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YET ANOTHER BUSINESS PROCESS MODELING CONCEPT

Sidnev Aleksandr (a)*
*Corresponding author

(a) Peter the Great St. Petersburg Polytechnic University, 195251, St.Petersburg, Polytechnicheskaya, 29, Russia
alex2922@gmail.com

Abstract

The task of business processes is important, relevant and occupies a worthy place in the field of business analysis. There is a large number of general purpose simulation systems, equipped with a detailed interface, statistical processing of simulation results and optimization of objects. The wide possibilities of objects of various types provided by such systems are accompanied by considerable difficulties in their mastering by users interested in business process but not being experts in the field of. In addition, manual construction of object simulation models in the environment can be very time-consuming. The article proposes an approach to the construction of a tool that provides automatic generation of executable simulation model of the business process, designed to run in the selected simulation system, but formed outside this environment. Such a tool can be a program-editor of a business process with the function of exporting a mathematical model of a business process to the executable file of its simulation model. The principal aspects of solving this problem in relation to simulation systems based on the formalisms of queuing networks and Petri nets are considered. A description is given of a functioning business process program-editor focused on using the GPSS World simulation system. The results of its application are demonstrated. The conclusion is made about the possibility and expediency of extending the proposed concept to other objects and simulation systems.

Keywords: Business process, business process, automated simulation model generating.

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1. Introduction

An objective assessment of various indicators of the business process is impossible without simulation. The choice of a business process format precedes the construction of its simulation model.

We will adhere to the following definition: a business process is an ordered set of activities, subordinated to the achievement of a single goal of completing a business process with a given result. Description and documentation of business processes is a necessary stage of implementation and successful functioning of the business process management system of the organization (Lapina et al., 2015; Yakimov, Kirpichnikov, Mokshin, Alyautdinova, & Pajgina, 2015; Zaharov, 2016). The presence of business processes that are properly documented provides a formal transition from a standardized description of the business process to its mathematical model (Artamonov, 2018).

Business analyst has a wide range of simulation systems that provide the construction and conduct experiments with the business process model. The process of building a model in a system environment can be tedious and require certain skills from the user. There is an objective contradiction: on the one hand, a business analyst is interested in obtaining an objective assessment of the time and cost indicators of the business process, and on the other hand, does not have the ability, and sometimes the desire, to master a complex system of simulation, which provides the construction of a simulation model of the business process.

The solution of this contradiction consists in the creation of a software product that provides an automated transition from a formal description of the object of a certain class to its simulation model intended for direct execution in a given simulation environment. This problem can be solved for a number of modern simulation systems (Gradišar & Mušič, 2012; Kanduč & Blaž, 2015).

To do this, certain requirements for the type and structure of the executable file of the simulation model must be met. These requirements, which are further described in the example of various simulation systems, can be defined as follows. The executable file of the simulation model must have the content and structure to be analyzed and decrypted. This condition is met by executable files of a significant number of simulation systems. In some cases, the model file is a text file (GPSS World (Safiullin, Devyatkov, & Zakirova, 2015) or C# file (Mobius (Keefe & Sanders, 2015), quite often it is an xml file (CPN Tools (Boubeta-Puig, Diaz, & Macia, 2019; Jensen & Kristensen, 2009), Anylogic (Nastyuk, Kulikova, Trubina, & Nazarov, 2017). In these and similar cases, the content of the executable file of the model can be analyzed and corrected. Thus, it becomes possible to automatically construct a simulation model intended to be launched in a given simulation environment, but formed outside this environment.

The feasibility of building such a bridge between the formal description of the business process and the modern simulation system is also due to the significant size and complex structure of real business processes.

2. Problem Statement

The task of building a simulation model of the business process is divided into the following stages.

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1. To propose a general mathematical model of the business process, which allows further transition from the initial description of the business process to the format of its representation in a given simulation system.

2. To analyze the simulation systems for the possibility of external formation of the executable file of the model

3. To offer the rule of formation of the executable file of the chosen system of simulation modelling

3. Research Questions

We will be guided by the proposed model of the business process EXECUTOR in the form of a queuing network. To form an executable file of the simulation model, regardless of the formalism proposed by this modelling environment, it is necessary to solve the following tasks within this formalism.

1. To form the elements of the business process EXECUTOR structure - nodes of a queuing network.

2. To set claim routing between the nodes of a queuing network.

3. To set the duration distribution laws for the claim service in the nodes of a queuing network.

4. To set the parameters of the input claim flow of a queuing network.

5. To form an algorithm for transforming the parameters of the business process EXECUTOR into a formal model used by the selected simulation system. Next, it is necessary to provide an adequate representation of the business process model in the format of the simulation model executable file.

The last problem, the most difficult for any simulation systems is solved in different ways.

4. Purpose of the Study

The purpose of the study is to prove the feasibility of the proposed approach to business process modelling. For this purpose, analysis of simulation systems is performed for the possibility of external generation of the executable model file. A number of simulation systems based on various formalisms of modelling object representation are considered

5. Research Methods

5.1. Business process formal definition

1. The modern business process description standard BPMN (Yakimov, Kirpichnikov, Mokshin, Alyautdinova, & Pajgina, 2015) basically forms the structure of the business process with the help of task elements and logical functions XOR and AND. Up to the formal image of these elements, the activity set with an arbitrary order of their sequence can be represented by a probabilistic graph, a sample of which is shown on the top of Fig. 1. The graph allowing parallelization of the business process and cyclic return to the already executed activities can be specified by the transmission matrix $\boldsymbol{P}$ of the following format.

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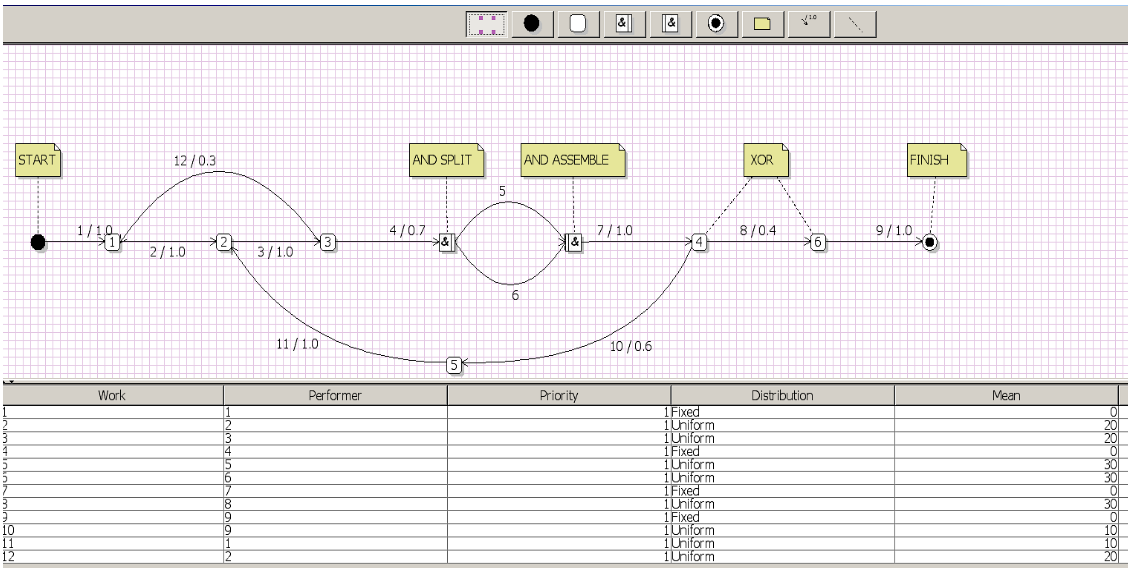
$\boldsymbol{P} = \{p_{ij}\}_{\substack{i=\overline{0,M} \\ j=\overline{0,M}}}$ where $\boldsymbol{M}$ is the number of activities that are part of the business process, and p_{ij} is the probability of transition to activity j after completion the activity i. Unlike the Markov matrix, the condition $\sum_{j=0}^{M} p_{ij} = 1$ is not satisfied for all rows i of the matrix $\boldsymbol{P} = \{p_{ij}\}$. If after the completion of activity i a simultaneous execution (parallelization) of several activities begins, for example, v and r, then $\sum_{j=0}^{M} p_{ij} = p_{iv} + p_{ir} = 2$. Parallelization of works ultimately ends with their integration. Let us assume that only after the completion of activities v and r it is possible to start activity l. Then each of the elements p_{vl} and p_{vl} of the $\boldsymbol{P}$ matrix is supplied with a suffix #, meaning that the transition to activity l is allowed only after the completion of all activities with the suffix #, indicated in column l of the matrix $\boldsymbol{P}$. The matrix $\boldsymbol{P}$ corresponding to the graph, Figure 01, is shown in Figure 02. In addition to the matrix $\boldsymbol{P}$, the matrix $\boldsymbol{B} = \{b_{i,r}\}$ for the executor assignment to activities is also given, where $b_{i,r} = 1 \vee 0$ depending on whether the activity i is assigned to the executor r. Adding data on the activity duration distributions and the input flow parameters, we can assume that the business process is specified. In fact, the formal business process EXECUTOR mathematical model is a nonlinear queuing network. Depending on the characteristics of the business process, this network can be homogeneous or heterogeneous, single-channel or multi-channel, open or closed.



Work	Performer	Priority	Distribution	Mean
1	1	1	Fixed	0
2	2	1	Uniform	20
3	3	1	Uniform	20
4	4	1	Fixed	0
5	5	1	Uniform	30
5	6	1	Uniform	30
7	7	1	Fixed	0
3	8	1	Uniform	30
9	9	1	Fixed	0
10	9	1	Uniform	10
11	1	1	Uniform	10
12	2	1	Uniform	20

Figure 01. Business process probabilistic graph

	0	1	2	3	4	5	6	7	8	9	10	11	12
0	0	1	0	0	0	0	0	0	0	0	0	0	0
1	0	0	1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	1	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0.7	0	0	0	0	0	0	0	0.3
4	0	0	0	0	0	1	1	0	0	0	0	0	0
5	0	0	0	0	0	0	0	1#	0	0	0	0	0
6	0	0	0	0	0	0	0	1#	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0.4	0	0.6	0	0
8	0	0	0	0	0	0	0	0	0	1	0	0	0
9	1	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	1	0
11	0	0	0	1	0	0	0	0	0	0	0	0	0
12	0	0	1	0	0	0	0	0	0	0	0	0	0

Figure 02. Business process transmission matrix ***P***

5.2. GPSS World: How to construct the business process simulation model executable file

The GPSS system is best suited for the queuing networks simulation. For any business process that is represented by a probabilistic graph or a transmission matrix, the GPSS simulation program code can be generated as a custom template consisting of a limited number of segments. Moreover, the text of a significant part of the segments remains unchanged, no matter how the structure and parameters of the business process change. The structure of the template program remains invariant with respect to the quantitative and qualitative parameters of the simulated business process. This is the point of using a single GPSS template for a business process simulation program. The expressive power of the GPSS system allows the routing of claims using a set of FUNCTION commands, each of which practically displays the corresponding row of the transmission matrix $\boldsymbol{P}$. FUNCTION commands are also used to define the activity duration distributions. The GPSS code of the business process modelling program is presented in the APPENDIX. Two program fragments are highlighted with bold: the one containing a set of FUNCTION commands that provide routing of claims in accordance with the probabilistic graph (Figure 01) and the one that determines the functioning of the queuing network node. The invariance of the last fragment with respect to the structure of the business process is provided by the use of the transaction parameters. The program Violet-BP, which provides automatic code generation GPSS-business process modelling program on its probabilistic graph is created by Dmitry Korenev on the concept and algorithm of the author. Program Violet-BP is written in Java based on an open framework of the Violet diagrams editor. Figure 1 shows a screen shot of the main application window. Figure 03 shows a histogram of the business process duration in question as the result of data processing obtained for 5000 experiments with the simulation model. After importing simulation results from GPSS World, a histogram and empirical distribution function are constructed, and then compared with the corresponding approximations obtained analytically (Sidnev, 2016) by three goodness of fit tests: Kolmogorov-Smirnov, Pearson (Chi-square), Kramer-Mises-Smirnov (omega-square) at the significance level $\alpha = 0.05$. The final choice between the null and alternative hypotheses is made by the majority principle. Figure 03 shows analytical PDF compared with the empirical one created by simulation. The Hypothesis H_0 is accepted by all three goodness of fit tests. Thus, the correctness of the generated GPSS-model of the business process is confirmed.

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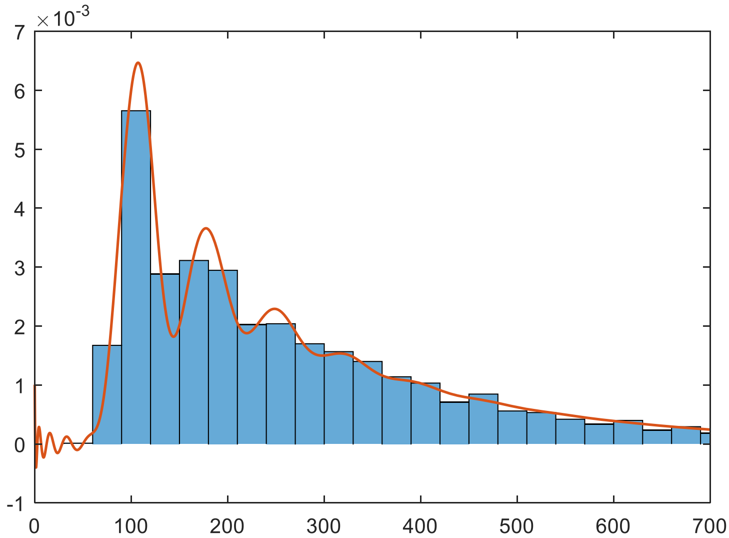

Figure 03. Business process histogram vs analytically obtained pdf

5.3. The executable file formation in the environment of modeling systems focused on the use of Petri nets formalism

The number of modeling packages using Petri nets, which are mentioned in various sources, clearly exceeded one hundred. Note also that the idea to use the Petri net formalism for queuing networks modelling is not new (Mutarraf, Barkaoui, Li, Wu & Qu, 2018) and is implemented, in particular, in the QPME package (Queuing Petri net Modelling Environment) (Al-Azzoni, 2017). It is proposed to consider the implementation of the proposed approach in relation to the simulation packages Mobius and CPN Tools, focused on the use of extended Petri nets. The structure of the Petri net is known to be given by a pair of matrices D^- and D^+ whose strings are the input and output transition functions of the Petri net.

The transmission matrix of queuing network is easily transformed into the mentioned pair of matrices. Figure 04 shows the matrix D^- and D^+, corresponding to the transmission matrix of the single-channel queuing network shown in Figure 02.

D^-

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}
t_0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
t_1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
t_2	0	1	0	0	0	0	0	0	0	0	0	0	0	0
t_3	0	0	1	0	0	0	0	0	0	0	0	0	0	0
t_4	0	0	0	1	0	0	0	0	0	0	0	0	0	0
t_5	0	0	0	0	1	0	0	0	0	0	0	0	0	0
t_6	0	0	0	0	0	1	0	0	0	0	0	0	0	0
t_7	0	0	0	0	0	0	0	0	0	0	0	0	1	1
t_8	0	0	0	0	0	0	0	1	0	0	0	0	0	0
t_9	0	0	0	0	0	0	0	0	1	0	0	0	1	0
t_{10}	0	0	0	0	0	0	0	0	0	1	0	0	0	0
t_{11}	0	0	0	0	0	0	0	0	0	0	1	0	0	0
t_{12}	0	0	0	0	0	0	0	0	0	0	0	1	0	0

D^+

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}
t_0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
t_1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
t_2	0	0	1	0	0	0	0	0	0	0	0	0	0	0
t_3	0	0	0	1	0	0	0	0	0	0	0	1	0	0
t_4	0	0	0	0	1	1	0	0	0	0	0	0	0	0
t_5	0	0	0	0	0	0	0	0	0	0	0	0	1	0
t_6	0	0	0	0	0	0	0	0	0	0	0	0	0	1
t_7	0	0	0	0	0	0	0	1	0	1	0	0	0	0
t_8	0	0	0	0	0	0	0	0	1	0	0	0	0	0
t_9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
t_{10}	0	0	0	0	0	0	0	0	0	0	1	0	0	0
t_{11}	0	0	1	0	0	0	0	0	0	0	0	0	0	0
t_{12}	0	1	0	0	0	0	0	0	0	0	0	0	0	0

Figure 04. D^- and D^+ matrices corresponding to the transmission matrix ***P***

The executable file of the CPN Tools simulation model has a cpn extension and is an xml file. The structure of the cpn file is open. The contents of the file can be modified with an external program by modifying, adding, removing lines of code, thereby determining the appropriate changes to the Petri net. Mobius (Keefe & Sanders, 2015) package involves the use of Stochastic Activity Networks formalism,

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which is an extended Petri nets. The object model in this case consists of three files with different extensions. Two of them are service files that are almost invariant to the content of the simulated object. The third file with the cpp extension is a C# code that is available for analysis and can be generated by an external program. Thus, the Petri net constructed from the initial representation of the probabilistic graph of the business process can be transformed into formalisms used by the CPN Tools and Mobius packages.

5.4. The executable file formation in the environment of Anylogic

Anylogic modeling system (Nastyuk et al., 2017) allows user to create simulation models based on several modeling paradigms. To model the business process EXECUTOR, a discrete-event approach to the simulation model construction is implemented (Babkin & Kopica, 2016). The executable file of the model with the extension alp is an xml file with obvious structural content. An Alp file consists of blocks, elements of the object model, placed between the opening and closing tags. The composition of the blocks is determined by the choice of the simulation object and the modeling problem. A process modeling library containing the necessary set of blocks for modeling business processes of the class in question is available in Anylogic. The functionality of the blocks can be extended to the required level if necessary. At the initial stage, a business process template model is formed in the Anylogic environment, which can then be modified by an external program in accordance with the structure and parameters of the business process under study. The possibility of creating an executable simulation model file outside the Anylogic system is confirmed by the analysis of the model construction process — the order of activity specified by the transmission matrix, and the parameters of the business process are obviously formally transformed into the appropriate blocks of the alp file. The experience of other authors in the external formation of the alp file is also positive (Kanduč & Blaž, 2015).

6. Findings

1. The proposed concept of business process modeling is fundamentally feasible.

2. The proposed concept has been brought to practical implementation in relation to the GPSS World simulation system — the Violet-BP business process model editor has been developed to automatically generate the GPSS program code.

3. The study of a number of modeling systems, namely, CPN Tools, Mobius, Anylogic, based on the use of different formalisms allows us to conclude that this modeling concept is applicable to them

7. Conclusion

The number of different simulation systems is increasing at high speed. This circumstance is primarily due to the emergence of new objects to be simulated and the need to obtain a tool especially designed for the new object simulation.

An alternative concept is to use well-known and reputed simulation systems together with specially developed software-editors that automatically generate the code of the object simulation program for some class of objects. The proposed concept of business process modeling can be developed in different directions and extended to any modeling objects.

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APPENDIX: GPSS MODEL CODE

```
; Generated by Violet-BP 0.1a
alpha EQU 3  ; order of Erlang distribution
GENERATE_TIMING VARIABLE (Exponential(1,0,130000))
T_IME   TABLE M1,0,30,40
DISTRIB_Fixed VARIABLE (FN$M_EAN)
DISTRIB_Uniform VARIABLE (Uniform(2,(0.4#FN$M_EAN),(1.6#FN$M_EAN)))
DISTRIB_Exponential VARIABLE (Exponential(1,0,FN$M_EAN))
DISTRIB_Triangular VARIABLE (Triangular(3,(0.4#FN$M_EAN),(1.6#FN$M_EAN),FN$M_EAN))
DISTRIB_Erlang VARIABLE (Gamma(3,0,(FN$M_EAN/alpha),alpha))
; Performers:
;  1 => 1
;  2 => 2
;  3 => 3
;  4 => 4
;  5 => 5
;  6 => 6
;  7 => 7
;  8 => 8
;  9 => 9
;
; Works:
;  1 => 1, 1001
;  2 => 2, 1002
;  3 => 3, 1003
;  4 => 4, 1004
;  7 => 5, 1005
;  8 => 6, 1006
;  9 => 7, 1007
;  10 => 8, 1008
;  11 => 9, 1009
;  12 => 10, 1010
;  5 => 11, 1011 #
;  6 => 12, 1012 #


NODE_NUM FUNCTION P$COLNUM,D12
  1,1/2,2/3,3/4,4/5,7/6,8/7,9/8,9/9,1/10,2/11,5/12,6

P_RIORITY FUNCTION P$COLNUM,D12
  1,1/2,1/3,1/4,1/5,1/6,1/7,1/8,1/9,1/10,1/11,1/12,1
M_EAN FUNCTION P$COLNUM,D12
1,0.0/2,20.0/3,20.0/4,0.0/5,0.0/6,30.0/7,0.0/8,10.0/9,10.0/10,20.0/11,30.0/12,30.0
D_ISTRIBUTION FUNCTION P$COLNUM,D12
  1,0/2,2/3,2/4,0/5,0/6,2/7,0/8,2/9,2/10,2/11,2/12,2
A_DVANCE   ADVANCE V$DISTRIB_Fixed
  TRANSFER ,R_ELEASE
  ADVANCE V$DISTRIB_Uniform
  TRANSFER ,R_ELEASE
; Transfer matrix:
GRID EQU 10
MAXCOLNUM EQU 12
```

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```
LINE_0   FUNCTION RN1,D13   ; generate
0.0,0/1.0,1/1.0,2/1.0,3/1.0,4/1.0,5/1.0,6/1.0,7/1.0,8/1.0,9/1.0,10/1.0,11/1.0,12
LINE_1   FUNCTION RN1,D13   ; 1
0.0,0/0.0,1/1.0,2/1.0,3/1.0,4/1.0,5/1.0,6/1.0,7/1.0,8/1.0,9/1.0,10/1.0,11/1.0,12
LINE_2   FUNCTION RN1,D13   ; 2
0.0,0/0.0,1/0.0,2/1.0,3/1.0,4/1.0,5/1.0,6/1.0,7/1.0,8/1.0,9/1.0,10/1.0,11/1.0,12
LINE_3   FUNCTION RN1,D13   ; 3
0.0,0/0.0,1/0.0,2/0.0,3/0.7,4/0.7,5/0.7,6/0.7,7/0.7,8/0.7,9/1.0,10/1.0,11/1.0,12
LINE_4   FUNCTION RN1,D13   ; 4
0.0,0/0.0,1/0.0,2/0.0,3/0.0,4/0.0,5/0.0,6/0.0,7/0.0,8/0.0,9/0.0,10/0.0,11/1.0,155   ; ->11  ->12
LINE_5   FUNCTION RN1,D13   ; 7
0.0,0/0.0,1/0.0,2/0.0,3/0.0,4/0.0,5/0.4,6/0.4,7/1.0,8/1.0,9/1.0,10/1.0,11/1.0,12
LINE_6   FUNCTION RN1,D13   ; 8
  0.0,0/0.0,1/0.0,2/0.0,3/0.0,4/0.0,5/0.0,6/1.0,7/1.0,8/1.0,9/1.0,10/1.0,11/1.0,12
LINE_7   FUNCTION RN1,D13   ; 9
1.0,0/1.0,1/1.0,2/1.0,3/1.0,4/1.0,5/1.0,6/1.0,7/1.0,8/1.0,9/1.0,10/1.0,11/1.0,12
LINE_8   FUNCTION RN1,D13   ; 10
0.0,0/0.0,1/0.0,2/0.0,3/0.0,4/0.0,5/0.0,6/0.0,7/0.0,8/1.0,9/1.0,10/1.0,11/1.0,12
LINE_9   FUNCTION RN1,D13   ; 11
0.0,0/0.0,1/0.0,2/1.0,3/1.0,4/1.0,5/1.0,6/1.0,7/1.0,8/1.0,9/1.0,10/1.0,11/1.0,12
LINE_10   FUNCTION RN1,D13   ; 12
0.0,0/0.0,1/1.0,2/1.0,3/1.0,4/1.0,5/1.0,6/1.0,7/1.0,8/1.0,9/1.0,10/1.0,11/1.0,12
LINE_11   FUNCTION RN1,D13   ; 5
0.0,0/0.0,1/0.0,2/0.0,3/0.0,4/1.0,5/1.0,6/1.0,7/1.0,8/1.0,9/1.0,10/1.0,11/1.0,12
LINE_12   FUNCTION RN1,D13   ; 6
0.0,0/0.0,1/0.0,2/0.0,3/0.0,4/1.0,5/1.0,6/1.0,7/1.0,8/1.0,9/1.0,10/1.0,11/1.0,12

ASSMB_OFF   FUNCTION P$COLNUM,D3
  10,1/11,0/12,0
A_SSEMBLE     ASSEMBLE 2
  TRANSFER ,M_OVE
GENERATE V$GENERATE_TIMING
ROW_0   ASSIGN COLNUM,FN$LINE_0
  TRANSFER ,SERV
ROW_1   ASSIGN COLNUM,FN$LINE_1
  TRANSFER ,SERV
ROW_2   ASSIGN COLNUM,FN$LINE_2
  TRANSFER ,SERV
ROW_3   ASSIGN COLNUM,FN$LINE_3
  TRANSFER ,SERV
ROW_4   ASSIGN COLNUM,FN$LINE_4
  TRANSFER ,SERV
ROW_5   ASSIGN COLNUM,FN$LINE_5
  TRANSFER ,SERV
ROW_6   ASSIGN COLNUM,FN$LINE_6
  TRANSFER ,SERV
ROW_7   ASSIGN COLNUM,FN$LINE_7
  TRANSFER ,SERV
ROW_8   ASSIGN COLNUM,FN$LINE_8
  TRANSFER ,SERV
ROW_9   ASSIGN COLNUM,FN$LINE_9
  TRANSFER ,SERV
ROW_10   ASSIGN COLNUM,FN$LINE_10
```

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```
  TRANSFER ,SERV
ROW_11   ASSIGN COLNUM,FN$LINE_11
  TRANSFER ,SERV
ROW_12   ASSIGN COLNUM,FN$LINE_12
  TRANSFER ,SERV
SERV   TEST NE P$COLNUM,0,FIN
     TEST G P$COLNUM,MAXCOLNUM,S_TART
S_PLIT   SAVEVALUE COLNUM_1,((P$COLNUM-
P$COLNUM@(MAXCOLNUM+1))/(MAXCOLNUM+1))
  SAVEVALUE COLNUM_2,(P$COLNUM@(MAXCOLNUM+1))
  SPLIT 1,CHILD
  ASSIGN COLNUM,X$COLNUM_1
  TRANSFER ,S_TART
CHILD ASSIGN COLNUM,X$COLNUM_2
  TRANSFER ,S_TART
S_TART   PRIORITY FN$P_RIORITY
  QUEUE (P$COLNUM+1000)
  QUEUE P$COLNUM
  SEIZE FN$NODE_NUM
  DEPART P$COLNUM
  TRANSFER FN,D_ISTRIBUTION,A_DVANCE
R_ELEASE   RELEASE FN$NODE_NUM
  DEPART (P$COLNUM+1000)
  TEST GE P$COLNUM,GRID,M_OVE
  TRANSFER FN,ASSMB_OFF,A_SSEMBLE
M_OVE  SAVEVALUE ROOTER,(P$COLNUM#2)
  ASSIGN ROOTER,X$ROOTER
  TRANSFER P,ROOTER,ROW_0
FIN   TABULATE T_IME
  TERMINATE 1
```