SIMULATION OF STOHASTIC SYSTEM OF PRINTING PROCEDURES

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1. Introduction

This paper shows an example of modelling and carrying out simulation experimenting as an example of micro and macro simulation of stohastic system printing procedures. First a Computer to Plate (CTP) system program model will be designed as a macrosystem where individual CTP modules will be researched thoroughly and where one module of the system will be optimized.

After simulation experimenting and optimizing, the CTP system will be built into the new printing system consisting of a five-colour offset machine and print finishing. This macro model will be used to measure the time necessary for printing different quantities of the same job that has arrived through the internet in compressed form. Each stohastic variable was made on basis of measurements carried out in the past 2 years.

A financial breakdown example will be given with the CTP system and a decision will be made whether to build up the system or not – depending on the market where this system is implemented. Experiments with set printing run quantities and measurement of time needed fo completing the job systems are going to be essential for the simulation of a digital analogous system where CTP is the digital part and where the offset and print finishing are the analogous parts. This is essential for bringing the right decisions in respect to completing jobs in fixed spaces of time. When negotiating long-term jobs and fixed printing runs, managements need to know how to make the best decisions and set the best contract terms.

A system can handle jobs without stoppages if the speed of servicing is higher than the speed of receiving new jobs. When we have a real-life situation there may be accidental disturbances in job arrival, servicing speed or both, and the result is having stoppages that cause the forming of waiting queues.

2. The CTP System Model

The CTP system consists of three modules: the imposition and processing module, the bitmapping module and the exposing and developing module. The imposition and processing module's work consists of the phase where the PostScript entry of the original PS file is transformed into the lower PostScript installation level and the phase where imposition commands are incorporated for a certain output offset plate size that is later the input object for the bitmapping module.

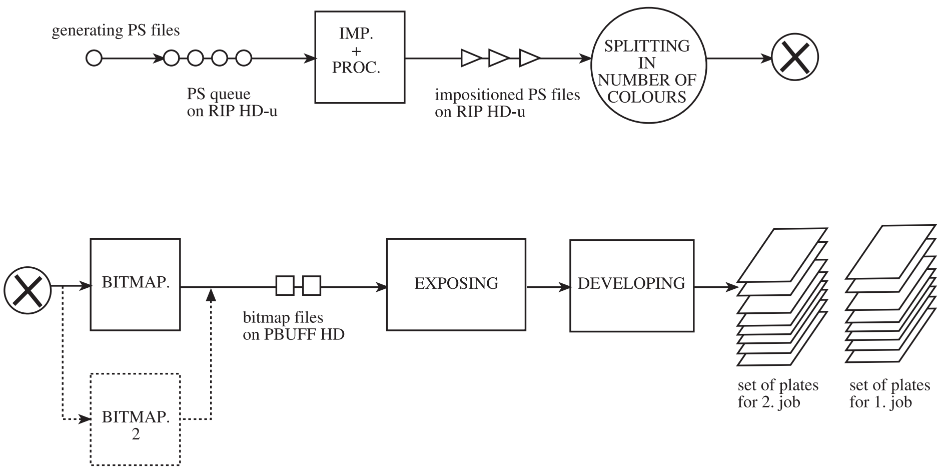

Figure 1. The CTP System

The bitmapping module makes a bitmap file of the job on a preset resolution and line frequency that will be exposed on the plate. This file is understood only by the exposing system and it is made on large PageBuffer discs. These two phases together are called the RIP-ing phase and they have been seperated into the two micromodules with the goal being better modelling, research of stoppages and possible optimization of the system.

The exposing and developing process are accessed by bitmapped files. The exposing phase is functionally connected with the chosen resolution and line frequency as well as the offset plate output size. The size of offset plates in our case will be taken as B1. The developing phase with on-line processor does not depend on the previously listed conditions but only on the offset plate type.

Figure 1. shows the CTP system and the formed queues position. The system is entered by PostScript entries arriving from the internet surroundings. They arrive into the model randomly, the arrival of the

subsequent one does not depend on the previous arrival. This is best simulated by generating transactions with exponential distribution.

After generating the PS file, the imposition and processing module is entered. If the job had been compressed this is where decompression takes place. Imposition is the process of multiplying the job on the output plate format. If, for example, the job has an A4 size, the imposition will make 8 copies of the job and will form a new PS entry that will fill the B1 output format with 9 A4 digital forms (1 original + 8 copies). In the processing phase all PostScript commands are transformed to a lower level. For instance, Bezier curves are transformed into small linear segments that will later be formed on the bitmap output resolution and in many other basic conversions linked with future bitmapping. A uniform distribution of processing time amounting to 20+-3 min for A4 jobs impressed on B1 output size was determined on basis of measurements taken throughout 2 years on a real-life system. A queue of PS entries is formed in front of this module on a RIP hard disc.

PS files for B1 size can be multicoloured. A separate B1 bitmap must be formed for each colour. This is the reason why the PS files must be separated into as many bitmaps as there are colours. Our case will be a job that has 9 colours - five colours for printing the front and four colours for printing the back sheet. Therefore, the bitmapping module must carry out 9 servicings for one input PS file. This is simulated in the model by the splitting process where one transaction will be split up into 8 transactions by having a total of 9 transactions passing through the bitmapping facility. Measurements have shown that the uniform distribution of 10+-2 minutes are necessary for servicing each colour. In front of the bitmapping there is a queue of B1 files forming on the RIP hard disc.

The formed bitmaps are saved on large capacity PageBuffer discs. As soon as one bitmap is formed it goes to the exposing process, and then to the online developing module where the B1 offset printing plate for one colour of a job comes out. A 9 colours job is ready for printing when 9 offset plates have all come out. This is called a set of transactions. The speed of exposing depends on the chosen resolution, and the developing process depends on the offset plate type. Measurements have shown that the joint time for exposing and developing of a B1 plate amounts to 5+-1 minutes.

3. Building a Program Simulation CTP Model

Experimenting on a physical model would be too expensive because the production material is expensive as well as the servicing units. Experimenting with a program simulation model should make it possible to estimate the profitability of replacement or expanding of the existing recources, i.e. the dynamic configuration of the system depending on the number of jobs and job completion terms.

Measurments based on the physical system have given the CTP system speed distributions applied in making the stohastic program model. Figure 2. shows the GPSS program consisting of a configuration with two bitmapping modules and this is only one state of the research model that is going to be explained later in the experimental part.

Transactions enter the model by the exponential distribution RVEXPO with a mean value of intermediate arrivals - TM. The transaction represents the input PS file. With each start-up of the model the TM variable is entered so as to experiment with the model in respect to different incoming speeds of job arrivals. The variable BB representing the number of colours of a job is also entered. In this way the model can be studied in respect to the different number of colours per job. The model has three Facilities:

- IMP for imposition and processing
- BITMAP for bitmapping
- OSVJ for exposing and developing

The BITMAP Facility has turned into Storage with two positions in the Figure 2 model so that experiments could be made with a virtual model having 2 bimapping modules. The time necessary for servicing each of these Facilities and Storages is determined in Advance blocks.

Queues interesting for reasearch reasons are formed at three points:

- QUEUE IMP formed on the RIP HD before the imposition and processing phase;
- QUEUE SPLITTING formed on the RIP HD before the splitting phase forming the number of copies of the input transaction before bitmapping;
- QUEUE OSVJ formed on the PageBuffer disc before the exposing phase.

Every input PS at the end of the model must generate the number of offset plates that corresponds to the number of printing colours (variable BB) that has been determined by PS. The impositioned PS enters the bitmapping phase only after the previous set of BB offset plates have been completed. This is regulated by the logic switch with name SPLITTING, positioned just before the said phase. The logic gate GATE LR is opened only when the LOGIC R block resets the switch at the end. This takes place only when the counting device B reaches the BB value, i.e. when one set of offset plates is completed. At start-up the logic switch is in the RESET position and so the first transaction freely enters the open gate into the SPLIT block.

The command ADVANCE 0 is positioned in front of the GENERATE block so that the speed of the incoming transactions does not change if there is a stoppage before the IMP facility. Otherwise the transaction that is ready to be generated would remain in the GENERATE block as long as the IMP is not free. So the transaction remains in the ADVANCE block making the load of the model constant and this is important for the output statistics and our research of the model.

The model in Figure 2 is designed for a number of 9000 transactions to come out of it and this can be modified with variable N in the START block. In such a manner the model has a sufficient number of transactions for regular functioning of all the model's stohastic variables. The input number of transactions is not equal to the output number of transactions because of the splitting transactions that take place before the bitmapping module.

```
******** CTP (ComputerToPlate)  with 2 bitmapping modules ********

      SIMULATE
      INTEGER &N
      INTEGER &BB,&B
      REAL &TM
      INITIAL LR(SPLITING)
      LET &N=9000             number of transactions
      BLET &B=0
      STORAGE S(BITMAP),2
      PUTPIC
0Put number of colours
      GETLIST &BB
      PUTPIC
0Put TM (min)
      GETLIST &TM
      GENERATE RVEXPO(1,&TM)
      ADVANCE 0
      QUEUE IMP
```

```
      SEIZE IMP
      DEPART IMP
      ADVANCE 20,3                  imposition and processing
      RELEASE IMP

      QUEUE SPLITING
      GATE LR SPLITING              Is the set of plates finished?
      DEPART SPLITING
      LOGIC S SPLITING
      SPLIT &BB-1,SKOK        splitting in number of colours

SKOKENTER BITMAP
      ADVANCE 10,2                  bitmapping of B1 format
      LEAVE BITMAP
      QUEUE OSVJ
      SEIZE OSVJ
      DEPART OSVJ
      ADVANCE     5,1   exposing and developing of B1 format
      RELEASE OSVJ
      BLET &B=&B+1
      TEST E &B,&BB,KRAJ
      BLET &B=0
      LOGIC R SPLITING
KRAJTERMINATE 1
      START &N
      END
```

Figure 2. GPSS model of CTP system with two bitmapping modules

The model with two bitmapping modules has a two position STORAGE. In this way a transaction enters the first free bitmap module (the ENTER BITMAP block) making the modules parallel, with a higher servicing capacity.

4. Experimenting with the CTP Model

Simulation experimenting is used for researching general dependencies of response and the simulation factor. In case it is concluded that the number of transactions in the queues is too high, designer factors must be changed. This can be done in three ways: reducing the speed of incoming transactions, enhancing the speed of servicing individual modules or increasing the number of servers.

This paper shows experiments based on changes made in respect to the transaction arrival speed factor and increase of the bitmapping modules number. The speed factor has 10 quantity levels that are reached by changing the average time of intermediate arrivals in the GENERATE block program. When the average time of intermediate arrivals iz 480 minutes, then there is one transaction in eight hours. When there is an incoming transaction at an average of 48 minutes, this means there are 10 transactions in 8 hours.

In a concrete experiment there is a certain combination of levels, one for each factor. Each of these combinations determines one model variant. The output variables, i.e. the variant model reactions resulting in the output simulation statistics with program models will be recorded for each variant as follows:

a) IMP average utilization; parameter AVERAGE UTILIZATION in the output statistics
b) BITMAP average utilization; parameter AVERAGE UTILIZATION in the output statistics
c) OSVJ average utilization; parameter AVERAGE UTILIZATION in the output statistics
d) IMP average waiting period; parameter $AVER.TIME/TR in the output QUEUE statistics
e) SPLITTING average waiting period; parameter $AVER.TIME/TR in the QUEUE statistics
f) OSVJ average waiting period; $AVER.TIME/TR in the QUEUE statistics

All the experimenting results are shown graphically where the results of the average waiting period recording is given in the logarithmic scale. First the dependency of the average waiting period and the usability of the exposing and developing module in respect to the number of input transactions is recorded without the influence of other models (IMP=0, BITAP=0). In this manner it may be established how many input transactions make the exposing and developing module become the bottleneck in the process.

The dependency of waiting is recorded and usability of bitmapping in respect to the number of input transactions because of itself alone (IMP=0, OSVJ=0). Thus it is established how many input transactions make bitmapping become the bottleneck of the process. The IMP module was recorded in the same manner (BITMAP=0, OSVJ=0). This is sumulation experimenting in steps that first determine the capacity of the very modules and with this knowledge further model variants are recorded where the influence of certain module stoppages are expected and the usability of the whole system is determined. Only those combinations and factor levels were chosen that were the matter of interest for the field of research of the number of input transactions (up to 11 in 8 hours) and those where the usability will amount to 70 and 80%. Those combinations that have waiting periods above 1,000 minutes and are on their way to cause total stoppages will not be taken into consideration.

Figure 3 is a graph showing the dependency of the average waiting period in a queue and usability of the module in respect to input jobs within a time period of 8 hours. There is complete stoppage of the exposing and developing module when there are more than 10 jobs in 8 hours, and it is most efficient for 7 to 8 jobs where it's usability amounts to 70 – 80%.

There is complete stoppage of the bitmapping module in cases when there are 5 jobs in 8 hours, and this module is most efficient for 4 jobs. This module is the most serious bottleneck of the system. Experimenting with the model that has only it's imposition channel open (IMP=0) is also shown, marked as the one waiting for bitmapping and exposing, and developing.

This graphic presentation does not cover experimenting with the imposition and processing module because experiments have shown that there is a stoppage at this module only when there are as many as 25 jobs in 8 hours. Therefore it can not cause complete stoppage of the system and is not to be considered further in the paper.

Two curves of the CTP system waiting period are shown in the graph, one with one bitmap module and the other one with two bitmap modules. This waiting period was measured in QUEUE SPLITTING, i.e. before the bitmapping, exposing and developing process. As the bitmap module is the most serious bottleneck of the system, experiments were carried out as if there were two modules. As imposition does not influence the capacity of the system, the two remaining modules are sufficient for determining the optimal solution. In this case there is complete stoppage of the CTP system only in cases when there are as many as 10 jobs in 8 hours. This experimenting has shown that it was sufficient to enhance the bitmapping module without enhancing another exposing unit and all of this had not been clear at the beginning.
From the financial point of view the crossing over to a CTP system with two bitmap modules is efficient if multiplication of the job value (P) and the number of jobs (BP) in 8 hours is higher then investments (U) into the bitmap module for the certain time period the investment applies to:
$BP = 480 / TM$ $\qquad$ $P \times BP > U$

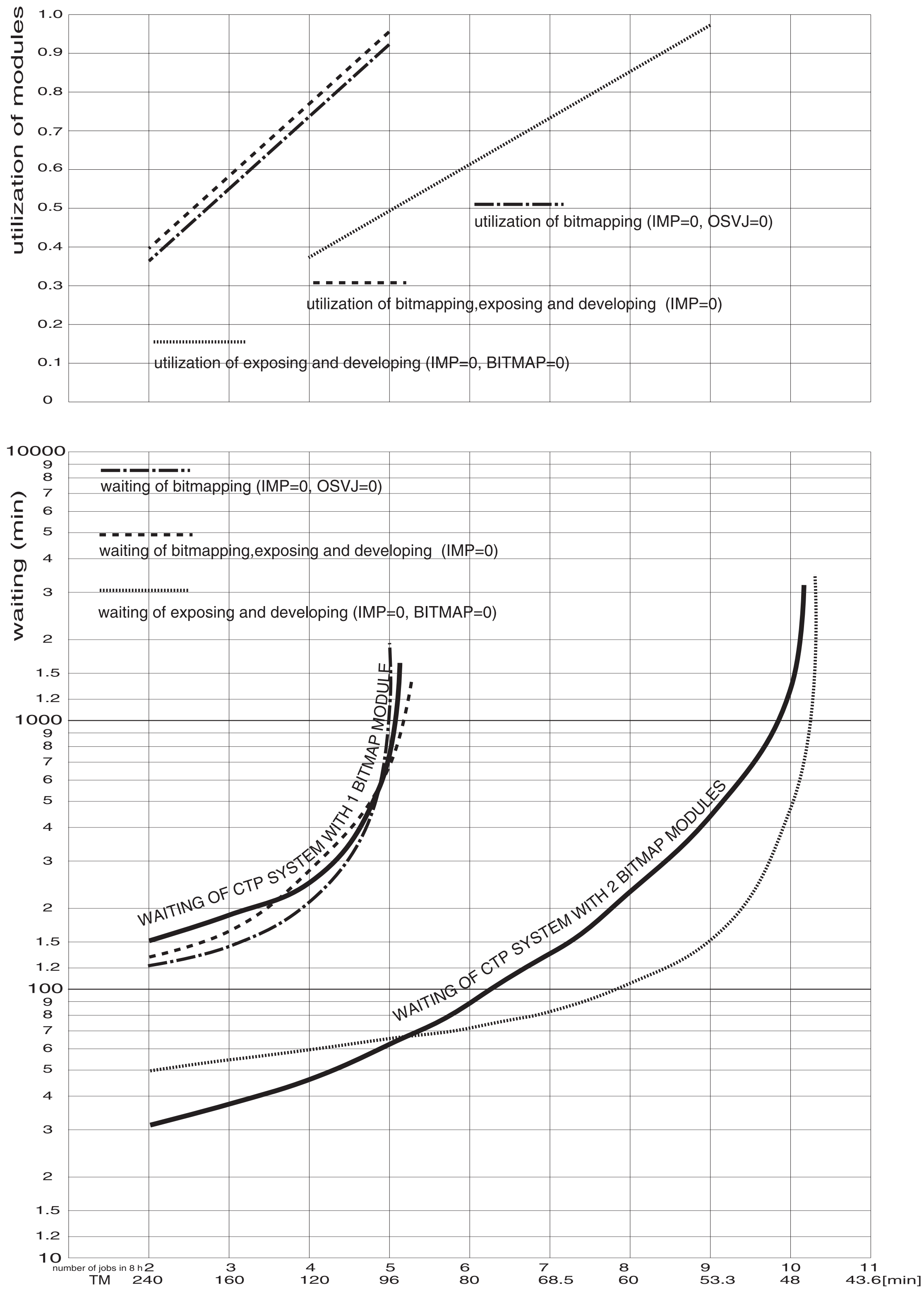

Figure 3. Dependency of the average waiting period in a queue and usability of the module in respect to the number of jobs in 8 hours

5. Digital Analogous System

Figure 4 shows the model for making offset prints. The analogous part is the offset machine and the digital part is the RIP system and the unit for photoexposing of offset plates directly from the computer (Computer To Plate Technology – CTP) described in the previous chapter. This model depends on the printing run of form and the number of colours in the print. Variables of the printing run and number of colours influence on the workflow of the offset machine, and only the colour number variable influences the CTP workflow.

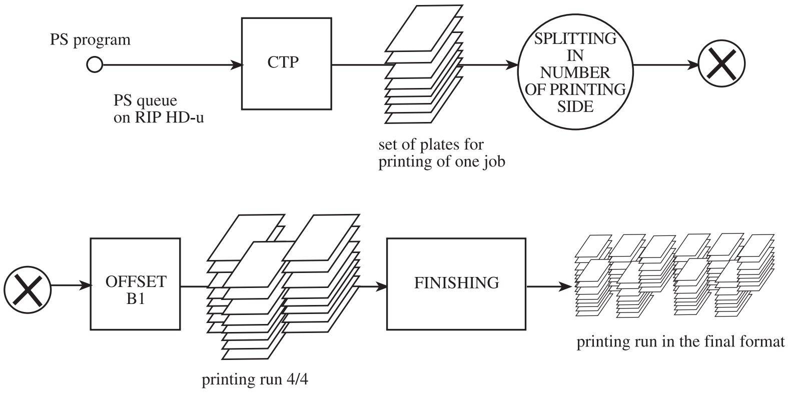

Figure 4 Model for a Digital Analogous printing system.

The offset plates for printing the front sheet colours are placed on the offset machine cylinders. After printing the front sheet the machine is washed and the offset plates for the back sheet are mounted. The printing material is turned over and placed at the input side. After the job on the printing unit is finished, all the sheets go through the finishing process that consists of drying time, cutting, counting and quality control.

The stohastic model was created by defining the RIP time necessary for processing and imposition, for bitmapping and exposing of a single offset plate, the time necessary for both sheet side printing and the time necessary for the finishing process. The model must provide the possibility to change the colours on the master as well as the size and the number of forms on the machine sheet and the printing run too.

When all the offset plates are developed, the offset machine preparation phase begins. It depends on the number of printing modules (cylinders) on which the prepared offset plates are fixed. Each module is for printing one colour. This paper describes a model with 5 such modules. The job that must be completed by this offset system is double side printing where 4 colours are printed in one run and 5 colours are printed in the other run (the fifth colour is the UV protective colour). The time of mounting the plates and washing the machine equals to a uniform distribution of 20+-3 minutes.

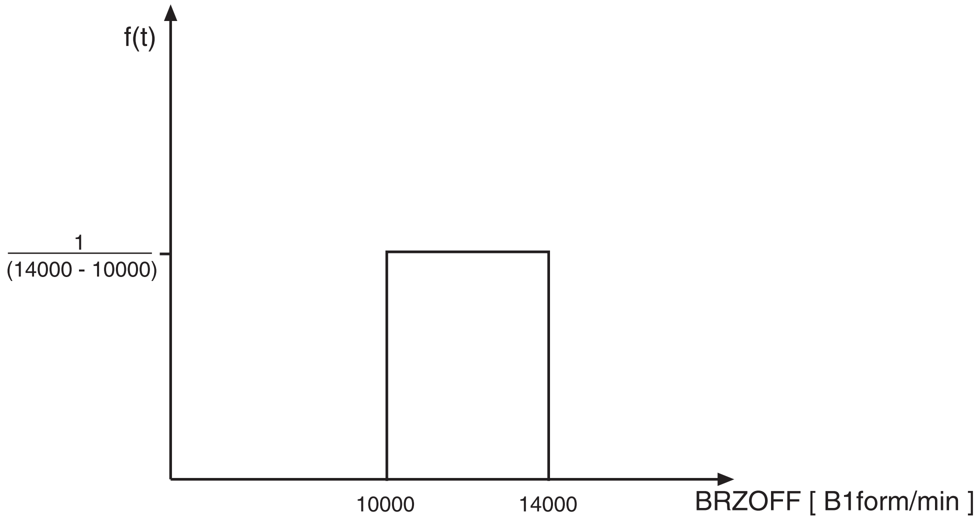

Figure 5. The uniform function of printing speed probability with a five-colour offset machine, B1 format

After offset plates for each colour are mounted on the printing modules, the printing phase is started-up and the speed is shown by a uniform probability function in Figure 5 that was calculated on basis of measurements of 324 samples of B1 printings on a five-colour offset printing machine. After the front sheet side has been completed, sheets are turned over and placed at the entrance of the machine that has been prepared with new offset plates for printing the back sheet side.

The time necessary for printing a certain quantity of B1 size sheets is calculated as follows:

t= (ANAKL x 60/FN(BRZOFF)   min

where ANAKL is the preset number of B1 sheets, FN(BRZOFF) is the continuous function of distribution of the offset machine calculated from the probability function in Figure 5. Variable ANAKL is calculated on basis of the preset printing run quantity of master NAKL and the number of forms of the master print BA4STR in the sheet of the machine with the calculation

ANAKL = (NAKL/BA4STR) x 1.10   pc,

and because of the existing rejects amounting to 10% there is the rejects factor of 1.10 as part of the calculation.
When the offset printing of any printing run quantity is completed, the offset colours need to dry before any final finishing is done. By measuring the drying time in 146 samples where both sides of the printed jobs needed to dry, the probability function in Figure 6a) resulted.
After drying, the sheets can go through final finishing. This includes cutting to a final size, quality control, rejects elimination and accessory colouring on the colouring machines. There were 22 measurements carried out on the final finishing of 150,000 masters. The probability function in Figure 6b) resulted.

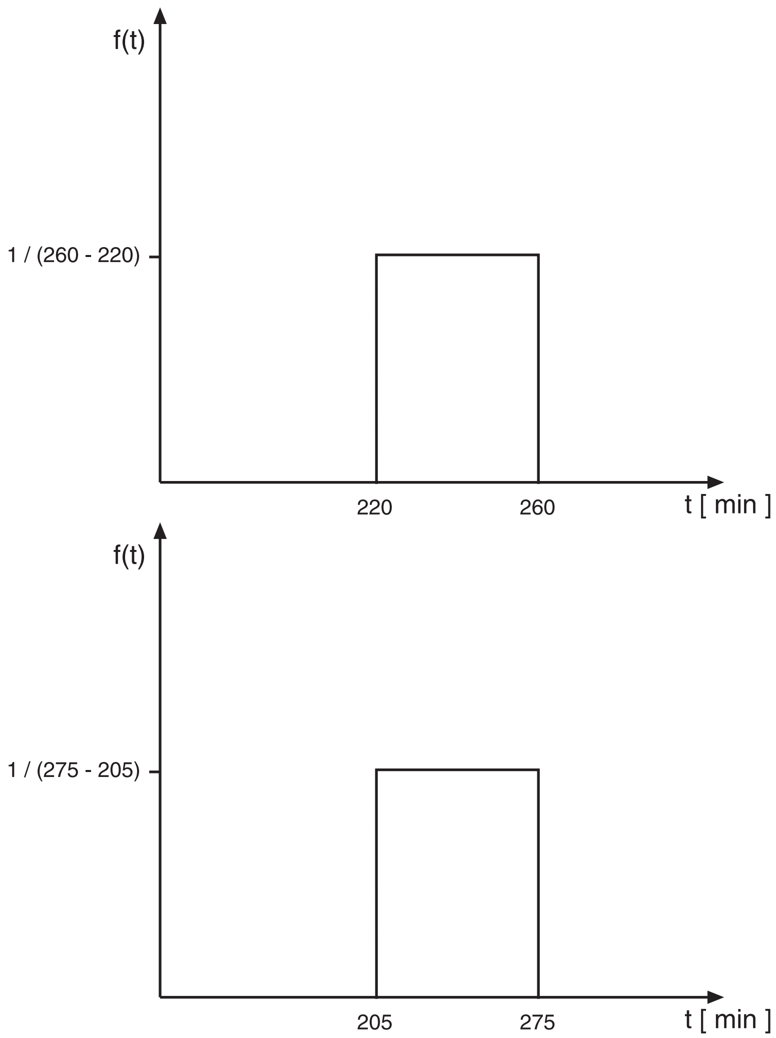

Figure 6
a) uniform probability function of drying time for double sided offset printing
b) uniform probability function of final processing time for a printing run of 150,000 copies

The time necessary to complete final processing of a certain printing run quantity NAKL is determined by:

t= FN(SUS)+(NAKLxFN(DOR)/150,000 min

where FN(SUS)is the continuous function of drying time distribution for offset colours of both side printing derived from the probability function in Figure 6a), and FN (DOR) represents the continuous function of print finishing time distribution derived from the probability function in Figure 6b).

6. The System's GPSS Program Solution

The dynamic element of the model is one certain job defined by the printing run quantity, the number of colours and number of printed pages represented in the GPSS program as one transaction. The idea is to go through with this model at least 1,000 times and this would be regulated by a simulation loop. In this manner all stohastic variables of the system could equal their stohastic values. During simulation in the part where the CTP system is simulated, it multiplies into several transactions, the number of which is defined by the number of offset plates necessary for a certain master colour. After completing the CTP system part, transactions once again merge into one single transaction. If the job is the printing of the master on both sides of the sheet, the transaction of the job is multiplied into two transactions in the offset printing simulation part. After completion of this phase they once again merge into one transaction that runs through to the end of the model.

The static elements are the RIP CTP system, photoexposing of the CTP system, the CTP developing unit, the offset machine, while the finishing process is just a time unit for stopping one job transaction. The RIP, photoexposing, the developing unit and the offset machine are represented by the term FACILITY and determine one-channel servicing.

At each start-up of the model the printing run quantity factor is entered through the variable NAKL and the colour number through variable BB. The program model shown in Figure 7 a also makes a output into a separate file. The example shown refers to certain quantity of sheets to be printed and gives the minimum, maximum and average time in minutes that are necessary to complete the job for the preset system through the C1 system variable of the GPSS time clock. In this manner it is possible to speed up the experimenting if we are only interested in the time that is necessary to complete the job. Otherwise we would have to follow up the standard output statistics for each model completion and it would take an extensive time period to determine the necessary values.

The program model is described in such a manner that all the parameters of each variable may be changed easily, and the configuration of the model may be easily changed as well.

```
********DIGITAL ANALOGOUS GPPS MODEL********
**********ANALOGIC-OFFSET****DIGITAL-ComputerToPlate(CTP)
      SIMULATE
      INTEGER &I,&N
      INTEGER &NAKL,&BB,&BS,&BA4STR
      REAL &ANAKL,&TRIP,&DTRIP
      REAL &VRIJ,&MIN,&MAX
      LET &MIN=999999.
      LET &MAX=-999999.
      LET &N=1000                   number of simulations
      PUTPIC
0Unesi nakladu formi  (npr.150000)
      GETLIST &NAKL
      PUTPIC
0Unesi broj boja mastera (npr.9)
      GETLIST &BB
OUT   FILEDEF     'MASTER2.OUT'
BRZOFF      FUNCTION RN(1),C2
0.0,10000/1.0,14000
SUS   FUNCTION RN(1),C2
0.0,220/1.0,260
DOR   FUNCTION RN(1),C2
0.0,205/1.0,275
      LET &BA4STR=9                 number of forms on B1 sheat
      LET &ANAKL=(&NAKL/&BA4STR)*1.10
      LET &TRIP=10                  av. time CTP for 1 plate
      LET &DTRIP=2                  +- of &TRIP
      LET &BS=2
      GENERATE    ,,,1
      ADVANCE 20,3                  imposition and processing
      SPLIT &BB-1,SKOK
SKOK  SEIZE CTPRIP
      ADVANCE &TRIP,&DTRIP
      RELEASE CTPRIP
      SEIZE OSVJ
      ADVANCE     2
      RELEASE OSVJ
      SEIZE RAZVIJ
      ADVANCE 3
      RELEASE RAZVIJ
      ASSEMBLE &BB                  assembling of 1 set of plates
      SPLIT &BS-1,SKOK2       number of printing sides (2 for dup)
SKOK2 SEIZE OFFSET
      ADVANCE 22,3
      ADVANCE (&ANAKL*60)/FN(BRZOFF)
      RELEASE     OFFSET
      ASSEMBLE &BS
****DORADA
```

```
      ADVANCE FN(SUS)+(&NAKL*FN(DOR)/150000)
      TERMINATE 1
****PETLJA IZVRSAVANJA MODELA
      DO &I=1,&N
      CLEAR
      START 1,NP
      LET &VRIJ=C1+&VRIJ
      IF &MIN>C1
      LET &MIN=C1
      ENDIF
      IF &MAX<C1
      LET &MAX=C1
      ENDIF
      ENDDO
      LET &VRIJ=&VRIJ/&N
      PUTPIC FILE=OUT,LINES=5,
      (&NAKL,&ANAKL,&MIN,(&MIN/60),&MAX,(&MAX/60),&VRIJ,(&VRIJ/60))

For printing run of * A4 master , * sheats
minimal *.*** min. or *.*** hours,
maximal *.*** min. or *.*** hours,
average *.*** min. or *.*** hours,
END
```

Figure 7 The Digital Analogous System GPSS Model

7. Experimenting with the Model

The goal of experimenting was to observe the average, minimum and maximum speeds of the model in cases of different printing run quantities. Figure 8 is a graph showing the average time necessary for completing the printing jobs in respect to preset quantities. Quantities from the number of 25,000 to 300,000 copies were analyzed.

Because of the built-in curve inside the GPSS model there are 1,000 independent start-ups of the model for each printing run quantity in order to comply with the statistic conditions of the model's stohastic variables. This means that the model went through 7,000 runs (7 printing runs x 1,000) to obtain the results shown in the chart.

700

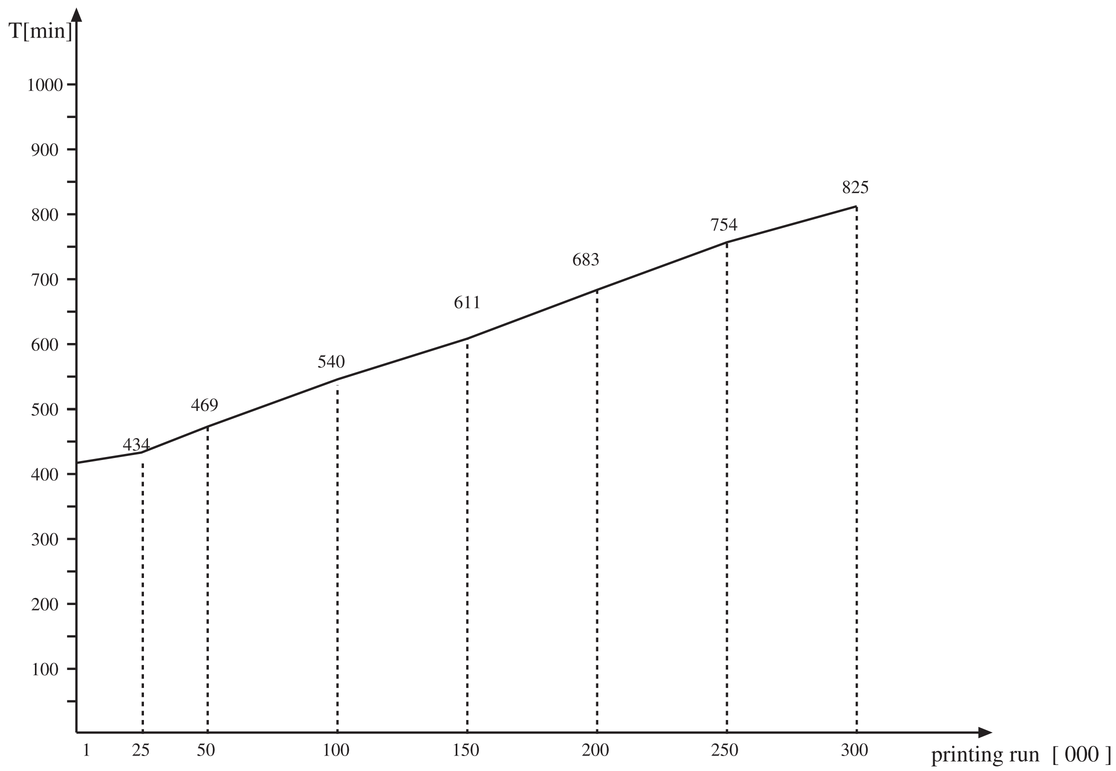

Figure 8. TheAverage Time Necessary to Complete the Printing System in Respect to the Preset Printing Run Quantities

There is saturation of the printing time in case of printing run quantities below 50,000 because the time necessary for preparing the machine is more extensive in respect to the time necessary for printing small printing run quantities.

8. Conclusion

This research work has shown that by making small interventions when creating the program model it is simple to lead experiments with different printing run quantities, different virtual configurations, or just to measure the time necessary for completing the whole model in order to bring the right decisions in completing certain jobs in preset time periods. This makes it possible for managements to contract jobs more efficiently when longer time periods and different printing run quantities are in question.

Today's conventional approach to solving computer graphics in respect to the digital side is by using the computer to plate method. The digital phase ends here by direct output on the offset plate. As there are digital inputs interwining with analogous conventional outputs and the finished job in the printed run, this system is called the digital analogous system.

Thus the CTP program model of the system may be the foundation for researching any RIP-ing system. This model is easily reconfigurated into various virtual variants, as for instance: one RIP with two exposing units, two RIPs with one exposing units or as shown in this paper - the case where the RIP was optimized in such a manner that another bitmapping module was placed inside it. Each servicing module may be speeded up or slowed down depending on the requested run workflow.

The model of the digital analogous system simulating CTP and offset is already being used as part of the analogous digital system for making the master in the high frequency individualization of reward games. It is part of the system for the individualization with the electrophotography technology with which it forms the complete system. These systems have different run workflows and different PostScript programming. Both of the systems use different PostScript files; one for the both sheet side master and the other for the individualization of forms.

The experiment results are the foundation for the stohastic simulation model and for doing research work in order to enhance the system. Experimenting with graphic systems is too expensive and because of this simulation of such was used as the foundation to determine bottlenecks of information flow, and to check the optimal configurations and program solutions.

This paper shows preset models as foundations for future research work of such modern graphic system situations.

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