Past and Future Sources of Productivity Growth in Fibre Drum Manufacturing

Donald E. Rutherford

FAR Associates

Thomas F. Rutherford

University of Colorado

May, 2002

Purpose

- Provide a historical case study of productivity improvements
- Evaluate prospects for continued gains through the application of information technology
- Practical application of optimization methods to a manufacturing process

Method

- Construct a programming model which calibrates to 1950 and 2000 practice

- Investigate one method through which information technology can affect the process

Figure 1: Equipment Layout in 1950

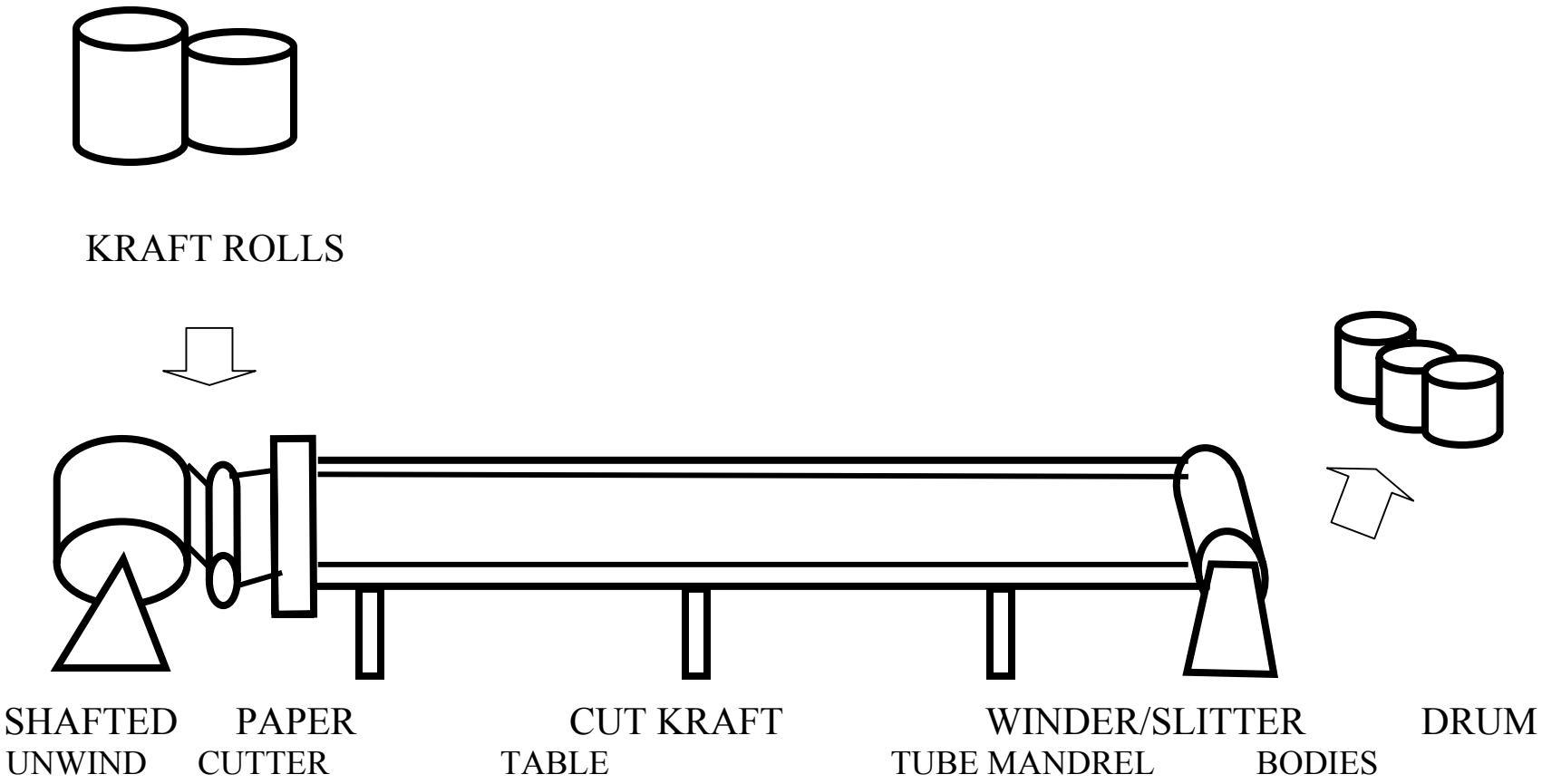
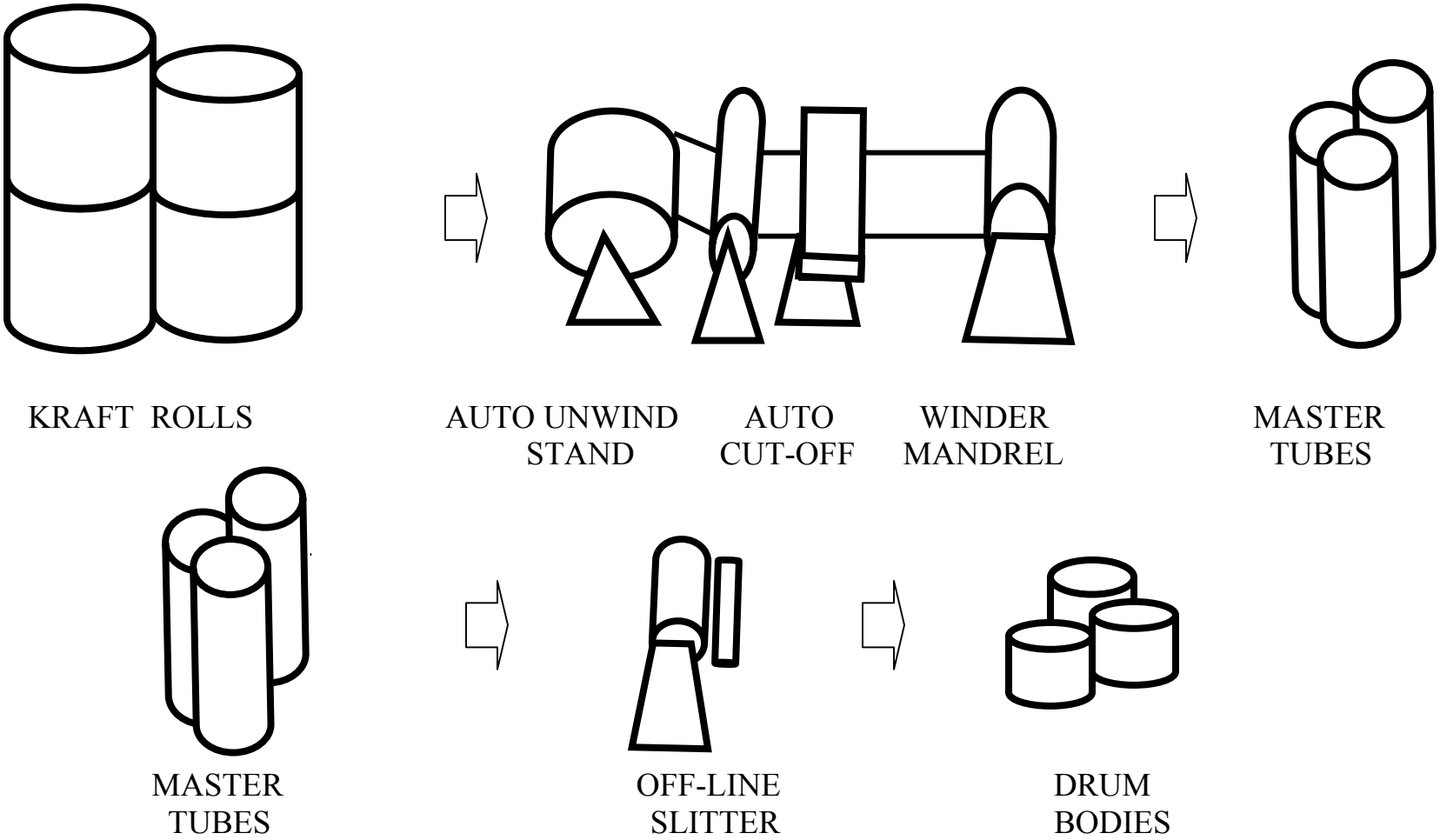


Figure 2: Equipment Layout in 2000



Composition of Drum Orders

	1950	2000
Total quantity of drums	77,500	77,500
Diameters	15.5 ", 21.5"	15.5", 21.5"
Wall thickness	6 ply - 44%	6 ply - 44%
	8 ply - 56%	8 ply - 56%
Average drum size	28 gallons	28 gallons

Master Kraft Rolls - Basis Weight of 46 lbs.

Roll Diameter	30"	54"
Roll Widths	43", 52", 60", 72", 76"	43", 52", 60", 72", 76"

Machine Run Time	1 min./pattern	18 sec./pattern

Machine Cost	Crew of 4 @ $65 per hr.	Crew of 5 @ $80 per hr.
Crew	1 Lead Operator @ $20/hr	1 Lead Operator @ $20/hr
	3 Helpers @ $15/hr	4 Helpers @ $15/hr

Winding & Slitting

Drums Bodies	$32/manhour	$85/manhour
Knife Change	5 mins./change	1 mins./change
Kraft Cost/M Sq. Ft.	$15	$15

Change Kraft Roll	30 mins.	18 mins.

Tube Winding and Drum Body Slitting Costs

	1950	2000	2000IT
c^M = machine operator cost ($/pattern)	1.1	0.4	0.4
c^K = pattern setup cost ($)	19.5	3.3	3.3
c^C = paper setup cost ($)	32.5	24.0	24.0

A Representative Order for a Two Week Planning Period

				Typical Cutting Pattern			
Gallons	Diameter	Truck Loads	Drum Orders	Drums per Tube	Trim Height	Kraft Width	Trim Loss
10	15.5	10	3000	5	15.0"	75.5"	0.5"
20	15.5	31	7000	2	27.2"	59.5"	5.1"
30	21.5	50	7300	3	21.9"	71.25"	5.55"
40	21.5	30	5400	2	28.3"	59.5"	2.9"
50	21.5	23	3000	2	34.7"	71.25"	1.85"
60	21.5	8	1000	1	40.8"	42.75"	1.95"

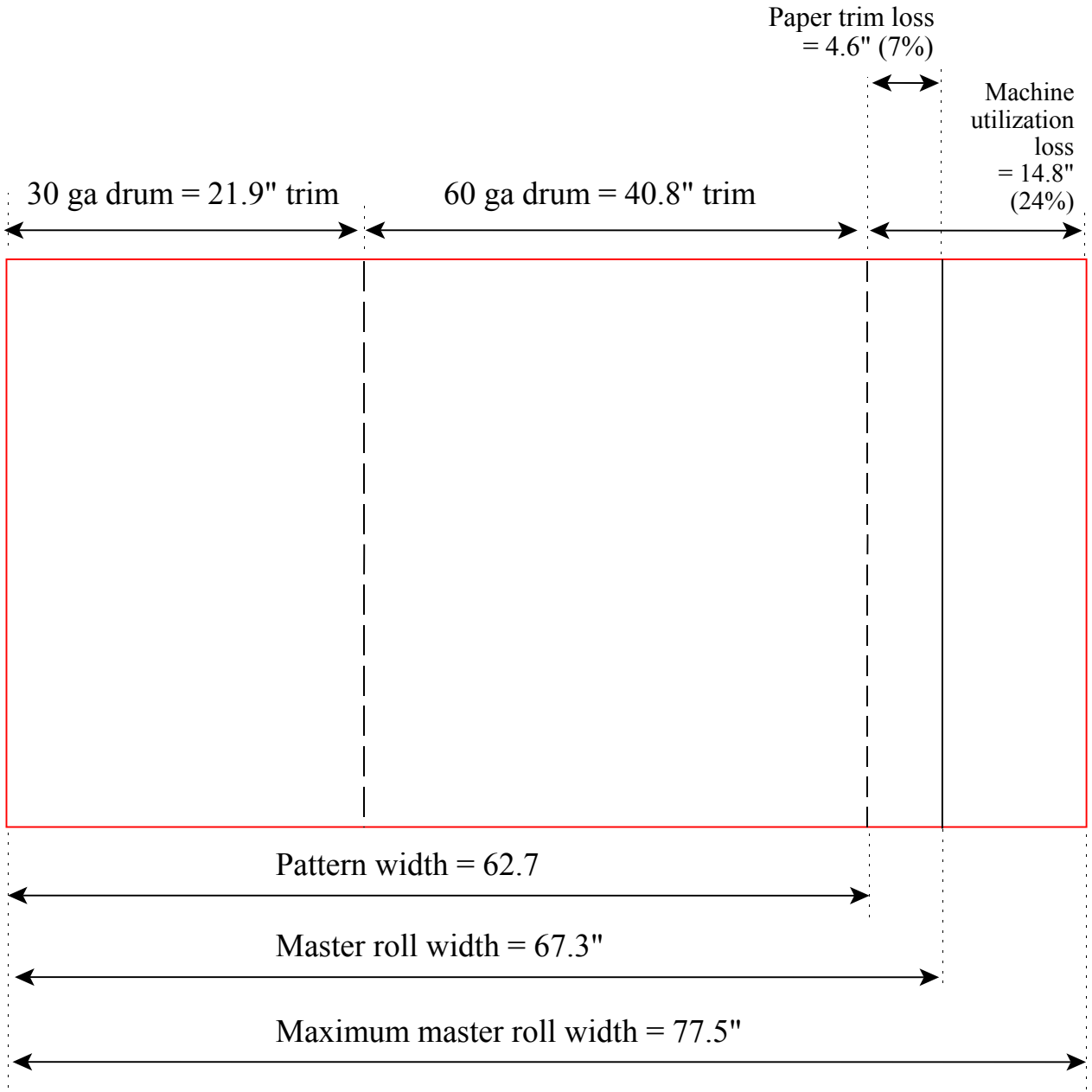
Symmetric Patterns

	Pattern Output (ϕ_{ji})						Optimal Configuration		
	10ga	20ga	30ga	40ga	50ga	60ga	Pattern Width	Kraft Width	Trim Loss
p_1	5						75.0	75.5	1%
p_2	4						60.0	67.3	12%
p_3		2					54.4	59.5	9%
p_4		1					27.2	42.8	57%
p_5			3				65.7	67.3	2%
p_6			2				43.8	51.8	18%
p_7			1				21.9	42.8	95%
p_8				2			56.6	59.5	5%
p_9				1			28.3	42.8	51%
p_{10}					2		69.4	71.3	3%
p_{11}					1		34.7	42.8	23%
p_{12}						1	40.8	42.8	5%

Asymmetric Patterns

	Pattern Output (ϕ_{ji})						Optimal Configuration		
	10ga	20ga	30ga	40ga	50ga	60ga	Pattern Width	Kraft Width	Trim Loss
p_{13}	1	1					42.2	42.8	1%
p_{14}	1	2					69.4	71.3	3%
p_{15}	3	1					72.2	75.5	5%
p_{16}			1	1			50.2	51.8	3%
p_{17}			2	1			72.1	75.5	5%
p_{18}			1		1		56.6	59.5	5%
p_{19}			1			1	62.7	67.3	7%
p_{20}				1	1		63.0	67.3	7%
p_{21}				1		1	69.1	71.3	3%
p_{22}					1	1	75.5	75.5	0%

Figure 3: Pattern 19 – Asymmetric, Two Slits



Model Decision Variables

X_{jpw} the number of times that pattern j is produced with ply p on paper of width w

Y_{jw} use of pattern j with paper width w

Z_w counts the number of Kraft master roll with width w which are required to cover the orders

Model Parameters

c^K, c^C the pattern and paper setup costs

c^P_{jp} liner board cost for pattern j, ply p cut from master roll with width w.

d_{ip} demand for drum i with wall thickness p

L_{jp} length of pattern j when applied with ply p

$\bar{L}$ length of a roll of Kraft paper

The Model Formulation: Mixed Integer Program

$$\min \qquad C = \sum_j c^K Y_j + \sum_w c^C Z_w + \sum_{j,p,w} X_{jpw}(c^M + c^P_{jpw})$$

$X_{jpw} \geq 0,$
$Y_j \in \{0,1\},$
$Z_w \in \{0,1,2,\ldots\}$

s.t.

$$\sum_{j,w} \phi_{ij} X_{jpw} = \bar{d}_{ip}$$

$$X_{jpw} \leq \bar{M}\ Y_{jw}$$

$$\sum_{jp} X_{jpw} L_{jp} \leq \bar{L} Z_w$$

Model Results

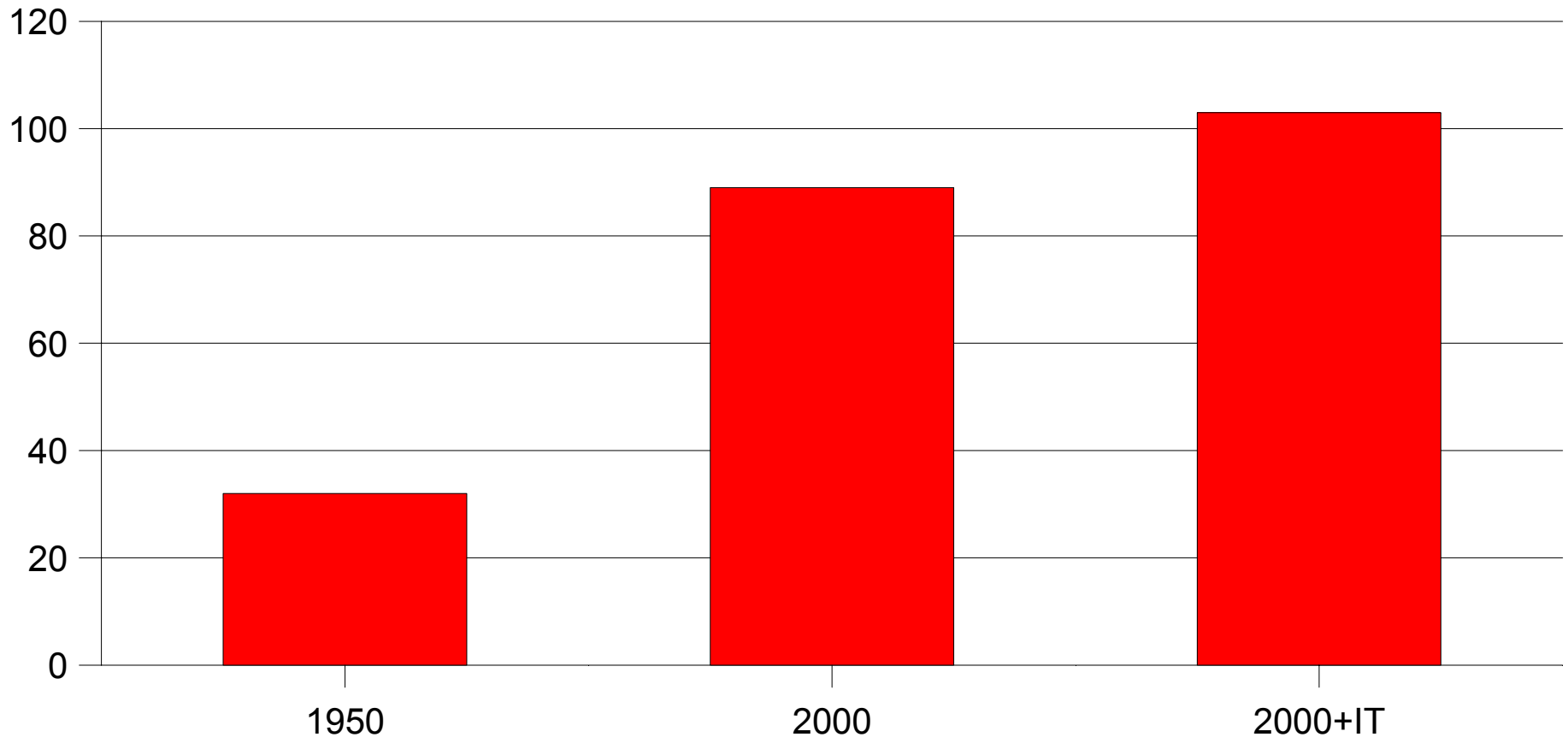
	1950	2000	2000 IT
Machine operator cost	33786	12475	10758
Kraft paper cost	89036	89036	88168
Paper setup cost	4550	1584	1368
Pattern setup cost	1170	20	27
Total	128542	103115	100321
Patterns	6	6	8
Master Tubes	31187	31187	26895
Knife Changes	60	6	8
Paper Changes	140	66	57
RunTime(Hrs)	520	156	134
Paper Utilization Efficiency	96%	96%	97%
Machine Utilization Efficiency	81%	81%	94%

Pattern and Kraft Usage

	1950	2000	2000 IT
p_1	2980	2980	864
p_3	10580	10580	0
p_5	7267	7267	384
p_8	5400	5400	192
p_{10}	3960	3960	3460
p_{12}	1000	1000	0
p_{14}	na	na	10580
p_{16}	na	na	182
p_{17}	na	na	10234
p_{22}	na	na	1000
w_{43}	45	45	0
w_{52}	0	0	8
w_{60}	513	513	7
w_{68}	308	308	17
w_{72}	168	168	431
w_{76}	81	81	501

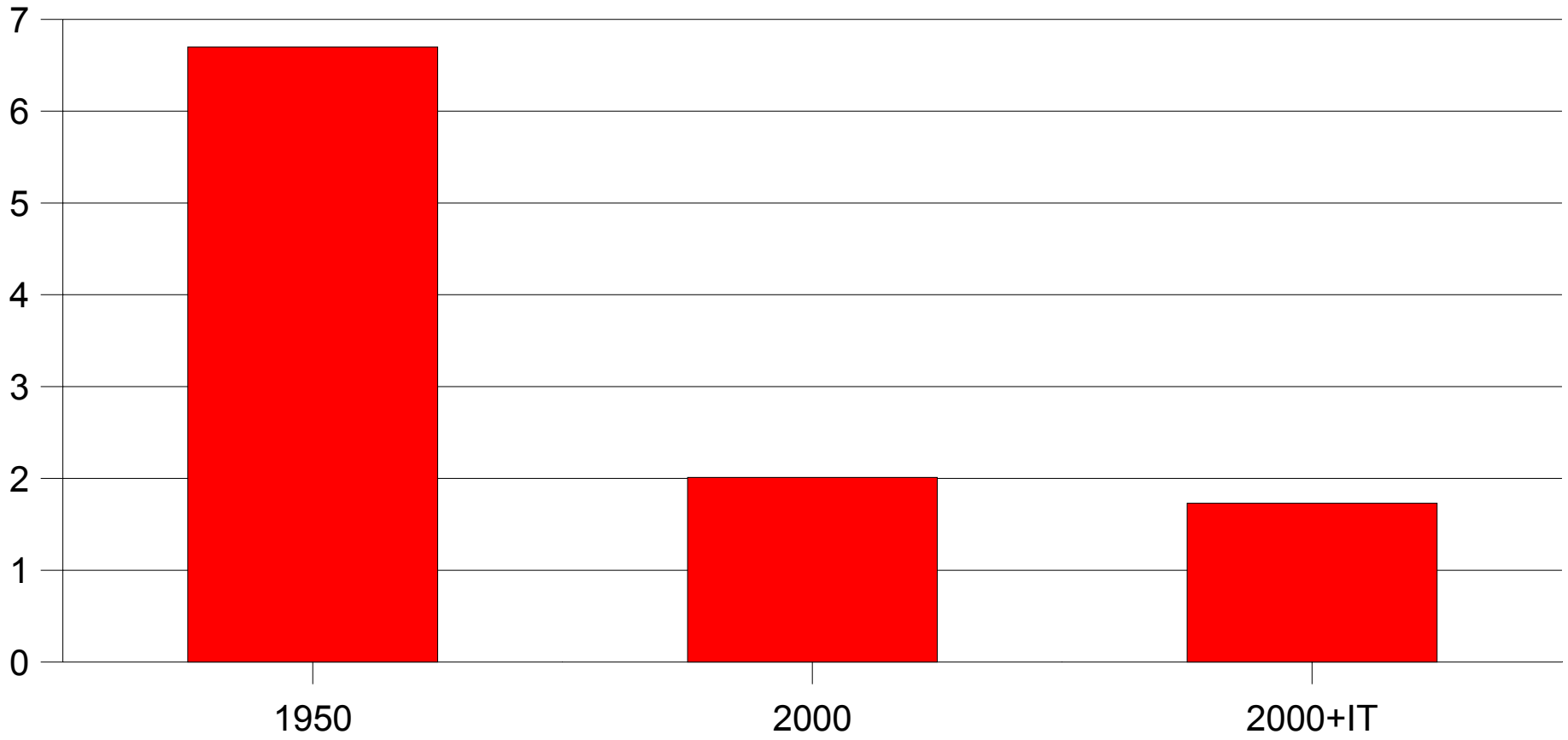
Labor Productivity

Drum Bodies per Manhour



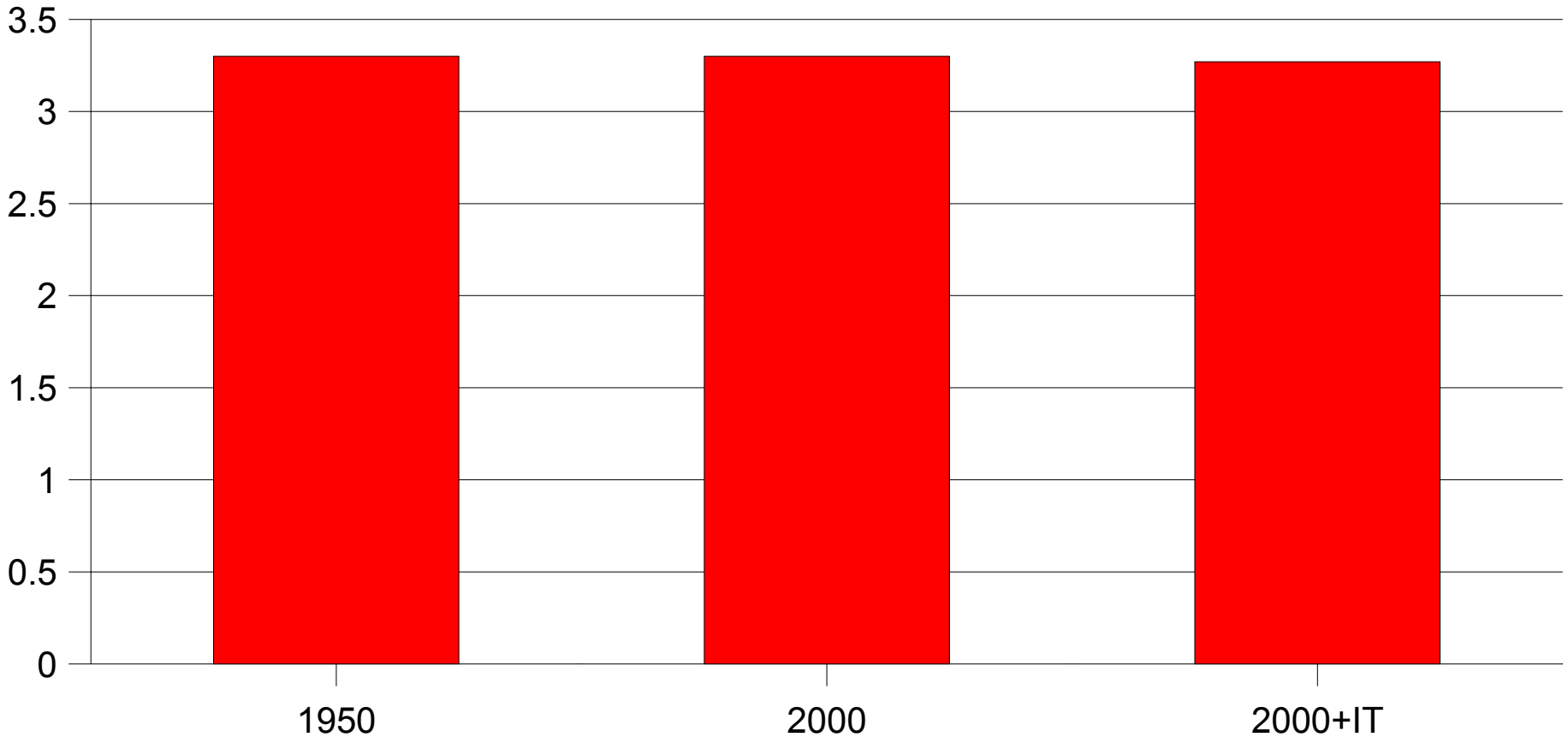
Machine Requirements

Hours per 1000 Drum Bodies



Kraft Paper Usage

Lbs per Drum Body



Paper Cost Share

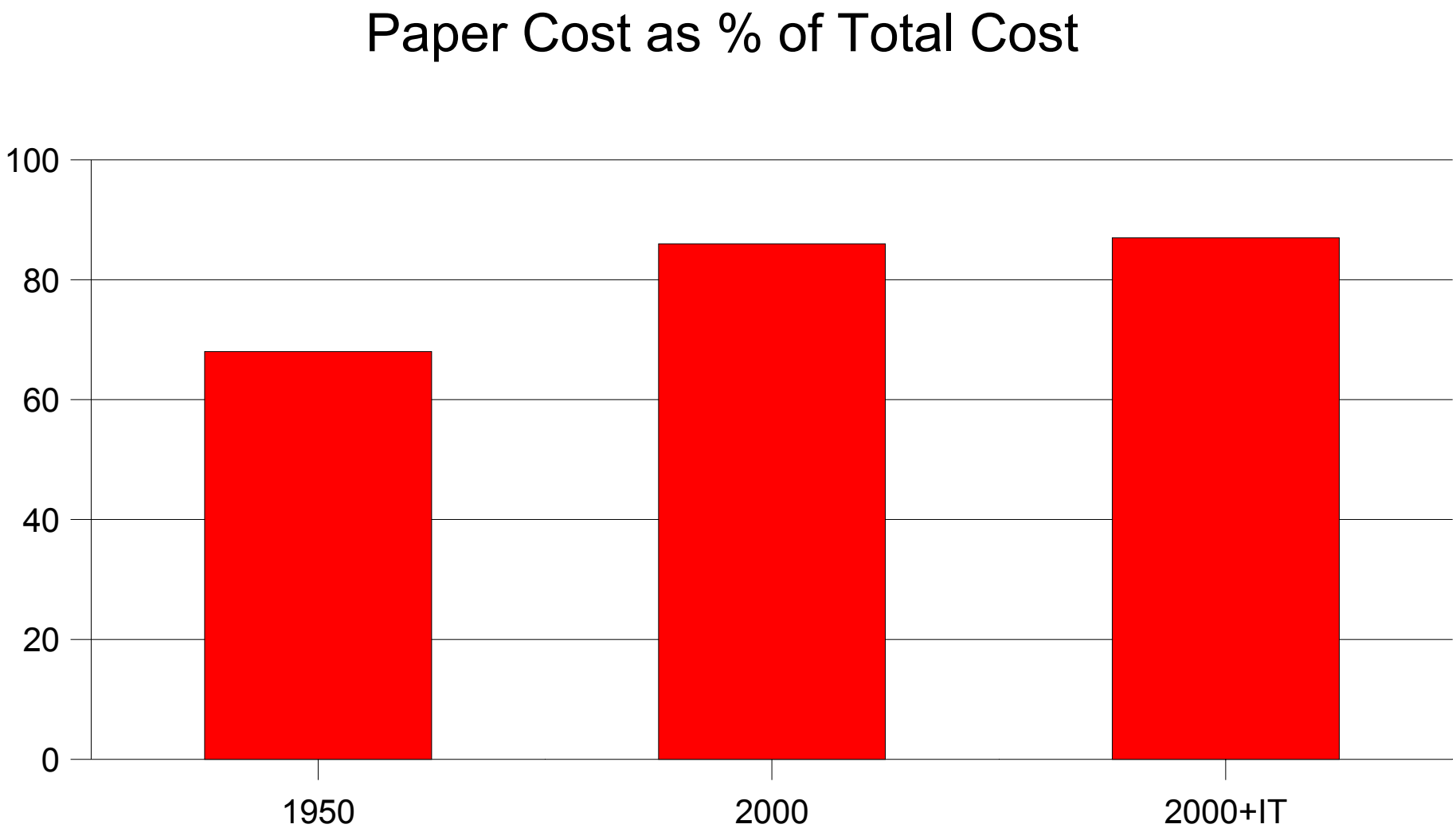


Figure 4: Sensitivity Analysis – Composition of Demand