1 Generator:

$G = \langle X, Y, S, \delta_{ext}, \delta_{int}, \lambda, ta \rangle$

$Y = \{arrive\} \times \{port0\}$

$S = \Re_0^+$

$\delta_{int}(s) = -(1/\lambda) \times ln(1 - rand)$

$\lambda(s) = (arrive, 0)$

$ta(s) = s$

2 Conveyor Belt:

$M = \langle X, Y, S, \delta_{ext}, \delta_{int}, \lambda, ta \rangle$

$X = \{arrive\} \times \{port0\} \cup \{start, stop\} \times \{port1\}$

$Y = \{leave, detect\} \times \{port0\}$

$S = Queue \times \Re_0^+ \times \Re_0^+$

$where\, s = (q, v, \sigma);$

'q' es la cola de las distancias

'v' es la velocidad de la cinta en un momento dado

$$\delta_{ext}((d1 \bullet q, v, \sigma), e, (x, port)) =$$
$$\begin{cases} (d1 \bullet q, v, \sigma) & if \quad (x, port) = (arrive, 0) \wedge v = 0 \\ (map(+e * v)(d1 \bullet q), 0, \infty) & if \quad (x, port) = (stop, 1) \\ (map(+e * v)(d1 \bullet q), V_c, (l' - d1')/V_c) & if \quad (x, port) = (start, 1) \\ (map(+e * v)(d1 \bullet q) \bullet 0, v, (l' - d1')/V_c) & if \quad (x, port) = (arrive, 0) \wedge v = V_c \end{cases}$$

$$where: \ d1' = d1 + e * v, \qquad l' = \begin{cases} l & if \quad d1 < l \\ l + \Delta l & if \quad d1 \geq l \end{cases}$$

$$\delta_{int}(d1 \bullet d2 \bullet q, v, \sigma) =$$
$$\begin{cases} (map(+\sigma * v)(d1 \bullet d2 \bullet q), v, \Delta l/V_c) & if \quad d1 < l \\ (map(+\sigma * v)(d2 \bullet q), v, (l - (d2 + \sigma * v))/V_c) & if \quad d1 \geq l \wedge d2 \neq \emptyset \\ (\emptyset, v, \infty) & if \quad d1 \geq l \wedge d2 = \emptyset \end{cases}$$

$$\lambda(d1 \bullet q, v, \sigma) = \begin{cases} (detect, 0) & if \quad d1 < l \\ (leave, 0) & if \quad d1 \geq l \end{cases}$$

$ta(d1 \bullet q, v, \sigma) = \sigma$

3 Rotary Table:

$M = \langle X, Y, S, \delta_{ext}, \delta_{int}, \lambda, ta \rangle$

$X = \{arrive\} \times \{port0\} \cup \{rotateLeft, rotateRight, moveUp, moveDown\} \times \{port1\} \cup \{pick\} \times \{port2\}$

$Y = \{up, down, left, right, picked\} \times \{port0\} \cup \{ready\} \times \{port1\}$

$S = \{picking, notPicking, picked\} \times \{downLeft, downRight, upLeft, upRight\} \times \Re_0^+ \times \Re_0^+$

$where\, s = (status, position, elapsed, \sigma)$

'status' es el estado del brazo robot

'position' es la posicion de la mesa rotatoria

'elapsed' lleva el tiempo transcurrido en un movimiento de la mesa rotatoria

$$\delta_{ext}((status, position, elapsed, \sigma), e, (x, port)) =$$

$$\begin{cases} (status, upLeft, 0, t_{mov}) & if \quad (x, port) = (rotateLeft, 1) \\ (status, upRight, 0, t_{mov}) & if \quad (x, port) = (moveUp, 1) \\ (status, downLeft, 0, t_{mov}) & if \quad (x, port) = (moveDown, 1) \\ (picked, position, elapsed, 0) & if \quad (x, port) = (pick, 2) \\ (status, downRight, 0, t_{mov}) & if \quad (x, port) = ((arrive, 0) \vee (rotateRight, 1)) \\ (status, position, elapsed', \sigma') & ow \end{cases}$$

$$where: \; elapsed' = elapsed + e, \qquad \sigma' = \begin{cases} t_{mov} - elapsed' & if \quad elapsed < t_{mov} \\ \infty & ow \end{cases}$$

$$\delta_{int}(status, position, elapsed, \sigma) =$$

$$\begin{cases} (status, position, elapsed, \infty) & if \quad status = picking \\ (notPicking, position, elapsed, \infty) & if \quad status = picked \\ (picking, position, elapsed, 0) & if \quad (status = notPicking) \wedge (position = upRight) \\ (status, position, elapsed + \sigma, \infty) & ow \end{cases}$$

$$\lambda(status, position, elapsed, \sigma) = \begin{cases} (ready, 1) & if \quad status = picking \\ (picked, 0) & if \quad status = picked \\ (down, 0) & if \quad status = downLeft \\ (right, 0) & if \quad status = downRight \\ (up, 0) & if \quad status = upRight \\ (left, 0) & if \quad status = upLeft \end{cases}$$

$$ta(status, position, elapsed, \sigma) = \sigma$$

4 System Control:

$M = \langle X, Y, S, \delta_{ext}, \delta_{int}, \lambda, ta \rangle$

$X = \{leave, detect\} \times \{port0\} \cup \{up, down, left, right, picked\} \times \{port1\}$

$Y = \{start, stop\} \times \{port0\} \cup \{arrive\} \times \{port1\} \cup \{rotateLeft, rotateRight, moveUp, moveDown\} \times \{port2\}$

$S = \{leave, detect, up, down, left, right, picked\} \times \{upLeft, upRight, downLeft, downRight\} \times \Re_0^+$

$where\ s = (signal, position, \sigma)$

'signal' lleva un evento de entrada

'position' es la posicion de la mesa rotatoria

$$\delta_{ext}((signal, position, \sigma), e, (x, port)) =$$
$$\begin{cases} (detect, position, 0) & if \quad (x, port) = (detect, 0) \wedge position \neq downLeft \\ (leave, downRight, 0) & if \quad (x, port) = (elave, 0) \wedge position = downLeft \\ (left, upLeft, 0) & if \quad (x, port) = (left, 1) \\ (down, downLeft, 0) & if \quad (x, port) = (down, 1) \\ (right, downRight, 0) & if \quad (x, port) = ((right, 1) \\ (up, upRight, 0) & if \quad (x, port) = ((up, 1) \\ (picked, position, 0) & if \quad (x, port) = ((picked, 1) \end{cases}$$

$$\delta_{int}(signal, position, \sigma) = (signal, position, \infty)$$

$$\lambda(signal, position, \sigma) = \begin{cases} (stop, 1) & if \quad signal = detect \\ (arrive, 1) & if \quad signal = leave \\ (moveDown, 2) & if \quad signal = left \\ (start, 0) & if \quad signal = down \\ (moveUp, 2) & if \quad signal = right \\ (rotateLeft, 2) & if \quad signal = picked \end{cases}$$

$$ta(signal, position, \sigma) = \sigma$$

5 Robot:

$M = \langle X, Y, S, \delta_{ext}, \delta_{int}, \lambda, ta \rangle$

$X = \{ready\} \times \{port0\}$

$Y = \{pick\} \times \{port0\}$

$S = \{busy, notBusy\} \times \Re_0^+$

$where\ s = (status, \sigma)$

'status' es el estado del brazo robot

$$\delta_{ext}((status,\sigma),e,(x,port)) = \begin{cases} (busy, rand*(b-a)+a) & if \quad (x,port)=(ready,0) \wedge status = notBusy \\ (status, \sigma - e) & ow \quad (x,port)=(down,1) \end{cases}$$

$$where: \ a = 6 \wedge b = 16$$

$$\delta_{int}(status,\sigma) = (notBusy, \infty)$$

$$\lambda(status,\sigma) = (pick, 0)$$

$$ta(status,\sigma) = \sigma$$

6 Conveyor Belt Statics:

$$M = \langle X, Y, S, \delta_{ext}, \delta_{int}, \lambda, ta \rangle$$

$$X = \{arrive\} \times \{port0\} \cup \{start, stop\} \times \{port1\}\{leave\} \times \{port2\}$$

$$Y = \Re \times \{port0\} \cup \Re \times \{port1\}$$

$$S = N \times \{running, stopped\} \times N \times N \times N \times \Re_0^+$$

$$where: \ s = (print, status, counter, rejected, onBelt, \sigma)$$

'print' dice el numero de puerto que se va a mostrar con gnuplot

'status' indica el estado de la cinta transportadora

'counter' cuenta la cantidad de arribos

'rejected' cuenta la cantidad de arribos rechazados dado que la cinta estaba detenida

'onBelt' cuenta la cantidad de piezas en la cinta transportadora

$$\delta_{ext}((print,status,counter,rejected,onBelt,\sigma),e,(x,port)) =$$

$$\begin{cases} (print, status, counter+1, rejected, onBelt+1, 0) & if \quad (x,port) = (arrive,0) \wedge status = running \\ (print, status, counter+1, rejected+1, onBelt, 0) & if \quad (x,port) = (arrive,0) \wedge status = stopped \\ (print, status, counter, rejected, onBelt-1, 0) & if \quad (x,port) = (leave,2) \\ (print, running, counter, rejected, onBelt, \sigma) & if \quad (x,port) = (start,1) \\ (print, stopped, counter+1, rejected, onBelt, \sigma) & if \quad (x,port) = (stop,1) \end{cases}$$

$$\delta_{int}(print,status,counter,rejected,onBelt,\sigma) = \begin{cases} (1, status, counter, rejected, onBelt, 0) & if \quad print = 0 \\ (0, status, counter, rejected, onBelt, \infty) & if \quad print = 1 \end{cases}$$

$$\lambda(print,status,counter,rejected,onBelt,\sigma) = \begin{cases} (rejected/counter, 0) & if \quad print = 0 \\ (onBelt, 1) & if \quad print = 1 \end{cases}$$

$$ta(print,status,counter,rejected,onBelt,\sigma) = \sigma$$