The Value of Sensor Information for Managing Perishable Goods

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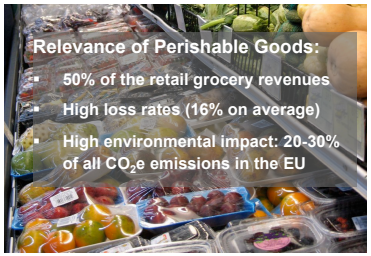
Motivation



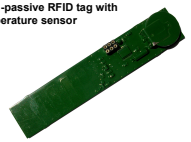
Research context

- Sensors enable quality measurement
- More information = more efficiency?
- Quantification of information value
- Economic and ecologic perspective
- Focus on retail supply chain and highly perishable goods

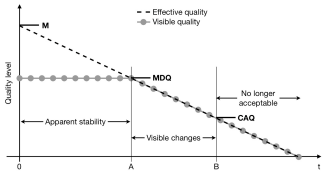
Sensor-based quality prediction

- Sensors (e.g. temperature) monitor environmental parameters
- Frequent use case: semi-passive RFID sensor tags attached to reusable transport items or cases such as RPC
- Recorded temperature history can be used with formulas from food science to predict quality level and remaining shelf-life
- Quality of prediction depends on prediction model, accuracy of initial quality assessment, measurements

Semi-passive RFID tag with temperature sensor



Quality model



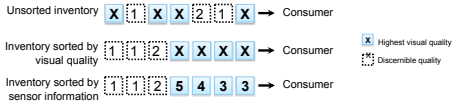
Quality experience

High-quality (Quality > MDQ)
- Customer can **not** distinguish between individual items
- Post-purchasing experience is always positive

Low-quality (CAQ < Quality < MDQ)
- Customer can distinguish individual items by visual features
- Quality is still high enough that consumer purchases it (i.e. not spoiled), but may get a negative post-purchase experience

Example: improving through better information

Highest-Quality-First-Out (HQFO) – numbers indicate remaining shelf-life



In-store logistics: Using information to reduce waste and increase customer satisfaction

Simulation model for benchmarking in-store issuing policies

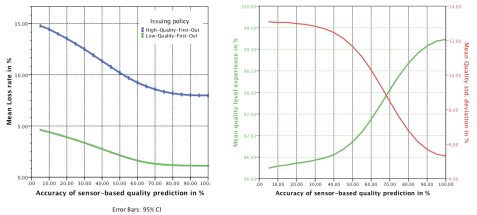
Benchmark of issuing policies with different information levels

Information used	HQFOS Sensor + ID	HQFO Human senses	LIFO ID	SIRO None	FIFO ID	LQFO Human senses	LQFOS Sensor + ID
	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Waste %	7.99	21.98	17.53	8.07	4.89	1.52	**1.12**
Quality level %	**99.23**	97.79	94.90	92.11	91.70	90.80	95.55
Quality deviation %	**5.32**	10.14	15.56	19.29	19.19	17.44	12.18
Low quality sales %	**3.53**	7.64	12.99	18.92	20.64	29.15	15.43
Out-of-stock %	1.49	1.97	1.72	1.35	1.20	0.99	**0.95**
Order frequency	0.91	0.96	0.95	0.93	0.91	0.89	**0.88**
Order size	8.23	9.28	8.79	8.11	8.02	7.96	**7.95**
Inventory level	14.86	17.59	15.50	**13.69**	14.05	14.81	14.92

N=68400, T=365

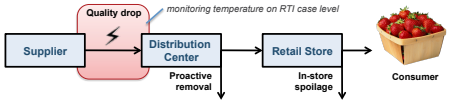
Goal: high quality — Goal: low waste

Analysis of inaccuracy of sensor-based shelf-life prediction



Profit gains of using sensor information for early decision-making in supply chains

Supply chain simulation model with early removal of goods

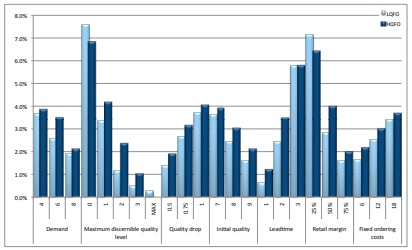


Base case results

M1 = without sensors M2 = with sensors	LQFO M1*	LQFO M2*	LQFO Change	HQFO M1*	HQFO M2*	HQFO Change
(s, S)	(22, 32)	(22, 32)		(20,29)	(20,29)	
Profit	25541	25976	+1.70%	20345	21730	+6.81%
Sold units	2861	2875	+0.49%	2588	2639	+1.97%
Holding amount	4524	4633	+2.41%	3218	3350	+4.10%
Total waste	88.6	58.2	-34.31%	335.9	262.0	-22.00%
In-store waste	88.6	29.3	-66.93%	335.9	241.7	-28.04%
Replenishments	267.18	265.87	-0.49%	288.31	287.11	-0.42%
Perceived quality	1.5814	1.6449	+4.02%	1.8705	1.9160	+2.43%
Effective quality	2.0467	1.9677	-3.86%	2.7804	2.6290	-5.45%
OOS	4.80%	4.34%	-9.58%	13.89%	12.18%	-12.31%

T=600, Warmup=100, Replications=100, CRN

Sensitivity analysis of information based profit gains



The impact of sensor-based management of perishables on CO_2e levels

Supply chain and sourcing scenarios of simulation

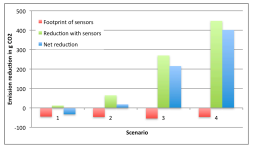
#	Scenario	Type	l_i	d_i	f_{ei}
1	Switzerland, national	lorry 3.5-7.5t	1	100km	$0.65736 g\,CO_2$ / $kg * km$
2	EU, short distance (=base case)	lorry 7.5-16t	2	500km	$0.29082 g\,CO_2$ / $kg * km$
3	EU, long distance	lorry 16-32t	3	1,500km	$0.16796 g\,CO_2$ / $kg * km$
4	International, med. distance	airplane	2	3,000km	$1.1468 g\,CO_2$ / $kg * km$

Simulation results by macro scenarios

Proportionally adjusted impact of profit-optimal sensor solutions for strawberries in Switzerland.

	Total	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Consumer demand per year (tonnes)	16,500	5,500	4,290	4,290	2,420
Consumer demand per year (number of trade units)	3,300,000	1,100,000	858,000	858,000	484,000
Profit U_1 (in $1000)	80,983	30,274	22,140	16,079	12,489
Profit increase $U2$ (in $1,000)	6,604	1,047	1,457	3,277	822
Emissions U_1 (t of CO_2)	21,054	2,282	2,554	3,888	12,330
Emission reduction U_2 (t of CO_2)	-359	36	-16	-185	-194
Purchasing volume U_1 (t)	18,250	5,551	4,577	5,540	2,582
Purchasing volume reduction U_2 (t)	-518	-39	-106	-313	-60

CO_2e savings vs. CO_2e of sensors



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