Trim loss minimization in finishing house

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Paper is produced in a standard width in a paper machine depending on the deckle. Different widths of paper, then, have to be slit from the same standard reel depending upon the requirements of the customers. The knives settings on the slitter for cutting are decided so as to result in the minimum trim loss. The orders for paper vary both in terms of widths and quantity of rolls. The selection of optimum knives settings for minimum trim loss is not possible on an intutive basis when the number of widths in the customer reqnirements are large. On a slitter with multiple knives, an infinite number of settings are possible. First it is required to pick out of these possible knives settings only those which satisfy one or more of the orders to be met while giving a trim loss lower than the smallest width ordered. Next is to decide on the number of reels to be cut at each setting so as to fulfil a ll the customer requirements keeping the trim loss at the minimum.

An algorithm has been developed for identifying all the feasible knives settings and the Simplex algorithm of linear programming has been used to choose the best settings (i) A computer programs in BASIC is presented, as listed in APPENDIX—A, to carry out these calculations. The program can be run on any personal computer or any other computer allowing use of BASIC.

The following data are required :

1. The width of the reel (deckle), m; after deducting the minimum required trimming of the edges.
2. The number of orders, separate orders have been considered for each width of reel in a reel order and width of sheets in a sheet order. For example, an order for reels of three widths will be considered equivalent to 3 orders.
3. The width and the number of rolls required in each order. Geuerally, in case of sheet orders the longer side of the sheet is taken in machine direction and hence a reel of a width equal to the width of the sheets required in an order can be slit before finally cutting them into sheets. If acceptable to the buyer a wider reel equal to the length of sheets can be slit. It is generally not considered a good practice to have aheets some having their longer side along machine direction and some along cross direction.

The program is made considering only one machine at a time but it can be modified to accomodate more than one machines.

A sample problem has been solved in APPENDIX B to illustrate the use of this program.

REFERENCE :

Taha H. A., "Operations Research—An Introduction", Mac Millan Publishing Co. Inc., New York (1982)

APPENDIX—A : Program Listing

```
dim x%(20), c(20, 150), s(20. 150), value (20),
b(20), rolls(20)
dim obj(150), w(20), trim (150), del (150),
rollsprod (20)
cls : beep
print "Trim loss Mini MISER" ; p
print "Width of pope reel after deducting minimum;
print "required trimming of edges";
input P
input "No. of orders"; m
totalroll=0
for k=1 to m
print
input "Width ordered"; w(k)
input "No. of rolls to be slit"; value (k)
rolls (k)=value (k)
totalroll=totalroll+ value (k)
next k
for k=2 to m
for j=1 to k—1
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    if w(k)>w(j) then 10
    dum1=w(k)
    dum2=value (k)
    for 1=k to j+1 step —1
    w(1)=w(1—1)
    value (1)=value (1—1)
    rolls (1)=value (1)
    next 1
    w (j)=dum1
    value (j)=dum2
    rolls (j)=value (j)
10  next j
    next k
    ns=1
    x%(1)=INT(P/w(1)
    if x%(1)<1 then 500
    c(1, 1)=x%(1) : s(1, 1)=x%(1)
    trim (1)=P–x%(1)*w(1)
    j=1
12  x%(j)=x%(j)—1
    if x%(j <0 then 20
    sum=0 0
    for k=j+1 to m : x%(k)=0 : next k
    for k=1 to j : sum=sum+x%(k)*w(k) : next k
    x%(j+1)INT((P—sum)/w(j+1))
    if x%(j+1)<1 then 12
    trim=P—sum—x%(j+1)*w(j+1)
    if trim > w(1) then 25
    if trim <0 then 25
18  ns=ns+1
    for i=1 to m : c(i, ns)=x%(i) : s(i, ns)=x%(i) :
    next i
    trim (ns)=trim
25  if j=>m—1 then 22
    j=j+1 : go to 12
22  x%(m—1)=x%(m—1)—1
    if x%(m—1) <0 then 20
    sum=0 : x%(m)=0
    for k=1 to (m—1) : sum=sum+x%(k)*w(k)
    next :
    x%(m)=INT((P—sum)/w(m))
    if x%(m)<1 then 22
    trim=P—sum—x%(m)*w(m)
    if trim > =w(1) then 22
    go to 18
20  j=j—1
    if j=0 then 100
    go to 12
100 cls : print : Rem feasible knife—settings determined
150 phase=1
    ns1=ns+m+m
155 for j=1 to ns1 : obj (j) = 0.0 : next j
    for i=1 to m
    c (i,ns+i) = –1.0
    c (i,ns+m+i) = 1.0
    b (i) = ns+m+i
    obj (ns+m+i)=1.0
    next i
120 rem simplex tableau
160 rem calculate del
    for j=1 to ns1
    sum=0 0
    for i=1 to m
    sum=sum + obj (b (i))* c (i,j)
    next i
    del (j) = obj (j) —sum
    next j
260 rem select largest negative del to fix entering
    variable
    jenter=0
    big=0
    for j=1 to ns1
    if del (j) > = 0 then 262
    if abs (del(j)) <= big then 262
    big = abs (del (j))
    jenter=j
262 next j
    if jenter = 0 then 400
270 rem smallest +ve value to fiix leaving variable
    i leave=0
    small = 9e9
    for i=1 to m
    if c(i,jenter) = 0 then 272
    if value (i)/c (i, jenter) < = 0 then 272
    if value (i) /c (i,jenter) > = small then 272
    i leave=i
    small = value (i)/c (i, jenter)
272 next i
    if i leave=0 then 290
    pivot= c (ileave, jenter)
280 rem gauss jordan
```

```
    for j=1 to nsl
    c (i leave, j) = c (i leave, j)/pivot
    next j
    Value (ileave)=value (i leave)/pivot
    for i=1 to m
    if i=ileave then 282
    dummy=c (i, jenter)
    for j=1 to nsl
    c(i,j) = c-(i,j)—dummy * c (i leave,j)
    next j
    value (i)=value (i)—dummy * value (i leave)
282 nent i
    b (i leave) = jenter
    iter = iter+1
    if iter > 50 then 505
    goto 120
400 rem perhaps optimum has come
    if phase=2 then 450
    for i=1 to m
    if b (i) > ns+m then 500
    next i
    phase = 2
    nsl=ns+m
    for j=1 to ns
    obj (j) = trim (j)
    next j
    iter=0
    go to 120
450 rem print the results
    cls : print
    print tab (3); "TABLE 1 Feasible knife settings"
    print tab (3);
    for k=1 to 4+7*m : print "—"; : next k
    print
    print tab (7*m/2—6); "Roll Widths, m";
    tab (3+7*m); "Trim"
    print tab (3);
    for k=1 to 7*m—4 : print "—"; : next k
    print tab (3+7*m); "loss"
    print tab (3);
    for i=1 to m
    print w (i); tab (3+7*i); : next i
    print
    print tab (3) :
    for k=1 to 4+7*m : print "—"; : next k
    print
    for j=1 to ns
    print tab (3);
    for i=1 to m
    print s (i,j); tab (3+7*i);
    next i
    print trim (j)
    next j
    print tab (3);
    for k=1 to 4+7*m : print "—"; : next k
    print : print
    print tab(3); "TABLE 2 Optimum Slitting Scheme":
    print
    print tab (3);
    for k=1 to 13+7*m : print "—"; : next k
    print tab (7*m/2=2); "Roll Widths, m"; tab
    (3+7*m); "Trim";
    print tab (10+7*m); "No. of"
    print tab (3);
    for k=1 to 7*m—4 : print "—"; : next k
    print tab (3+7*m); "loss"; tab (10+7*m); "reels"
    print tab (3);
    for i=1 to m : print w (i); tab (3+7*i); : next i ;
    print
    print tab (3) ;
    for k=1 to 13+7*m : print "—"; : next k
    print : trimlosss =O.O
    for i=1 to m
    if b (i) > ns then 470
    print tab (3) ;
    for j=1 to m
    rollsprod (j) = rollsprod (j) + s (j,b(i )*INT
    (value (i) +.9)
    print s (j,b(i)), tab (3+7*j);
    next j
    print trim (b(i)); tab (10+7*m); INT(value (i) +.9)
    trimloss=trimloss+trim (b(i)) * (int value(i)+ 9))
    print
470 next i
    print tab (3);
    for k=1 to 13+7*m : print "—"; : next k
    print: print tab (3);
    for j=1 to m
    print rolls (j); tab (3+7*j);
    next j
    print "rolls ordered" : print : print tab (3);
    for j=1 to m
    print rollsprod (j); tab (3+7*j);
    next j
    print "rolls produced"
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print :print tab (3); "Total trim loss %=";
print trimloss * 100.0/(P * totalroll)
stop : end
500 print "first phase not optimized" : end
505 print "iterations exceed 50; job terminated" : end
290 rem breaking tie
    big = O
    jl=jenter +1
    big=abs (del (jenter))
    for j=jl to nsl
    if del (j) > = O then 292
    if abs (del (j)) = big then jenter = j
292 next j if jenter = (jl—1) then end
    goto 270
```

APPENDIX—B : Sample Problem

To illustrate the use of this program let us take the following sample problem

A paper mill has a single paper machine. The wibth of the paper at the pope reel after deducting the minimum edge trimmings is 6 m. The mill, at a particular time has 5 orders at hand as given below.

order no.	width, m	no. of rolls
1	1.75	30
2	1.2	20
3	2.5	50
4	3.2	25
5	4.5	45

The soluction of the above problem is yielded in the form of two tables as given below :

```
Trim loss Mini MISER
Width of pope reel after dedueting minimum required trimming of edges ? 6
No. of orders ? 5
Width ordered ? 1·75
No. of rolls ? 30
Width ordered ? 1·2
No. of rolls ? 20
Width ordered ? 2 5
No. of rolls ? 50
Width ordered ? 3·2
No of rolls ? 25
Width ordered ? 4·5
No. of rolls ? 45
```

TABLE 1 Feasible knife settings

Roll Widths, m					Trim loss
1.2	1.75	2.5	3.2	4.5	
5	0	0	0	0	0
3	1	0	0	0	.65
2	2	0	0	0	.1
2	0	1	9	0	1.1
2	0	0	1	0	.4
1	1	1	0	0	.55
1	0	0	0	1	.3
0	3	0	0	0	.75
0	2	1	0	0	0
0	1	0	1	0	1.05
0	0	2	0	0	1
0	0	1	1	0	.3

TABLE 2 Optimum Slitting Scheme

Roll Widths, m					Trim loss	No. of reels
1.2	1,75	2.5	3.2	4 5		
1	0	0	0	1	.3	45
0	2	1	0	0	0	25
0	0	1	1	0	.3	25
20	30	50	25	45	rolls ordered	
45	50	50	25	45	rolls produced	

Total trim loss % =2.05882

It is interesting to note that the rolls of smaller sizes, namely, 1 2 m and 1.75 m are more than their ordered numbers in the minimum trim loss scheme which is not so obvious in an purely intutive approach The excess rolls can be utilized in some future orders if possible. If these rolls have to be repulped for any reason then they must be added to the trim loss.