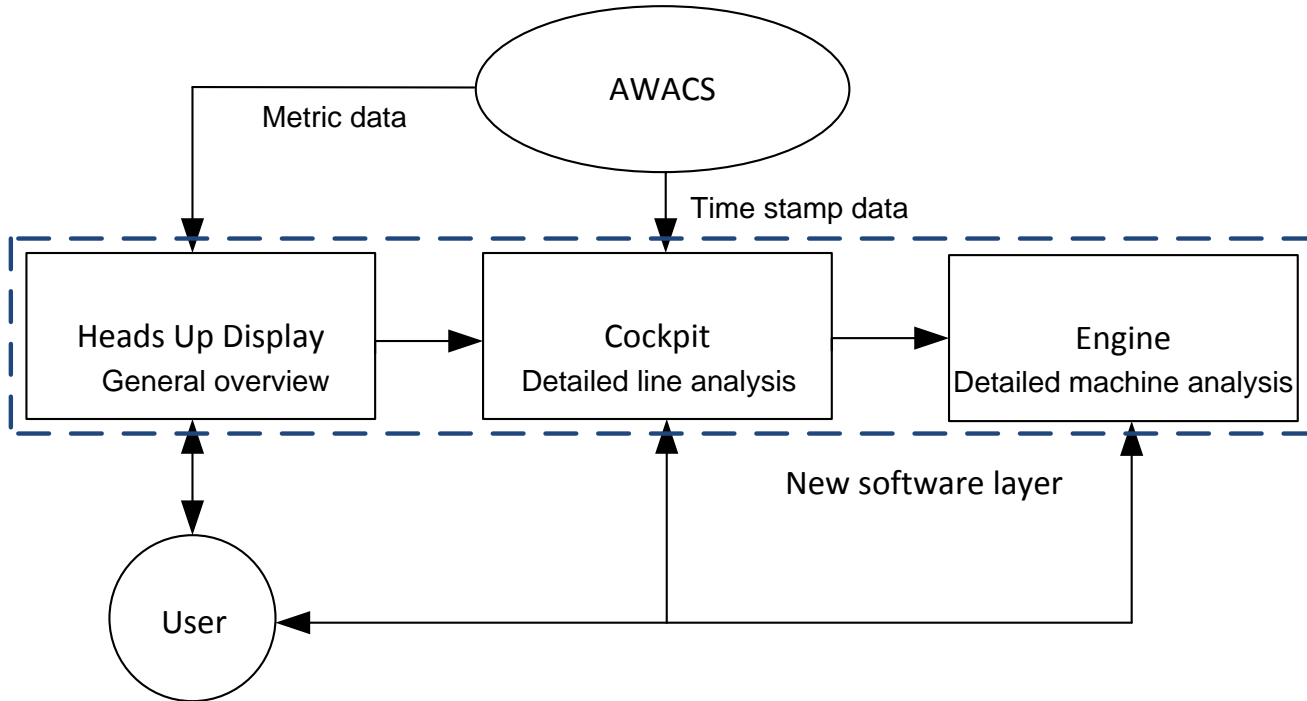
**Target user group:** Production managers, quality managers, maintenance managers

- **Cockpit:** Line analysis tool
  - What happened on this production line?
  - What should I do first?

**Target user group:** Production supervisors, maintenance supervisors

- **Engine:** Equipment specific information
  - Target user group:** Maintenance engineers, technicians

## The software



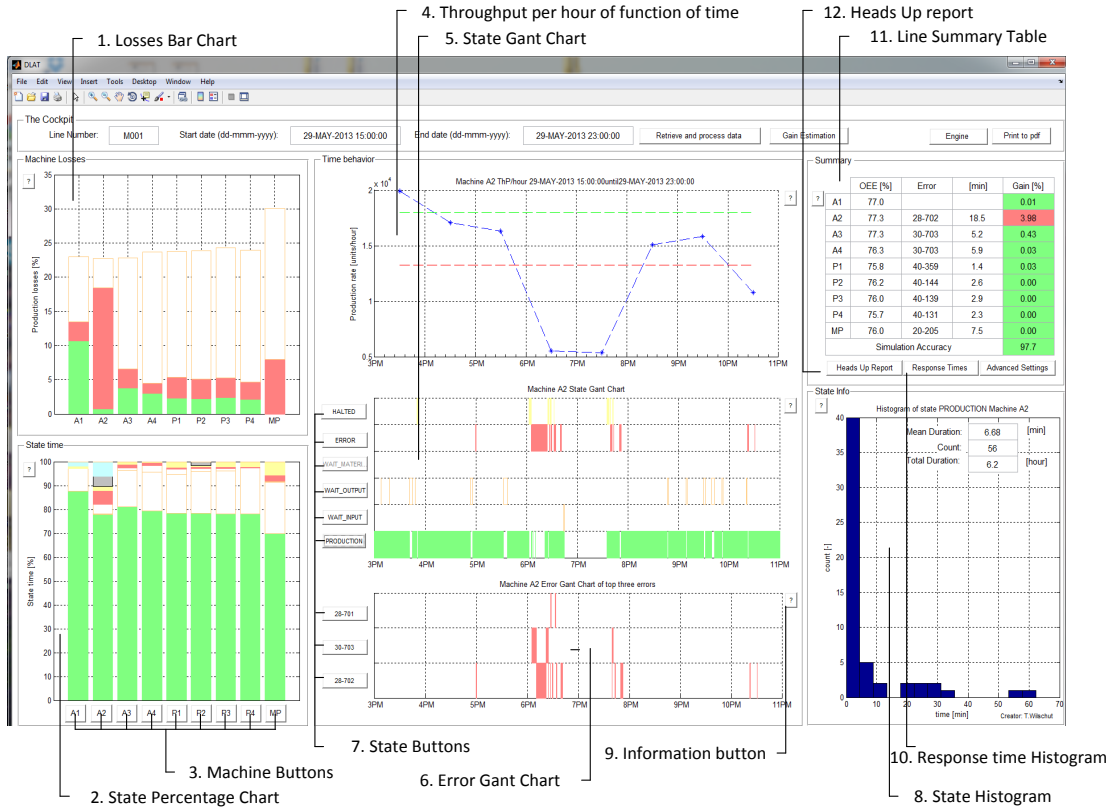
# The software: Heads Up Display

1. Line Name Button: opens Cockpit view  
 2. OEE Button: Gives the OEE of the MP. Pressing gives the details: Die type, Bottleneck machine, gain  
 3. Q-Indicator: indicates whether or not too many errors have occurred in shift: Pressing gives details: Errors on which it triggered.  
 4. Drop down menu to select additional parameter: Throughput, assist time, down time....  
 5. Clues; Information which could explain bad performance  
 6. Clue Button, scans for 'special events' (long powerdown states etc.)

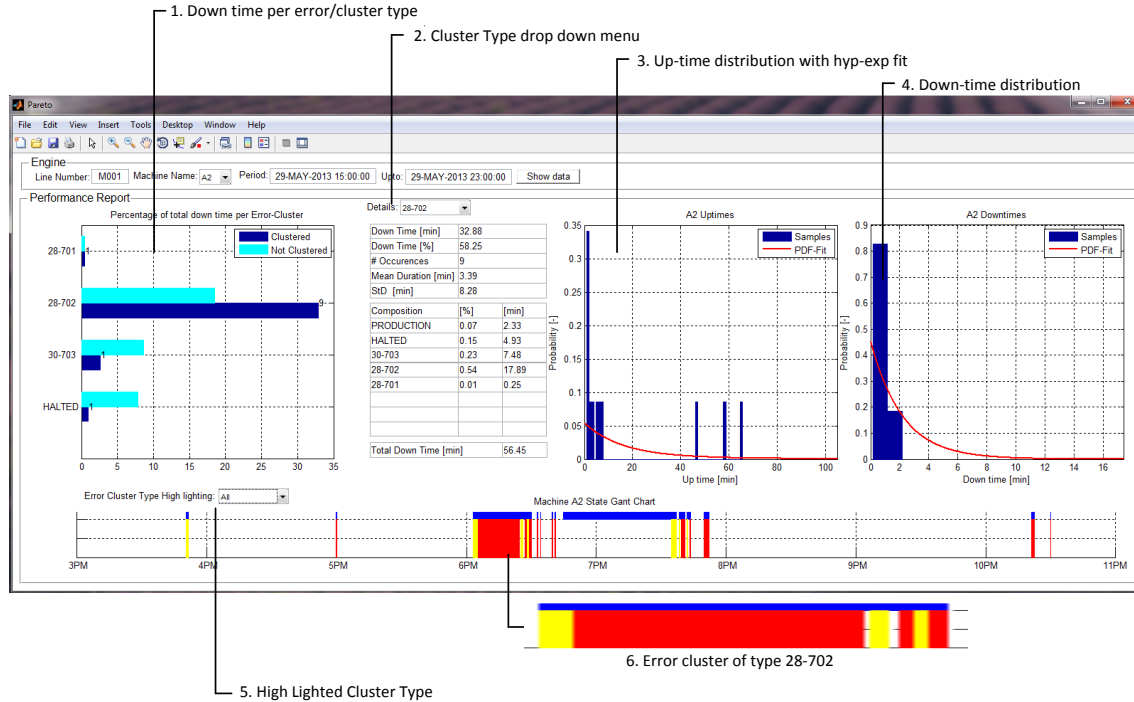
Line Number	OEE [%]	Q-Indicator	upm	Clues
M001	75.8	+	292	A1 SLOSS 10.7%; A2 DOWN 12.1%; A2 Setup 6.1%;
M002	86.4	-	285	
M003	84.2	-	288	
M004	89.6	-	296	
M005	76.8	-	294	P2 SLOSS 5.8%; A1 DOWN 100%; A1 Halt 100%;
M006	80.2	-	288	
M007	0	-	0	P1 SLOSS 100%; A4 DOWN 31%; A4 Pwrdn 29.2%
M008	86.1	-	285	
M009	0	-	0	P2 SLOSS 32.1%; MP DOWN 100%; MP Setup 100%;
M010	88.3	-	284	
M011	80.9	-	296	
M012	82.3	-	285	P1 SLOSS 18.4%; MP DOWN 100%; MP Pwrdn 100%
M013	81.2	-	281	
M014	80.2	-	288	
M015	74.3	-	287	P1 SLOSS 18.7%;
M016	85.3	-	245	P2 SLOSS 39.4%; A3 DOWN 100%; A3 Setup 100%;
M017	88.8	-	292	P3 SLOSS 42.2%; MP DOWN 24.4%; MP Halt 24.4%; A4 Pwrdn 8.5%
M018	49.2	-	278	A3 SLOSS 44.7%;
M019	86	-	289	
M020	88.7	-	91	P4 SLOSS 66.3%;
M021	10.7	-	49	
M022	0	-	0	A2 SLOSS 99.6%; MP DOWN 100%; P1 Halt 100%; MP Pwrdn 100%
M023	0	-	0	A1 DOWN 100%; MP Halt 100%; A1 Pwrdn 100% A2 Setup 100%;
M024	89.2	-	378	
M025	87.6	-	273	
M026	85.3	-	271	
M027	81.3	-	293	A4 SLOSS 8.9%; P4 DOWN 46.5%; P4 Halt 46.5%; A4 Setup 12.3%;
M028	1.1	-	4	A4 SLOSS 99.2%;
M029	91.4	-	285	
M030	84	-	286	
M031	79.6	-	289	A2 SLOSS 99.9%;
M032	86	-	285	

7. Opens file in which Q-indicator and OEE settings can be modified  
 8. Generates full heads up report for all lines.  
 9. Updates shown data  
 10. End of last shift in data  
 11. Number of shifts included in data

# The software: Cockpit

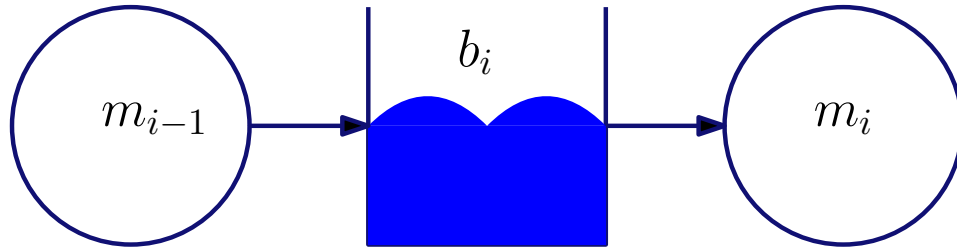


# The software: Engine



## Fluid flow simulation model

- **Discrete flow** of products through assembly line is modelled as **continuous fluid flow**
- Natural due to high production rates: products literally flow through equipment
- Production line consists of nine machines  $m_1, \dots, m_9$ , in series separated by finite buffers  $b_1, \dots, b_8$



- Buffer content is **continuous**
- Machine states are **discrete**
- Machine up and down time distributions are **fitted to data**
- Model describes **interactions** between machines in the assembly line

## Validation of fluid flow simulation model

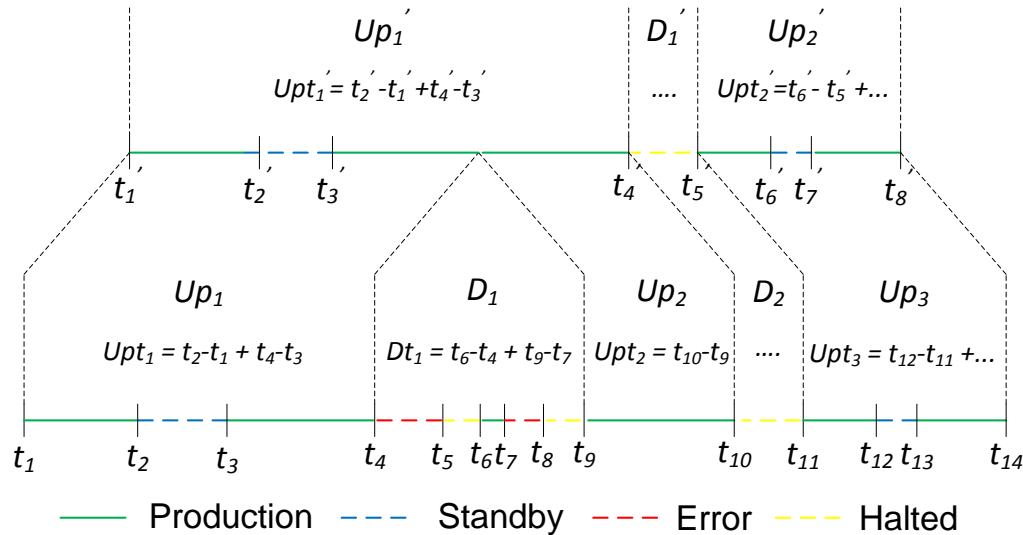
#Shifts	Absolute Error [%]				
	1	3	6	12	18
Data set 1	5.43	0.01	4.74	1.43	3.78
2	9.60	7.88	5.14	0.82	18.34
3	1.81	0.53	3.26	8.29	0.34
4	10.2	1.07	1.99	3.59	1.56
5	6.58	3.33	0.73	4.71	3.29
6	14.8	6.07	4.38	2.55	3.52
7	8.27	0.83	2.49	3.97	3.46
8	13.5	2.49	1.59	3.03	6.28
9	7.90	2.99	2.66	3.25	5.92
10	11.3	3.24	0.15	8.45	2.58
Average Error	8.93	2.84	2.72	4.01	4.91
Maximum Error	14.8	7.88	5.14	8.45	18.3

- On average the simulation model has an accuracy  $> 95\%$  if the data set is  $\geq 3$  shifts
- However, in the presence of rare events (such as long power downs) the simulation model is not accurate



## Setting maintenance priorities

- **Maintenance capacity is limited** so priorities need to be set!
- Simulation model is used to help set these priorities
  - Estimate the effect of **removing an error** from the system in terms of **throughput gain**
  - Removing certain errors from the event list of a machine modifies both up and down times



## Estimating throughput gain

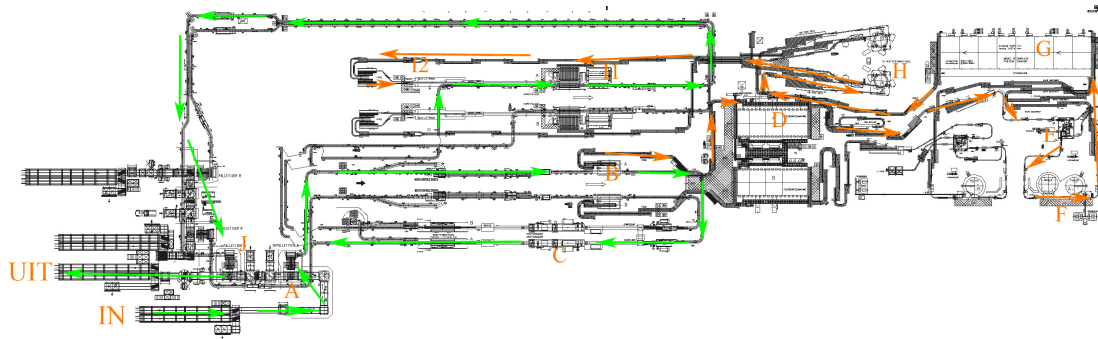
- Throughput gain is estimated by comparing “base simulation” with “what if” simulation

Date	17-04-13		19-04-13		28-04-13	
Machine	Error type	Gain [%]	Error type	Gain [%]	Error type	Gain [%]
1	28-702	0.11	40-702	0.02	28-552	0.00
2	30-709	0.18	40-702	0.06	30-703	0.00
3	30-34	0.07	40-703	0.05	30-703	0.14
4	28-702	0.22	40-703	0.04	30-703	0.00
5	40-144	0.14	40-145	0.04	40-351	0.00
6	40-145	0.05	40-356	0.61	40-135	1.91
7	40-359	0.04	40-135	1.10	40-144	1.93
8	40-139	1.74	40-356	0.88	40-144	0.00
9	20-165	0.06	20-177	0.16	20-177	0.00

- On different days different error-types are dominant

## Conclusions and remarks

- Effective integration of data analysis and simulation
- Maintenance crew can better focus their attention and set priorities
- Fluid flow simulation model can accurately predict production line behavior
  - Fluid model has also been used for packaging lines at Heineken (line configuration)



- Use chronological list of up and down time events as input to the simulation model
- **Few percent increase in the Overall Equipment Efficiency** within the first few months after implementation!