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KANBAN-TYPE GRAPHIC MODEL OF SERIAL-PARALLEL MATERIAL PROCESSING WITH STOCKS ON THE FLOW

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Abstract: *The work presents a Kanban-type graphic model of serial-parallel material processing with storage on the flow, substantiated on the basis of Taiichi Ohno’s work – “The Toyota Production System, an Alternative to the Serial Production”, Finmedia and SC IKAR MANAGEMENT CONSULT SRL Publishing House, Bucharest 2005, and Liker K. I.’s work “The Toyota Way. 14 Management Principles from the World's Greatest Manufactures”, McGraw-Hill, Two Penn Plaza, New-York, 2004. The model underlay the reorganization of the manufacturing flows by Kanban processes integrated in a metal and PVC carpentry factory of Romania.*

Key words: *mixed, integrated Kanban graphic model.*

1. CURRENT STATE AND GENERAL ASPECTS

This work is a natural continuation of the work [1]. That is why the basic principles, notations and conclusions of the work [1] will be used in this work, too.

In this work, the following additional notations will be used: Stl_i – the current work station, joining several machines, working posts of the same kind, which perform simultaneously, in parallel, the same technological operation, being placed on a technologically indivisible production area, connected in series, upstream and downstream, with another PL, Stl, technologically adjacent, requiring a *branching post (PRa)*, called *loading post (Pi)*, on the input, upstream, and a *joining post (Pre)*, also called *unloading post (Pd)***,** on the output, downstream.

In Fig. 1, the Kanban graphic model is presented, and in Fig. 2 – the complete serial-parallel (mixed) material processing cycle, with stocks on the flow.

2. THE NEED FOR A WORK STATION WITH POSTS IN PARALLEL

In a serial manufacturing system as in [1], in actual manufacturing environments, it is possible that $T_{c(i-1)} \neq \neq T_{ci} \neq T_{c(i+1)}$ and $(T_{c(i-1)}, T_{c(i+1)}) << T_{ci}$, so that $T_{ci} = k_{(i-1)}T_{c(i-1)}$ and $T_{ci} = k_{(i+1)}T_{c(i+1)}$, in which $(k_{(i-1)}, k_{(i+1)})>1$; this results in very big asynchronisms $\Delta T_{c(i-1)\mathrm{I}} = = T_{ci} - T_{c(i-1)}$, $\Delta T_{c(i+1)\mathrm{i}} = T_{ci} - T_{c(i+1)},$ which do not provide the rhythmicity called for the production. In order to provide the rhythmicity called for the production in an imposed actual time fund, the only technical solution allowed remains the use of a work station with identical posts in parallel, as in Fig. 1.

The partition of three identical working posts in parallel $(<\mathrm{PL}_{(j-1)}, \mathrm{PL}_j, \mathrm{PL}_{(j+1)}>)_i$ is considered, where j is the current index of the working post in parallel, $1 \leq j \leq p_i$, $j \in \mathbf{N}$, partition forming the current Stl_i, equivalent to PL_i of [1], in a serial SFa; there is the assignment $\mathrm{OT}_i \to \mathrm{Stl}_i$, with T_{ci} subject to the above conditions and restrictions. If $\mathrm{PL}_{(i-1)}$ and $\mathrm{PL}_{(i+1)}$ provide the rhythmicity called for the production, then, in order to be able to provide it, Stl_i should be composed of $p_i = \max(T_{ci}/T_{c(i-1)},\ T_{ci}\ \ T_{c(i+1)},\ \ldots,\ T_{ci}\ \ T_{c(i\pm\alpha)})$ and $p_i \in \mathbf{N}$ posts in parallel, which should function with staggered internal cycles, with $j_{\max} = p_i$, called *staggering factor*, expressed by the number p_i of identical posts in parallel from Stl_i.

Any $\mathrm{PL}_j \subset \mathrm{St}l_i$ functions with $T_{c(j-1)} = T_{cj} = T_{c(j+1)} = = T_{ci}$, but staggered in time with the moments $t_{(j-1)} < < t_j < t_{(j+1)}$, so that $t_j = T_{ci/pi}$ and $t_{(j-1)} \to T_{c(j-1)}$, $t_j \to T_{cj}$, $t_{(j+1)} \to T_{c(j+1)}$ form the simply ordered sequence $(t_{(j-1)}|t_j|t_{(j+1)})_i \to T_{c(j-1)}|T_{cj}|T_{c(j+1)})_i$ which must fulfill the functional precedence condition $(t_{(j-1)}+T_{c(j-1)}) < < (t_j+c_j)<(t_{(j+1)}+T_{c(j+1)})$ or $(t_{(j-1)} + T_{ci})|(t_j + T_{ci})|\ \tilde{A}(t_{(j+1)} + + T_{ci})$, from which it follows that $t_j = t_{(j-1)} + T_{ci}/_{pi}$, $t_{(j+1)} = t_j + T_{ci}/_{pi}$, $t_i = t_{(j+1)} + T_{ci}/_{pi}$ and $t_i - t_{(j-1)} = T_{ci}$.

3. STRUCTURE OF STATION Stl_i

In the conditions and with the restrictions above, PL_i of [1] turns into a Stl_i with the following structure, requiring:

- a loading post (Pi) on the input Stl_i upstream, with the function of material distribution (PRa) in $\forall \mathrm{PL}_j \subset \mathrm{St}l_i$; an unloading post (Pd) on the output Stl_i downstream, with the function of joining (PRe) the materials collected from $\forall \mathrm{PL}_j \subset \mathrm{St}l_i$;
- two storers: one $\mathrm{ST}_{i,i}$ coupled with Pi and the other $\mathrm{ST}_{i,d}$ coupled with Pd, both movable between two adjacent points, in Kanban relation;
- a proper and particular communications system, in Kanban relation;
- in such a structure, Stl_i becomes a *parallel technological module* in structuring a serial material flow, in Kanban relation, as in [1].

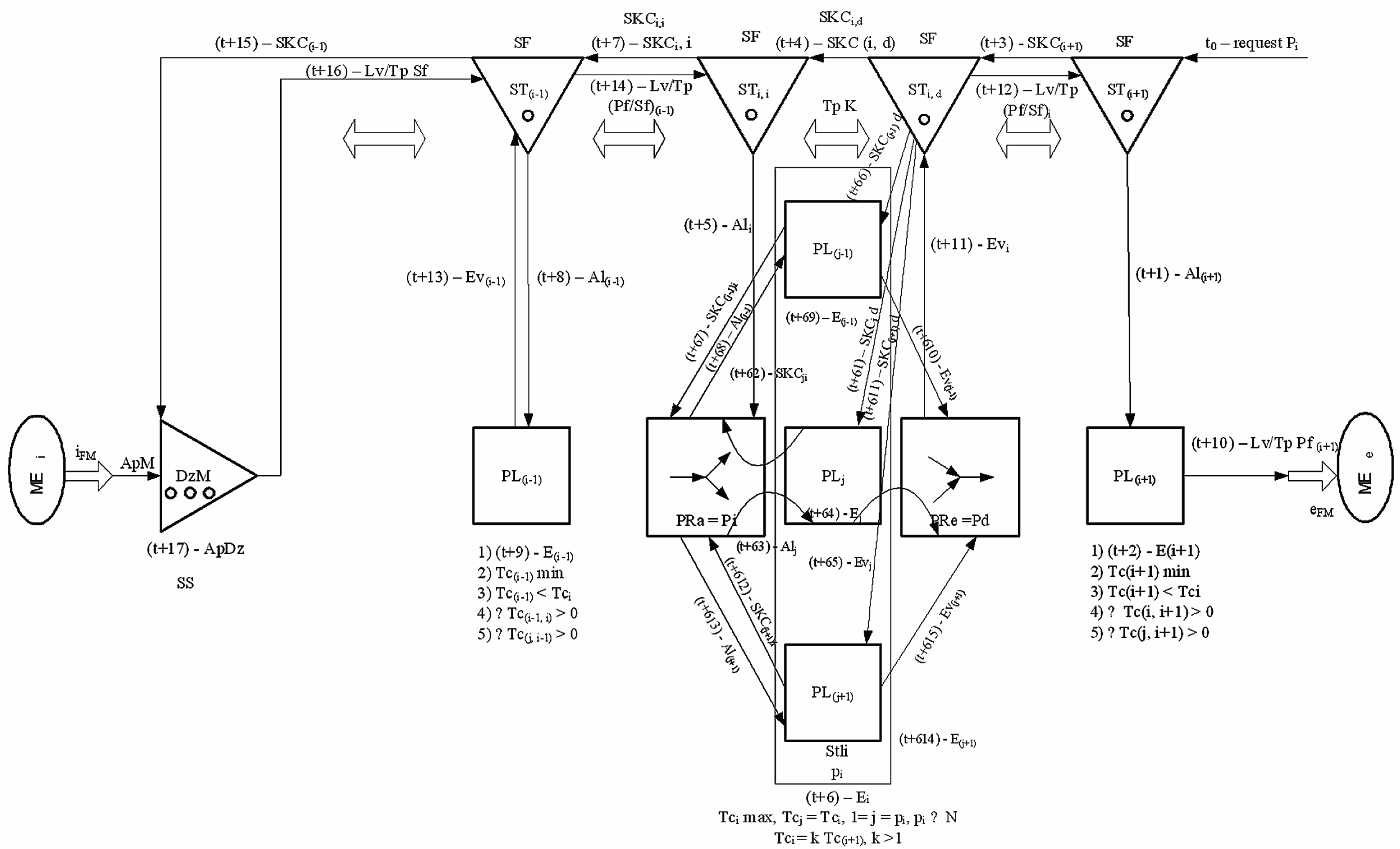

Fig. 1. Kanban serial-parallel graphic model with stocks on the flow.

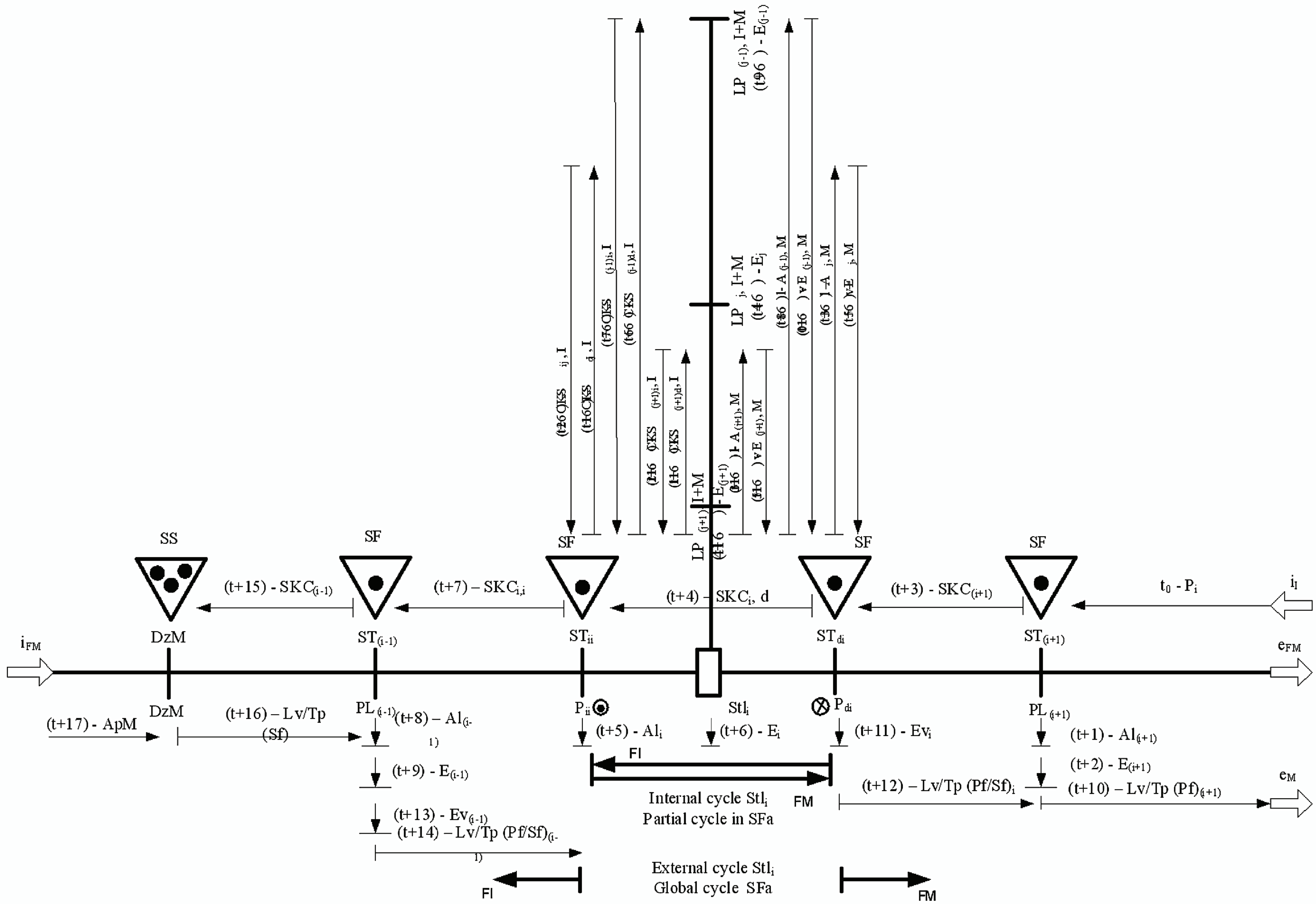

Fig. 2. The complete serial-parallel (mixed) material processing cycle, with stocks on the flow.

4. IDENTIFICATION OF MATERIAL ACTIVITIES

In a Stl_i, parallelly aggregated of p_i PL$_j$, the material activities are divided into two categories:

- activities outside the station: Lv/Tp$_{(i-1)}$ and Lv/Tp$_i$;
- activities inside the station: Al$_i$|Al$_{(j-1)}$|,
- E$_{(j-1)}$|Al$_j$|E$_j$|Al$_{(j+1)}$|E$_{(j+1)}$|Ev$_{(j-1)}$|Ev$_j$|Ev$_{(j+1)}$|Ev$_i$, equivalent to Al$_i$|E$_i$|Ev$_i$ – called the *material partial cycle of* Stl_i.

The corresponding informatic activities are also of two types:

- outside the station: SKC$_{(i+1)}$, SKC$_{i(i,d)}$, SKC$_{(i-1)}$,
- inside the station: SKC$_{(j-1)d}$| SKC$_{(j-1)i}$| SKC$_{jd}$| SKC$_{ji}$| SKC$_{(j+1)d}$| SKC$_{(j+1)I}$.

5. PARTIAL AND GLOBAL CYCLES

The partial cycle is that corresponding to a single working post of the station and this can be any PL$_j$, $1 \le \forall j \le p_i$, being identical for $\forall\, j \subset p_i$ and it consists of the ordered sequence of the inside activities: SKC$_{jd}$| SKC$_{ji}$| Al$_j$| E$_j$| Ev$_j$.

The global cycle is that corresponding to the entire work station and therefore it should also include, beside the internal couplings, the external ones, with the input and output exo environments: SKC$_{(i+1)}$| SKC$_{i(i,d)}$| SKC$_{(i-1)}$| Lv/Tp$_{(i-1)}$| Al$_i$| SKC$_{(j-1)d}$| SKC$_{(j-1)i}$| Al$_{(j-1)}$| E$_{(j-1)}$| SKC$_{jd}$| SKC$_{ji}$| Al$_j$| E$_j$| SKC$_{(j+1)d}$| SKC$_{(j+1)i}$| Al$_{(j+1)}$| E$_{(j+1)}$| Ev$_{(j-1)}$| Ev$_j$| Ev$_{(j+1)}$| Ev$_i$.

In Fig. 3, the inputs and outputs of a PL$_j$, are presented, and in Fig. 4 – the inputs and outputs of a Stl_i.

The following rules result from the figures below:

- A parallel working post PL$_j$ of a serial work station Stl_i has an informatic request input – SKC$_{jd}$ in Kanban relation and a material output – Ev$_j$.
- A serial work station Stl_i has, as in [1], equivalent to a current PL$_i$, two inputs and two outputs each, pairs-one informatic and the other material.

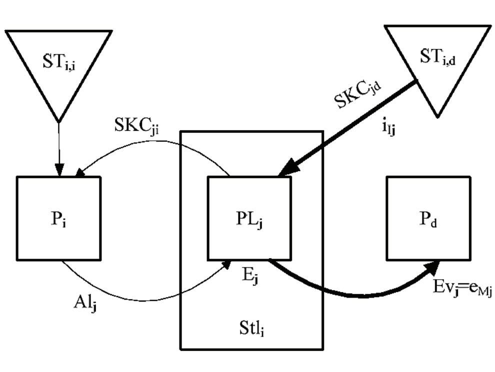

Fig. 3. Inputs/outputs diagram for a PL$_j$ of Stl_i.

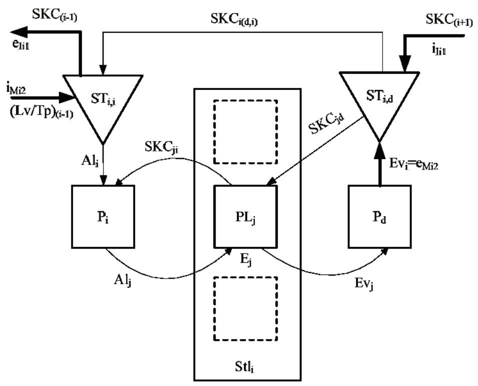

Fig. 4. Inputs/outputs diagram for Stl_i.

6. SEQUENTIAL ORDERING OF THE CYCLES

According to the previous statement, the partial cycle for a certain PL$_j$ from a certain Stl_i, in Kanban relation, will be: $(t+61)|(t+62)|(t+63)|(t+64)|(t+65)$.

The global cycle for a Stl$_i$ in Kanban relation will be: $(t+3)|(t+4)|(t+7|(t+14)|(t+5)|$ … $|(t+61)|(t+62)|$ $(t+63)|(t+64)|(t+65)$ | … | $(t+11)$.

7. CONCLUSIONS

Such a manufacturing structure, in Kanban relation, has been applied in an actual production environment and validated by animated and experimental simulation.

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