Modeling the process of producing knitwear by generalized nets

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Abstract: This paper models the manufacturing process of knitwear using the apparatus of generalized nets. The model can be used as an element for the simulation and control of knitwear production for the purpose of optimization. It allows for the monitoring of the extent to which the set of activities corresponds to the production requirements.
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1 Introduction

The article refers to the manufacturing process of knitting factory 'Lady Sofia'. 'Lady Sofia' is a Bulgarian manufacturer of stockings and tights, which has become a market leader over the years. This article describes the processes through which the item goes from receiving raw materials to a product ready to be sold. The first stage of production is receiving the necessary yarns: polyurethane and polyamide. Once the yarns are available, what follows is the loading of the knitting machines and setting the machine for the particular product. After knitting the item, it goes through quality control. If there is a problem with the quality, the product is discarded; otherwise, the product proceeds to the next stage of production. After knitting, part of the products pass through fixation, and the rest go to storage. Fixation is a process in which the product is placed in a chamber, a vacuum is established and the product is solidified by steam. This process retains the structure, stabilizes the item and helps sewing. The next stage through which all products pass is sewing. It consists of three basic operations: sewing fingers, sewing the bottom piece and sewing a gusset. Tailored products go into storage, from where they move to the next process, dyeing. Dyeing is an uninterrupted process that includes several stages. The first stage is the selection of a dyeing machine depending on the type and the material of the product. Products with elastic thread are passed through static dyeing and placed into dyeing bags while all the others are dyed by turning the material into a drum. Polyamides are dyed with acid dyes, as each color has a corresponding recipe. The second stage of the dyeing process begins with arranging the material in the dyeing machine, filling

with water and adding surface active agents (surfactants). Next is a control of the PH of the bath, adding the colorant and gradually raising the temperature from 40 ℃ until 97-98 ℃. The final stage is strengthening and softening, and then the products are centrifuged and taken out. Next they go to ironing or directly to storage, then to packing.

2   Generalized net model

All stages of the production process will be described by a generalized net. Literature review showed that processes in textile production have not been object of detailed modelling with the apparatus of generalized nets, with only few results like [2].

The model of generalized nets containing 29 transitions, from Z_1 to Z_{29}, which represent:

- Z_1 - Supply of material Polyamide
- Z_2 - Supply of materia Polyurethane
- Z_3 - Loading of the knitting machines
- Z_4 - Knitting machine 1
- Z_5 - Knitting machine 2
- Z_6 - Knitting machine 3
- Z_7 - Knitting machine 4
- Z_8 - Knitting machine 5
- Z_9 - Quality Control 1
- Z_{10} - Quality Control 2
- Z_{11} - Quality Control 3
- Z_{12} - Quality Control 4
- Z_{13} - Quality Control 5
- Z_{14} - Rejection of irregular products
- Z_{15} – Storage knitted products
- Z_{16} - Fixing products
- Z_{17} - Sortoing for sewing
- Z_{18} - Sewing fingers
- Z_{19} - Sewing bottom
- Z_{20} - Sewing a gusset
- Z_{21} - Storage of sewn products
- Z_{22} - Static dyeing
- Z_{23} - Dyeing by rotation
- Z_{24} - Strengthening
- Z_{25} - Softening
- Z_{26} - Storage after dyeing
- Z_{27} - Ironing
- Z_{28} - Packaging
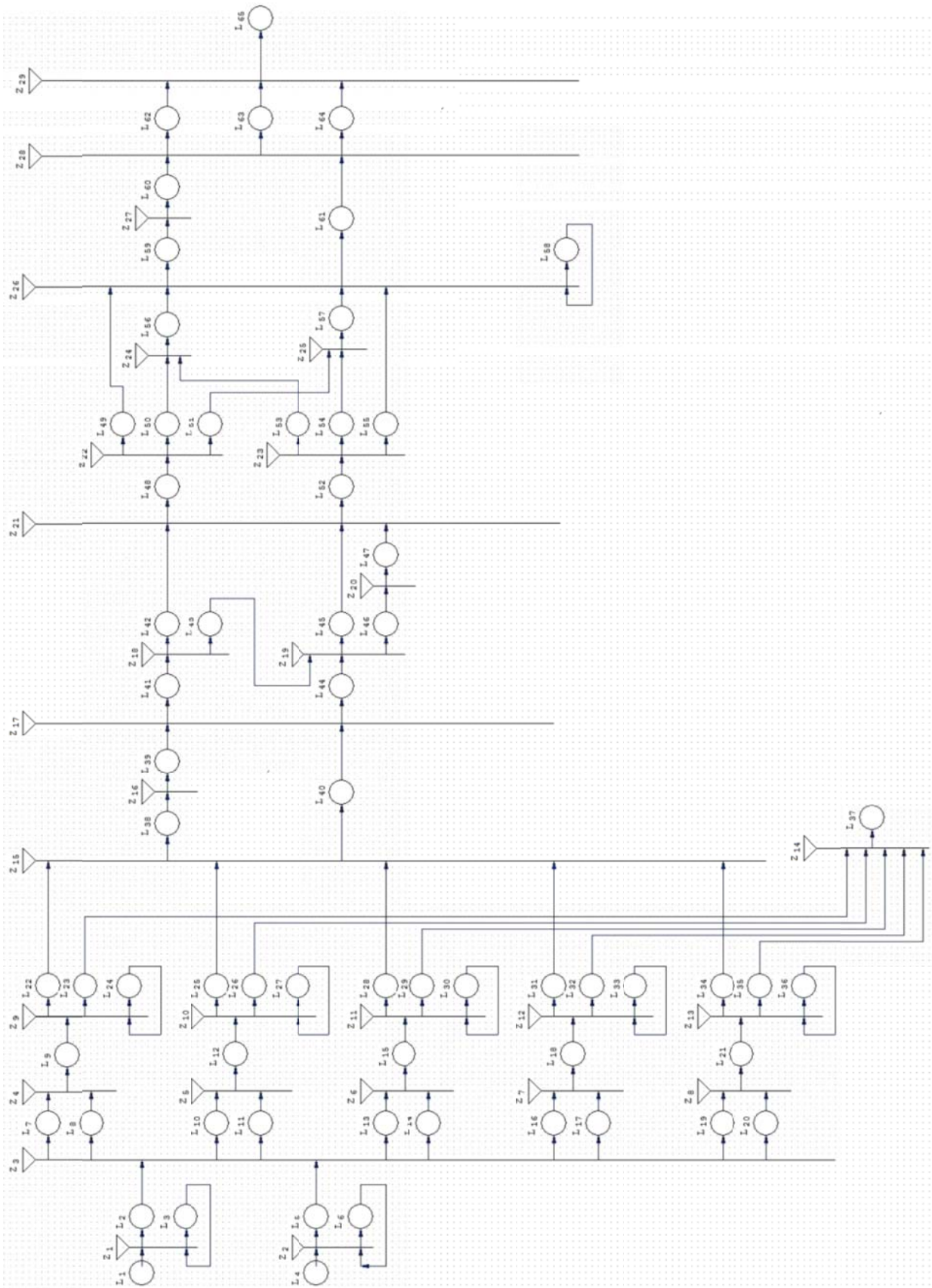- Z_{29} - Storage of packaged products

Figure 1. Generalized nets modeling the manufacturing process
of knitting factory Lady Sofia

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From place L_1 enters token with the following initial characteristic „Polyamide, weight, quality".

$$Z_1 = \langle \{L_1, L_3\}, \{L_2, L_3\}, R_1 \rangle,$$

$$R_1 = \begin{array}{c|cc}
 & L_2 & L_3 \\
\hline
L_1 & false & true \\
L_3 & W_{3,2} & false
\end{array}$$

where $W_{3,2}$ = "The yarn is available".

In place L_3 the token does not obtain any new characteristic and stays with characteristic „The yarn is available in storage" and passes in place L_2. In place L_4 enters token with the following initial characteristic: „Polyurethane, weight, quality".

$$Z_2 = \langle \{L_4, L_6\}, \{L_5, L_6\}, R_2 \rangle,$$

$$R_2 = \begin{array}{c|cc}
 & L_5 & L_6 \\
\hline
L_4 & false & true \\
L_6 & W_{6,5} & false
\end{array}$$

where $W_{6,5}$ = „The yarn is available".

In place L_6 the token does not obtain any new characteristic and stays with characteristic „The yarn is available in storage" and passes in place L_5. In places L_2 and L_6 enter tokens with characteristic: "The yarns are ready to be loaded on the knitting machines" and transfer to places $L_7, L_8, L_{10}, L_{11}, L_{13}, L_{14}, L_{16}, L_{17}, L_{19}, L_{20}$.

$$Z_3 = \langle \{L_2, L_6\}, \{L_7, L_8, L_{10}, L_{11}, L_{13}, L_{14}, L_{16}, L_{17}, L_{19}, L_{20}\}, R_3 \rangle,$$

$$R_3 = \begin{array}{c|cccccccccc}
 & L_7 & L_8 & L_{10} & L_{11} & L_{13} & L_{14} & L_{16} & L_{17} & L_{19} & L_{20} \\
\hline
L_2 & true & false & true & false & true & false & true & false & true & false \\
L_6 & false & true & false & true & false & true & false & true & false & true
\end{array}$$

In places L_7 and L_8 enter tokens with the following characteristic: "The yarns are loaded on the knitting machines" and after knitting pass in place L_9.

$$Z_4 = \langle \{L_7, L_8\}, \{L_9\}, R_4 \rangle, \qquad\qquad Z_5 = \langle \{L_{10}, L_{11}\}, \{L_{12}\}, R_5 \rangle,$$

$$R_4 = \begin{array}{c|c}
 & L_9 \\
\hline
L_7 & true \\
L_8 & true
\end{array}
\qquad\qquad
R_5 = \begin{array}{c|c}
 & L_{12} \\
\hline
L_{10} & true \\
L_{11} & true
\end{array}$$

In places L_{10} and L_{11} enter tokens with the following characteristic: "The yarns are loaded on the knitting machines" and after knitting pass in place L_{12}. In places L_{13} and L_{14} enter tokens with the following characteristic:" The yarns are loaded on the knitting machines" and after knitting pass in place L_{15}.

$$Z_6 = \langle \{L_{13}, L_{14}\}, \{L_{15}\}, R_6 \rangle, \qquad\qquad Z_7 = \langle \{L_{16}, L_{17}\}, \{L_{18}\}, R_7 \rangle,$$

$$R_6 = \begin{array}{c|c} & L_{15} \\ \hline L_{13} & true \\ L_{14} & true \end{array} \qquad\qquad R_7 = \begin{array}{c|c} & L_{18} \\ \hline L_{16} & true \\ L_{17} & true \end{array}$$

In places L_{16} and L_{17} enter tokens with the following characteristic: "The yarns are loaded on the knitting machines" and after knitting pass in place L_{18}. In places L_{19} and L_{20} enter tokens with the following characteristic: "The yarns are loaded on the knitting machines" and after knitting pass in place L_{21}.

$$Z_8 = \langle \{L_{19}, L_{20}\}, \{L_{21}\}, R_8 \rangle,$$

$$R_8 = \begin{array}{c|c} & L_{21} \\ \hline L_{19} & true \\ L_{20} & true \end{array}$$

In place L_9 enters token with the following characteristic: "The product is knitted".

$$Z_9 = \langle \{L_9, L_{24}\}, \{L_{22}, L_{23}, L_{24}\}, R_9 \rangle,$$

$$R_9 = \begin{array}{c|ccc} & L_{22} & L_{23} & L_{24} \\ \hline L_9 & false & false & true \\ L_{24} & W_{24,22} & W_{24,23} & false \end{array}$$

where

- $W_{24,22} = $ „The product has passed quality control"
- $W_{24,23} = $ „Discarding products"

In place L_{24} the token does not obtain any new characteristic and stays with characteristic „The product is knitted" and passes to places L_{22} and L_{23}. In place L_{12} enters token with the following characteristic: "The product is knitted".

$$Z_{10} = \langle \{L_{12}, L_{27}\}, \{L_{25}, L_{26}, L_{27}\}, R_{10} \rangle,$$

$$R_{10} = \begin{array}{c|ccc} & L_{25} & L_{26} & L_{27} \\ \hline L_{12} & false & false & true \\ L_{27} & W_{27,25} & W_{27,26} & false \end{array}$$

where

- $W_{27,25} = $ „The product has passed quality control"
- $W_{27,26} = $ „Discarded products"

In place L_{27} the token does not obtain any new characteristic and stays with characteristic „The product is knitted" and passes to places L_{25} and L_{26}. In place L_{15} enters token with the following characteristic: "The product is knitted".

$$Z_{11} = \langle \{L_{15}, L_{30}\}, \{L_{28}, L_{29}, L_{30}\}, R_{11} \rangle,$$

$$R_{11} = \begin{array}{c|ccc} & L_{29} & L_{29} & L_{30} \\ \hline L_{15} & \textit{false} & \textit{false} & \textit{true} \\ L_{30} & W_{30,28} & W_{30,29} & \textit{false} \end{array}$$

where

- $W_{30,28}$ = „The product has passed quality control"
- $W_{30,29}$ = „Discarded products"

In place L_{30} the token does not obtain any new characteristic and stays with characteristic „The product is knitted" and passes to places L_{28} and L_{29}. In place L_{18} enters token with the following characteristic: "The product is knitted".

$$Z_{12} = \langle \{L_{18}, L_{33}\}, \{L_{31}, L_{32}, L_{33}\}, R_{12}\rangle,$$

$$R_{12} = \begin{array}{c|ccc} & L_{31} & L_{32} & L_{33} \\ \hline L_{18} & \textit{false} & \textit{false} & \textit{true} \\ L_{33} & W_{33,31} & W_{33,32} & \textit{false} \end{array}$$

where

- $W_{33,31}$ = „The product has passed quality control"
- $W_{33,32}$ = „Discarded products"

In place L_{33} the token does not obtain any new characteristic and stays with characteristic „The product is knitted" and passes to places L_{31} and L_{32}. In place L_{21} enters token with the following characteristic: "The product is knitted".

$$Z_{13} = \langle \{L_{21}, L_{36}\}, \{L_{34}, L_{35}, L_{36}\}, R_{13}\rangle,$$

$$R_{13} = \begin{array}{c|ccc} & L_{34} & L_{35} & L_{36} \\ \hline L_{21} & \textit{false} & \textit{false} & \textit{true} \\ L_{36} & W_{36,34} & W_{36,35} & \textit{false} \end{array}$$

where

- $W_{36,34}$ = „The product has passed quality control"
- $W_{36,35}$ = „Discarded products"

In place L_{36} the token does not obtain any new characteristic and stays with characteristic „The product is knitted" and passes to places L_{34} and L_{35}. In places $L_{23}, L_{26}, L_{29}, L_{32}$ and L_{35} enter tokens with the following characteristic: "The product is irregular" and pass to place L_{37} with characteristic: „Discarded".

$$Z_{14} = \langle \{L_{23}, L_{26}, L_{29}, L_{32}, L_{35}\}, \{L_{37}\}, R_{14}\rangle,$$

$$R_{14} = \begin{array}{c|c} & L_{37} \\ \hline L_{23} & true \\ L_{26} & true \\ L_{29} & true \\ L_{32} & true \\ L_{32} & true \end{array}$$

In places L_{22}, L_{25}, L_{28}, L_{31} and L_{34} enter tokens with the following characteristic: "The product has passed through the quality control" and pass to places L_{38} and L_{40}.

$$Z_{15} = \langle \{L_{22}, L_{25}, L_{28}, L_{31}, L_{34}\}, \{L_{38}, L_{40}\}, R_{15} \rangle,$$

$$R_{15} = \begin{array}{c|cc} & L_{38} & L_{40} \\ \hline L_{22} & true & true \\ L_{25} & true & true \\ L_{28} & true & true \\ L_{31} & true & true \\ L_{34} & true & true \end{array}$$

In place L_{38} enters token with the following characteristic: "The product is intended for fixing" and passes to place L_{39}.

$$Z_{16} = \langle \{L_{38}\}, \{L_{39}\}, R_{16} \rangle,$$

$$R_{16} = \begin{array}{c|c} & L_{39} \\ \hline L_{38} & true \end{array}$$

In places L_{39} and L_{40} enter tokens with the following characteristic: "The product is sorted for sewing" and pass to places L_{41} and L_{44} .

$$Z_{17} = \langle \{L_{39}, L_{40}\}, \{L_{41}, L_{44}\}, R_{17} \rangle,$$

$$R_{17} = \begin{array}{c|cc} & L_{41} & L_{44} \\ \hline L_{39} & true & true \\ L_{40} & true & true \end{array}$$

In place L_{41} enters token with the following characteristic: "The product is sorted for sewing fingers" and passes to places L_{42} and L_{43}.

$$Z_{18} = \langle \{L_{41}\}, \{L_{42}, L_{43}\}, R_{18} \rangle,$$

$$R_{18} = \begin{array}{c|cc} & L_{42} & L_{43} \\ \hline L_{41} & true & true \end{array}$$

In places L_{43} and L_{44} enter tokens with the following characteristic: "The product is sorted for sewing a gusset " and pass to places L_{45} and L_{46} .

$$Z_{19} = \langle \{L_{43}, L_{44}\}, \{L_{45}, L_{46}\}, R_{19} \rangle,$$

$$R_{19} = \begin{array}{c|cc} & L_{45} & L_{46} \\ \hline L_{43} & true & true \\ L_{44} & true & true \end{array}$$

In place L_{46} enters token with the following characteristic: "The product is sorted for sewing bottom" and passes to place L_{47}.

$$Z_{20} = \langle \{L_{46}\}, \{L_{47}\}, R_{20} \rangle,$$

$$R_{16} = \begin{array}{c|c} & L_{47} \\ \hline L_{46} & true \end{array}$$

In places L_{42}, L_{45} and L_{47} enter tokens with the following characteristic: "The product is tailored" and pass to places L_{48} and L_{62}.

$$Z_{21} = \langle \{L_{42}, L_{45}, L_{47}\}, \{L_{48}, L_{62}\}, R_{21} \rangle,$$

$$R_{21} = \begin{array}{c|cc} & L_{48} & L_{62} \\ \hline L_{42} & true & true \\ L_{45} & true & true \\ L_{47} & true & true \end{array}$$

In place L_{48} enters token with the following characteristic: "The product is sorted for static dyeing" and pass to places L_{49}, L_{50} and L_{51}.

$$Z_{22} = \langle \{L_{48}\}, \{L_{49}, L_{50}, L_{51}\}, R_{22} \rangle,$$

$$R_{22} = \begin{array}{c|ccc} & L_{49} & L_{50} & L_{51} \\ \hline L_{62} & true & true & true \end{array}$$

In place L_{62} enters token with the following characteristic: "The product is sorted for dyeing by rotation" and passes to places L_{63}, L_{64} and L_{65}.

$$Z_{23} = \langle \{L_{62}\}, \{L_{63}, L_{64}, L_{65}\}, R_{23} \rangle,$$

$$R_{23} = \begin{array}{c|ccc} & L_{63} & L_{64} & L_{65} \\ \hline L_{62} & true & true & true \end{array}$$

In places L_{50} and L_{53} enter tokens with the following characteristic: "The product is sorted for strengthening" and pass to place L_{56}.

$$Z_{24} = \langle \{L_{50}, L_{53}\}, \{L_{56}\}, R_{24} \rangle,$$

$$R_{24} = \begin{array}{c|c} & L_{56} \\ \hline L_{46} & true \\ L_{53} & true \end{array}$$

In places L_{51} and L_{54} enter tokens with the following characteristic: "The product is sorted for softening" and pass to place L_{57}.

$$Z_{25} = \langle \{L_{51}, L_{54}\}, \{L_{57}\}, R_{25} \rangle,$$

$$R_{25} = \begin{array}{c|c} & L_{57} \\ \hline L_{51} & true \\ L_{54} & true \end{array}$$

In places L_{49}, L_{55}, L_{56} and L_{57} enter tokens with the following characteristic: "The products are stored after dyeing"

$$Z_{26} = \langle \{L_{49}, L_{55}, L_{56}, L_{57}, L_{58}\}, \{L_{59}, L_{61}, L_{58}\}, R_{26} \rangle,$$

$$R_{26} = \begin{array}{c|ccc} & L_{59} & L_{61} & L_{58} \\ \hline L_{49} & false & false & true \\ L_{55} & false & false & true \\ L_{56} & false & false & true \\ L_{57} & false & false & true \end{array}$$

where

- $W_{58,59}$ = "The product passes to Ironing"
- $W_{58,61}$ = "The product passes to Packaging"

In place L_{58} the token does not obtain any new characteristic and stays with characteristic „The products are stored after dyeing" and pass to places L_{59} and L_{61}. In place L_{59} enters token with the following characteristic: "The product is sorted for ironing" and passes to place L_{60}.

$$Z_{27} = \langle \{L_{59}\}, \{L_{60}\}, R_{27} \rangle,$$

$$R_{27} = \begin{array}{c|c} & L_{59} \\ \hline L_{60} & true \end{array}$$

In places L_{60} and L_{61} enter tokens with the following characteristic: "The product is ready for packaging" and passes to places L_{62}, L_{63} and L_{64}.

$$Z_{28} = \langle \{L_{60}, L_{61}\}, \{L_{62}, L_{63}, L_{64}\}, R_{28} \rangle,$$

$$R_{28} = \begin{array}{c|ccc} & L_{62} & L_{63} & L_{64} \\ \hline L_{60} & true & true & true \\ L_{61} & true & true & true \end{array}$$

In places L_{62}, L_{63} and L_{64} enter tokens with the following characteristic, respectively:" Packing in cartons", "Wrapping in cellophane" and „Packing in bundles" and transfer to place L_{65} with characteristic: "The product is ready for sale".

$$Z_{29} = \langle \{L_{62}, L_{63}, L_{64}\}, \{L_{65}\}, R_{29} \rangle,$$

$$R_{29} = \begin{array}{c|c} & L_{65} \\ \hline L_{62} & true \\ L_{63} & true \\ L_{64} & true \end{array}$$

3   Conclusion

The purpose of this model is to show how the process of production of stockings and tights can be represented by generalized nets. Since processes are complex and are related to various factors and circumstances, the model could be extended in different directions.

References

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