SCHEDULING AND ROUTING …

I. Scheduling and routing coordination

2 communities

Scheduling community

Routing community

Scheduling community

Scheduling with transportation

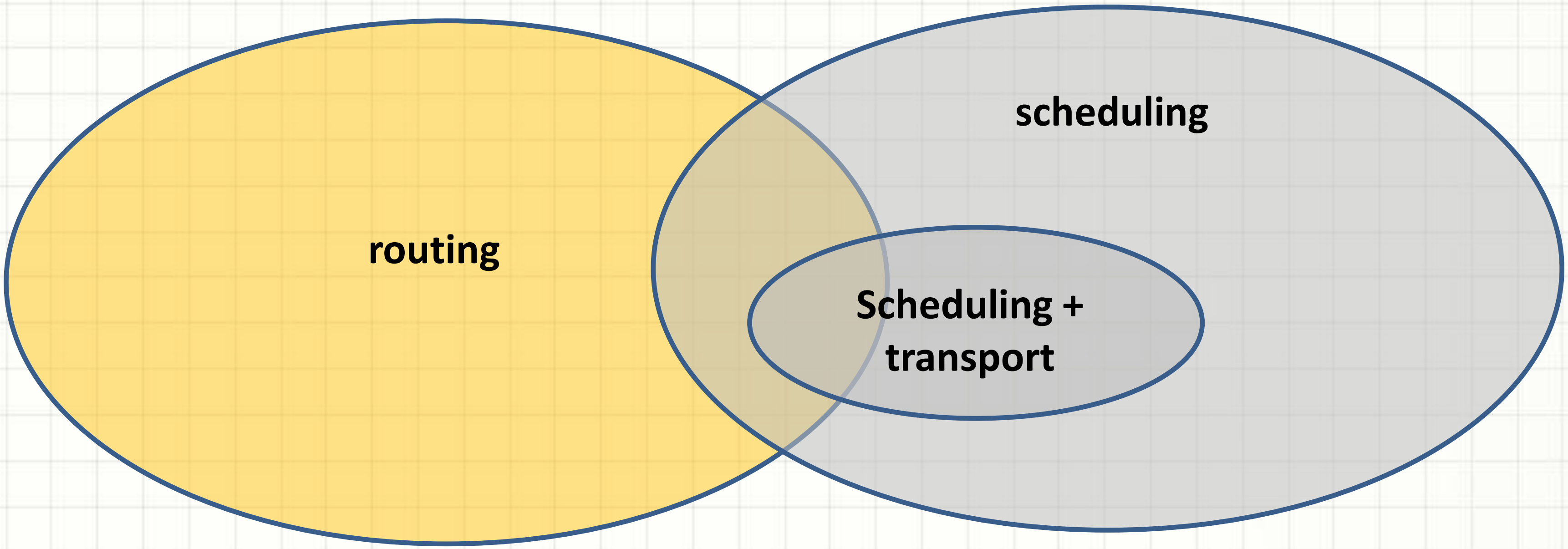
Example : Job-Shop with transport

Routing community

No Scheduling

Pick up and deliveries are… available…

I. Scheduling and routing coordination



I. Scheduling and routing coordination

- Current works
  - Collaboration with LIMOS/LAAS
    - Disjunctive Scheduling ➔ update the graphe
  - PhD Thesis (M. Vinot)
    - Scheduling with extra constraints
  - -Collaboration LIMOS/Bologna

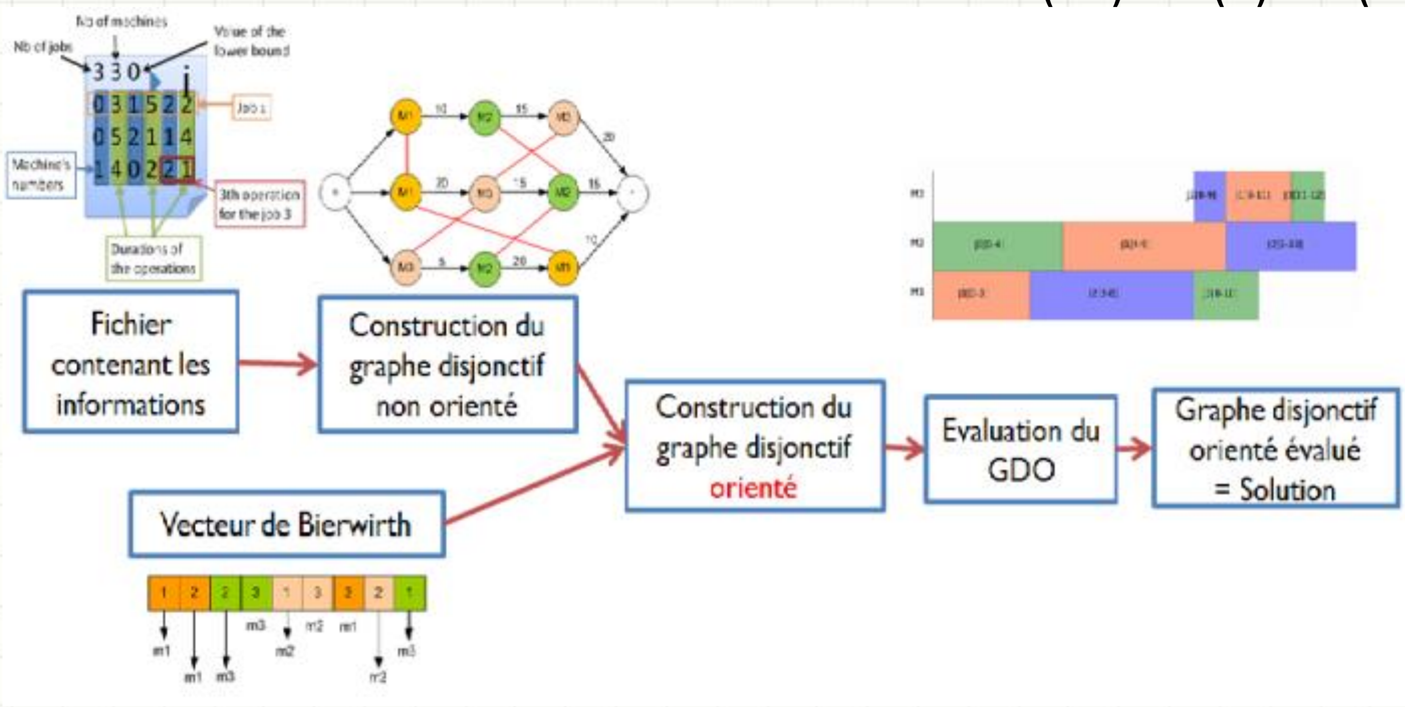
I. Scheduling and routing coordination

- Questions
  - How researchers in scheduling include transportation in the problems ?
  - How Supply chain optimization is achieved ?

II. Scheduling and transport

- Example : job-shop

J1 : M1(10) M2(10) M3(100)
J2 : M2(4) M1(30) M3(10)
J3 : M3(20) M2(5) M3(10)

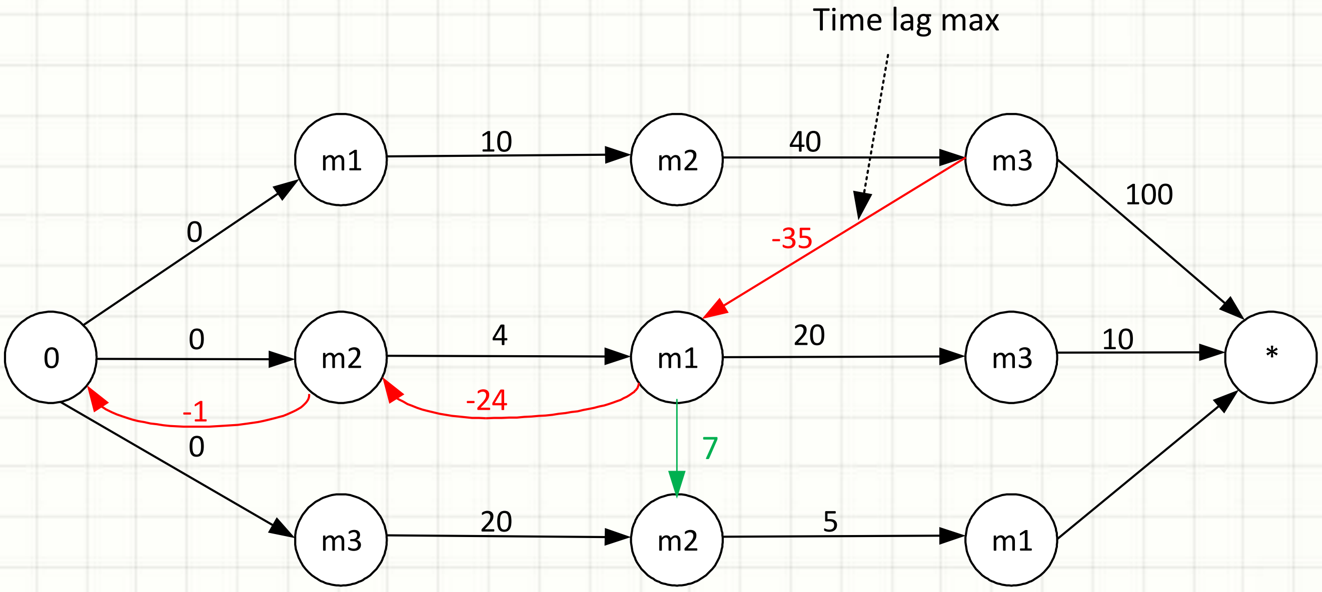


II. Scheduling and transport

- Example : job-shop

J1 : M1(10) M2(10) M3(100)
J2 : M2(4) M1(30) M3(10)
J3 : M3(20) M2(5) M3(10)

- Non oriented disjunctive graph

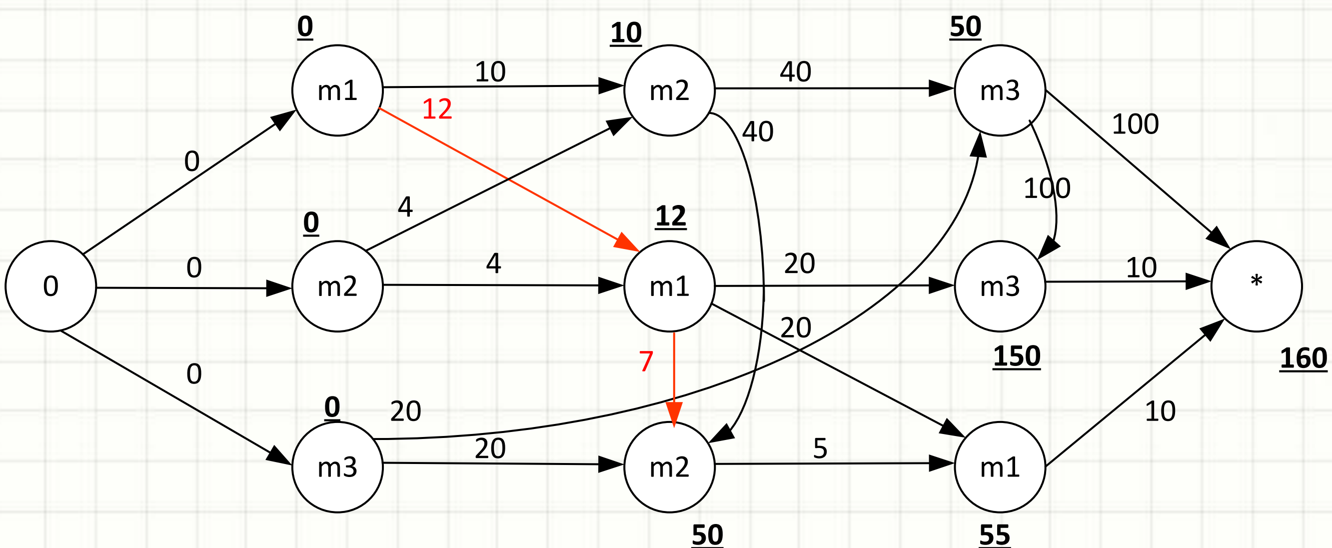


II. Scheduling and transport

- Scheduling ?
  - A disjunction between operation

J1 : M1(10) M2(10) M3(100)
J2 : M2(4) M1(30) M3(10)
J3 : M3(20) M2(5) M3(10)

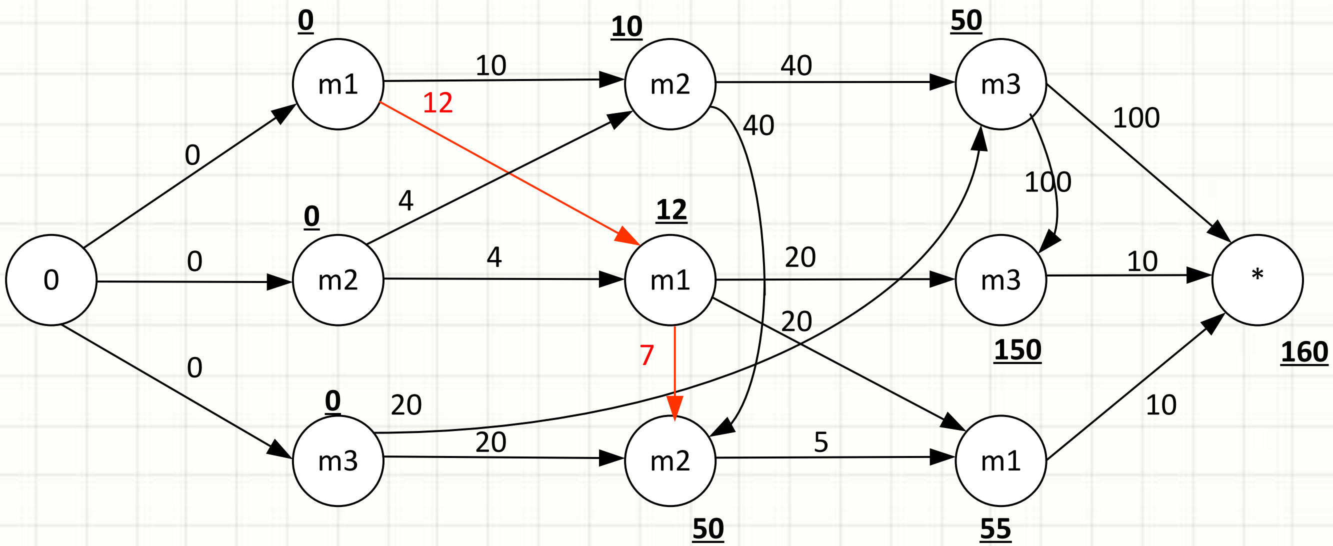
m1		m2		m3		m3		m1
1	2	1	2	2	1	3	3	3
	m2		m1		m3		m2	



II. Scheduling and transport

- Scheduling ?
  - A solution : an evaluation of the graph

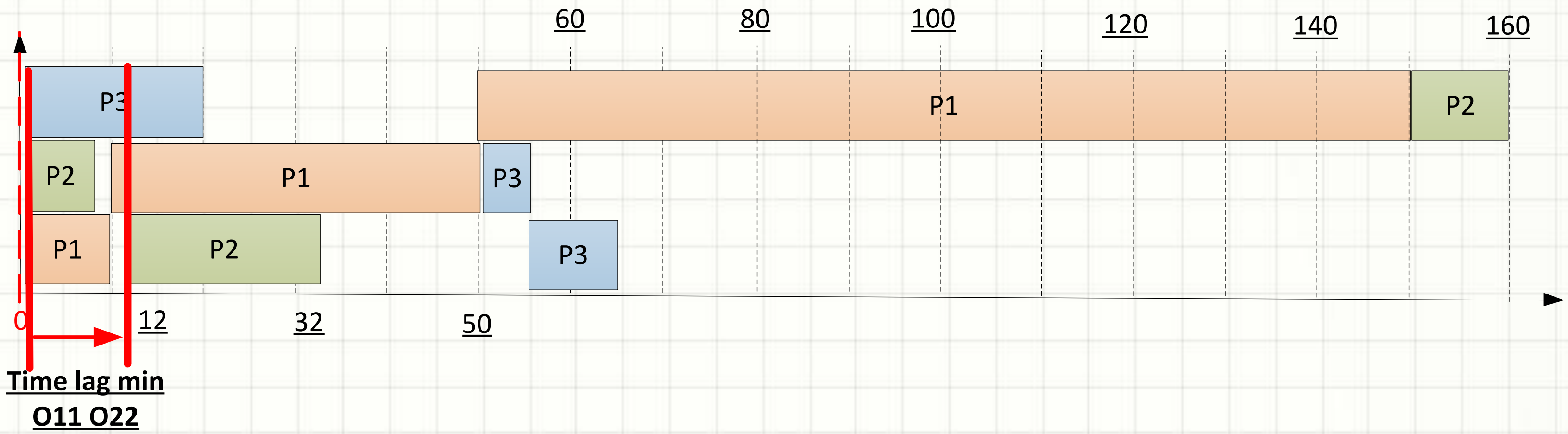
J1 : M1(10) M2(10) M3(100)
J2 : M2(4) M1(30) M3(10)
J3 : M3(20) M2(5) M3(10)



II. Scheduling and transport

- Scheduling ?
  - Example : job-shop

J1 : M1(10) M2(10) M3(100)
J2 : M2(4) M1(30) M3(10)
J3 : M3(20) M2(5) M3(10)



II. Scheduling and transport

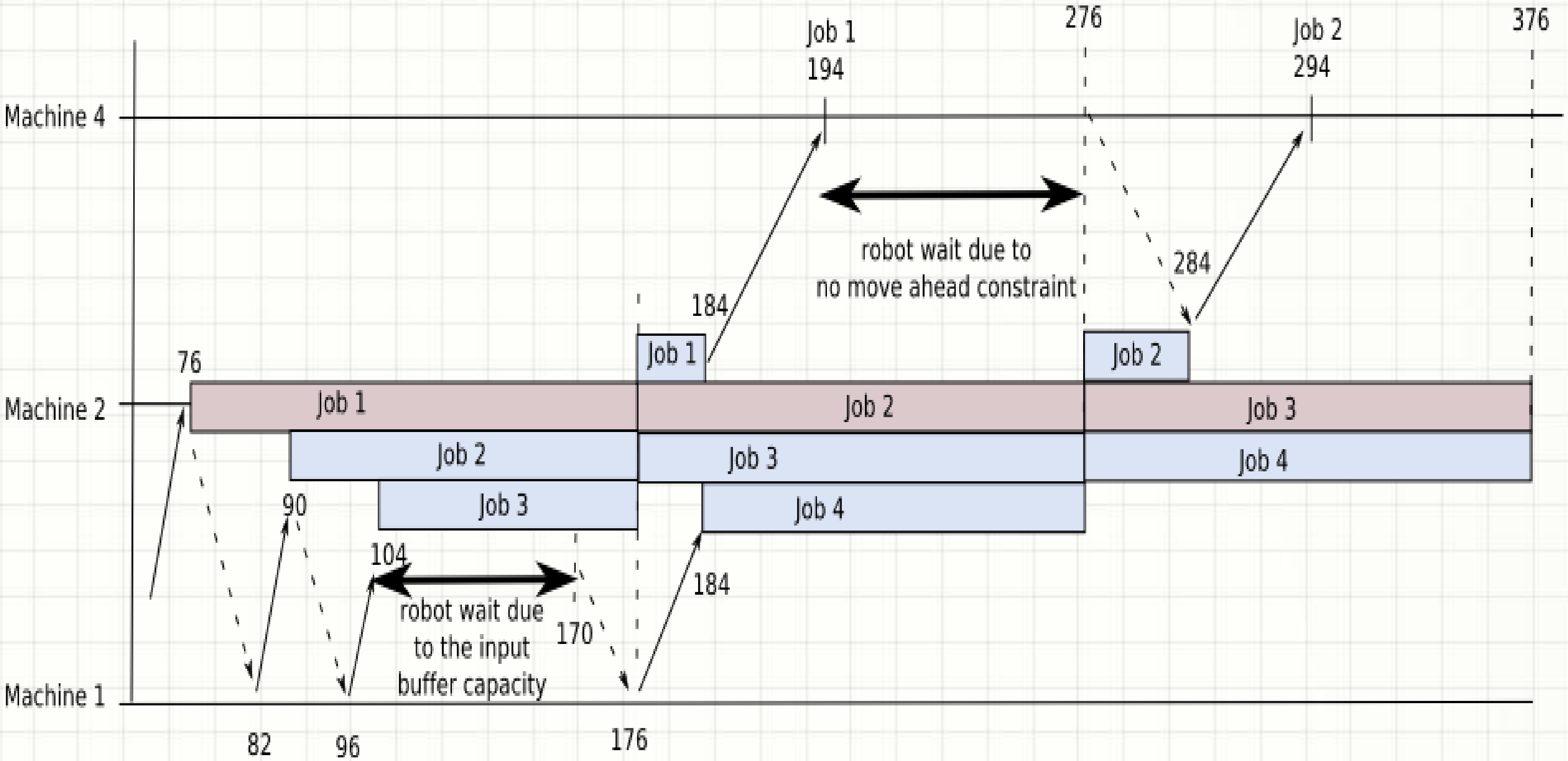
- Scheduling ? And the transport ?

Mohand Larabi. « Le problème de job-shop avec transport : modélisation et optimisation ». PhD Thesis. Clermont Ferrand University. 15 dec 2010.

Johann Hurink, Sigrid Knust. Tabu search algorithms for job-shop problems with a single transport robot. European Journal of Operational Research, Volume 162, Issue 1, 1 April 2005, Pages 99-111.

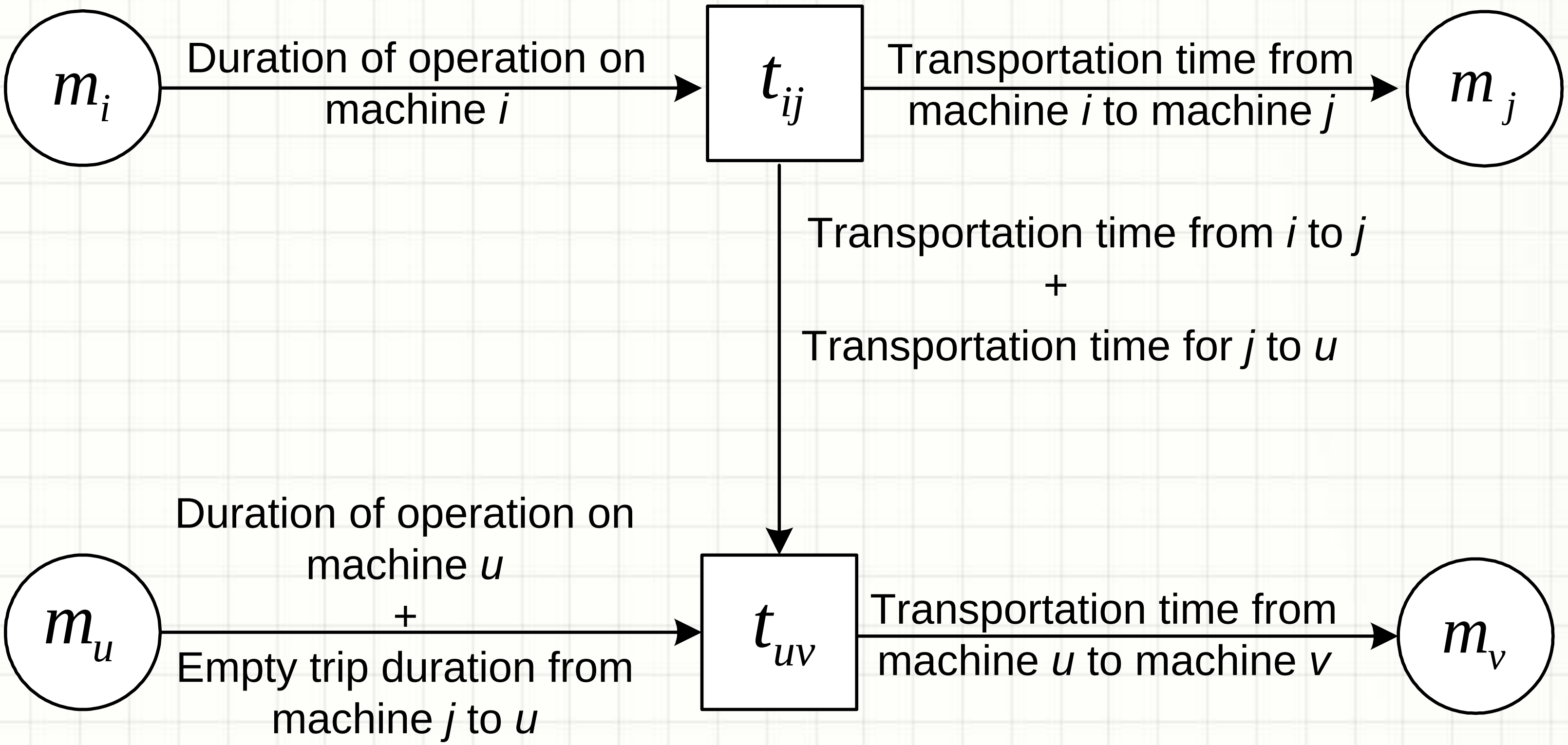
II. Scheduling and transport

- What does it mean ?



II. Scheduling and transport

- 1 robot with capacity 1



II. Scheduling **and transport**

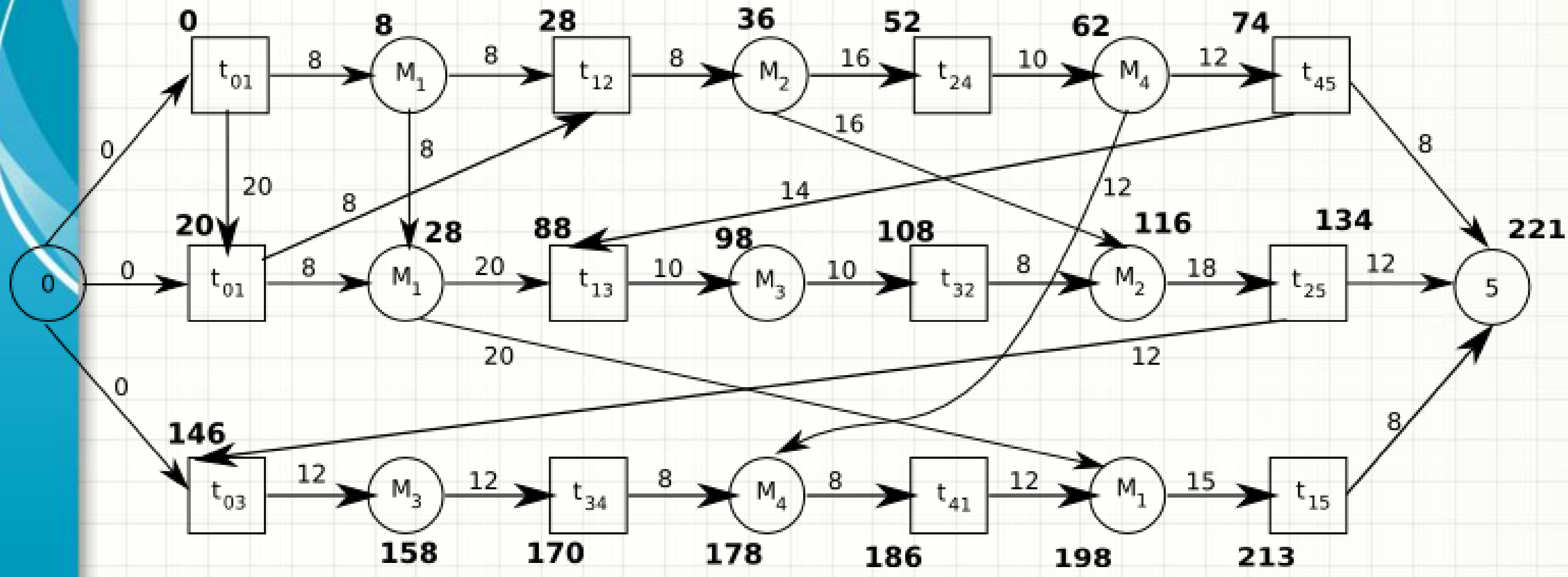
- 1 robot with capacity 1

Job 1	Machine 1 Processing time: 8	Machine 2 Processing time: 16	Machine 4 Processing time: 12
Job 2	Machine 1 Processing time: 20	Machine 3 Processing time: 10	Machine 2 Processing time: 18
Job 3	Machine 3 Processing time: 12	Machine 4 Processing time: 8	Machine 1 Processing time: 15

	m_1/m_6	m_2	m_3	m_4	m_5
m_1/m_6	0	6	8	10	12
m_2	12	0	6	8	10
m_3	10	6	0	6	8
m_4	8	8	6	0	6
m_5	6	10	8	6	0

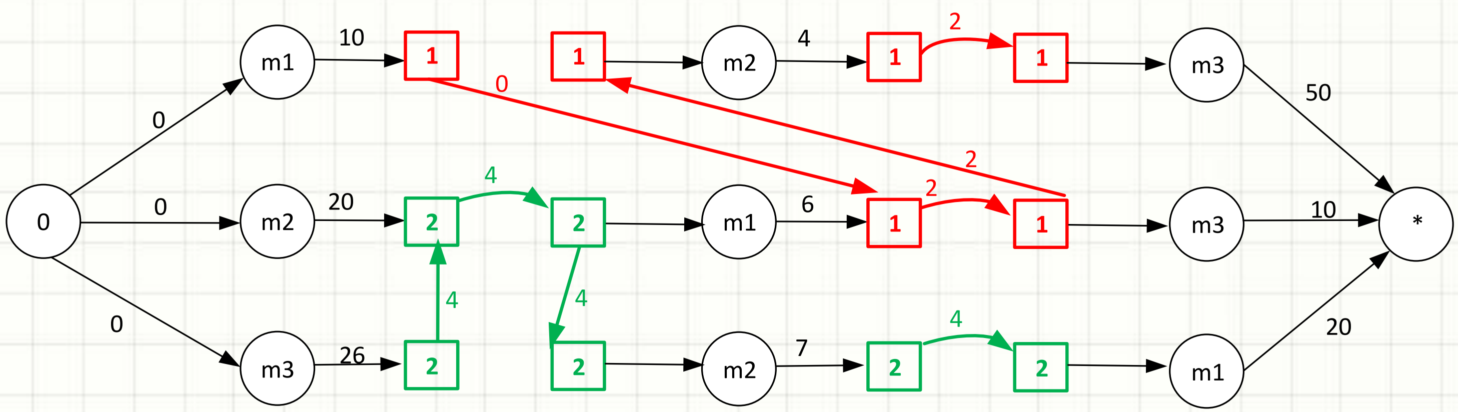
II. Scheduling and transport

- 1 robot with capacity = 1



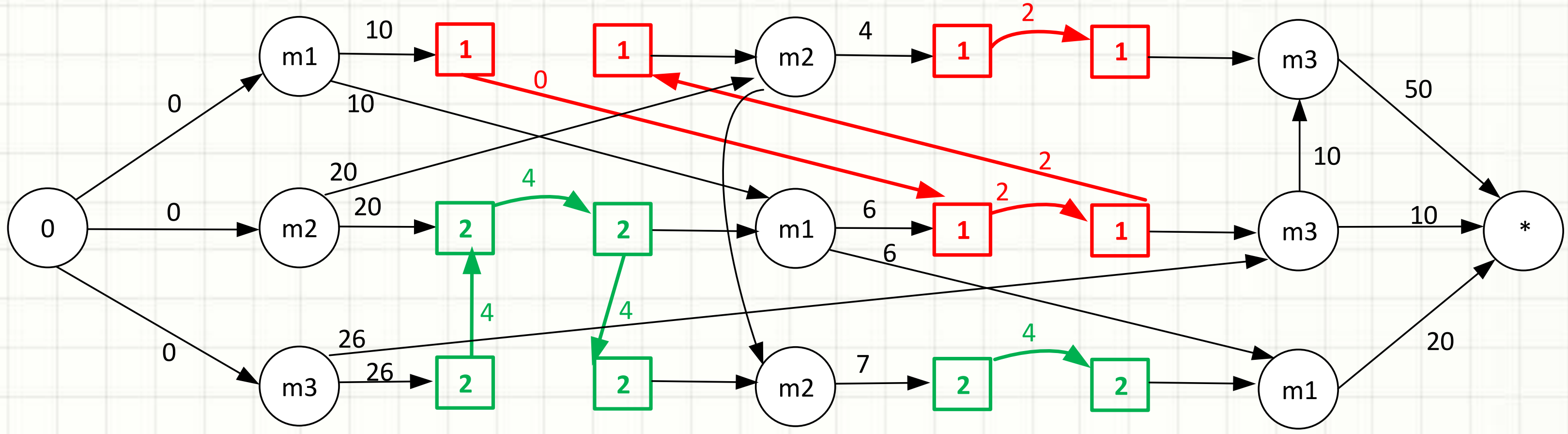
II. Scheduling and transport

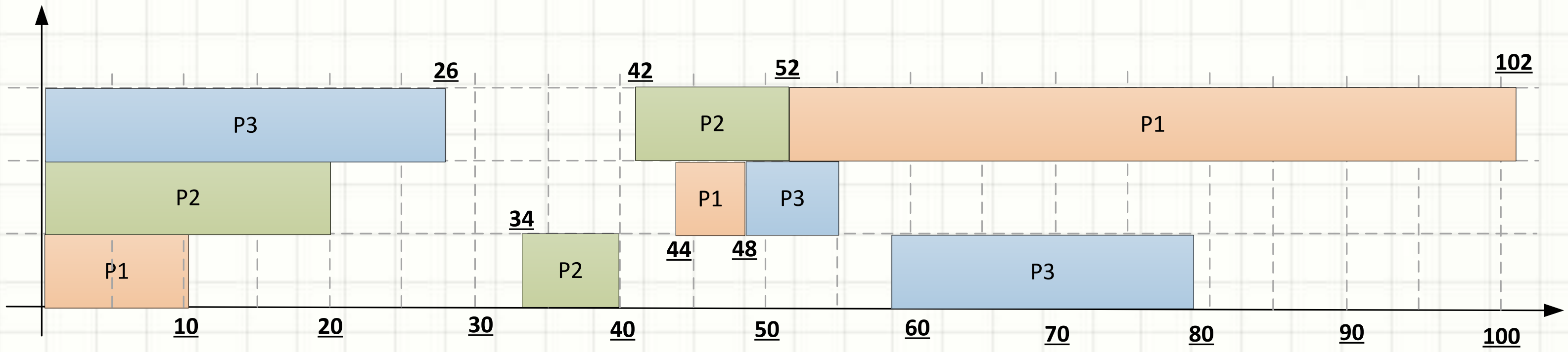
- 2 robots : a solution for the routing



II. Scheduling and transport

- A solution for the routing and the scheduling





II. Scheduling and transport

- Remarks
  - It is possible
  - No specific algorithms for the routing…

Why ?

Semi active solutions

Feasibility check !

II. Scheduling and transport

Instances

Hurink J. and Knust S. (2005). Tabu search algorithms for job-shop problems with a single transport robot, European Journal of Operational Research, Vol. 162, No 1, pp. 99-111

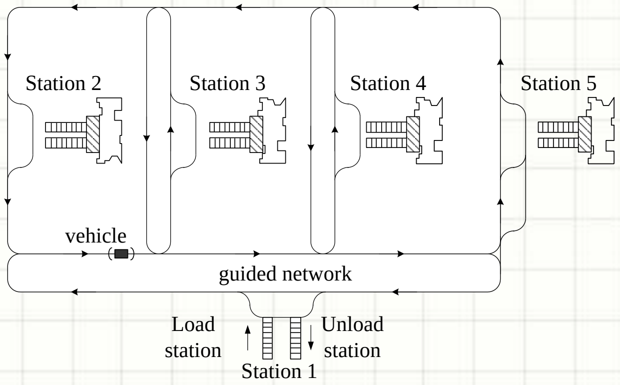
Bilge U and Ulusoy. A time windows appoach to simulteneous scheduling of machines and material handling system in a FMS. Operations Research. 43(6). Pp. 1058-1070. 1995.

Ulusoy U., F. Sivrikay-eSrifoglu and Bilge U. A genetic algorithm approach to the simultaneous scheduling of machines and automated guided vehicles. Computers and Operations Research. 24(4). pp. 335-351. 1997.

Last publications

Houssem Eddine Nouri, Olfa Belkahla Driss, Khaled Ghédira. Simultaneous scheduling of machines and transport robots in flexible job shopenvironment using hybrid metaheuristics based on clustered holonic multiagent model. Computers & Industrial Engineering, In Press, Corrected Proof, March 2016

II. Scheduling and transport



Layout 1

	M1	M2	M3	M4	M5	M6
M1	0	6	8	10	12	0
M2	12	0	6	8	10	12
M3	10	6	0	6	8	10
M4	8	8	6	0	6	8
M5	6	10	8	6	0	6
M6	0	6	8	10	12	0

Jobset 1

```
Type 1: M1(0); M2(8);  M3(16); M5(12); M6(0)
Type 2: M1(0); M2(20); M4(10); M3(18); M6(0)
Type 3: M1(0); M4(12); M5(8);  M2(15); M6(0)
Type 4: M1(0); M5(14); M3(18); M6(0)
Type 5: M1(0); M4(10); M2(15); M6(0)
```

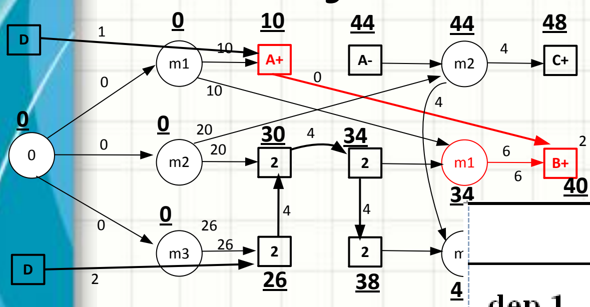
III. First trend : disjunctive….

- Classical scheduling approaches
- Extensions….????

- <u>2 kinds of extensions</u>
  - New definition of Earliest Starting Times
  - New definition of routing considering some specific scheduling approaches

III. First trend : disjunctive….

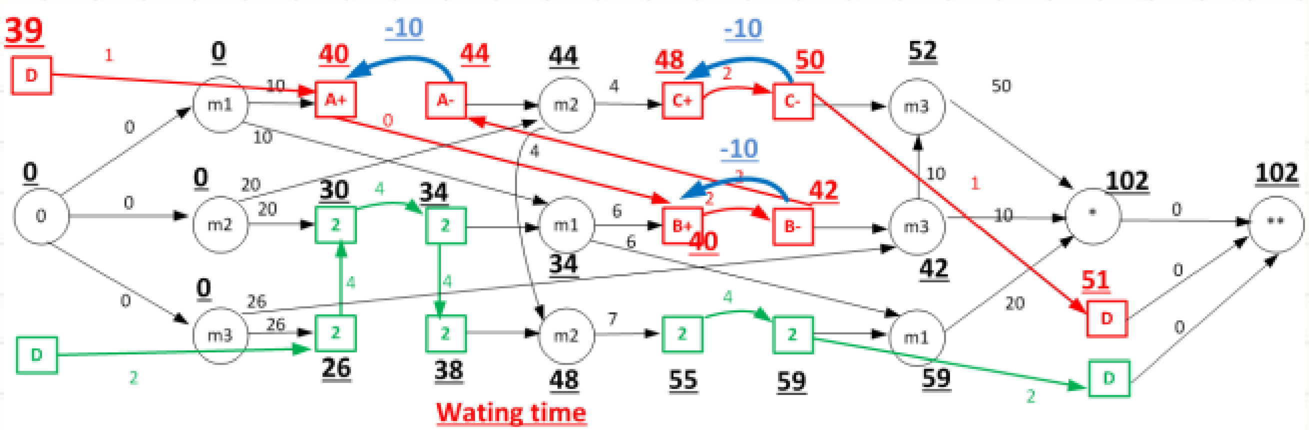
- Disjunctive modelisation

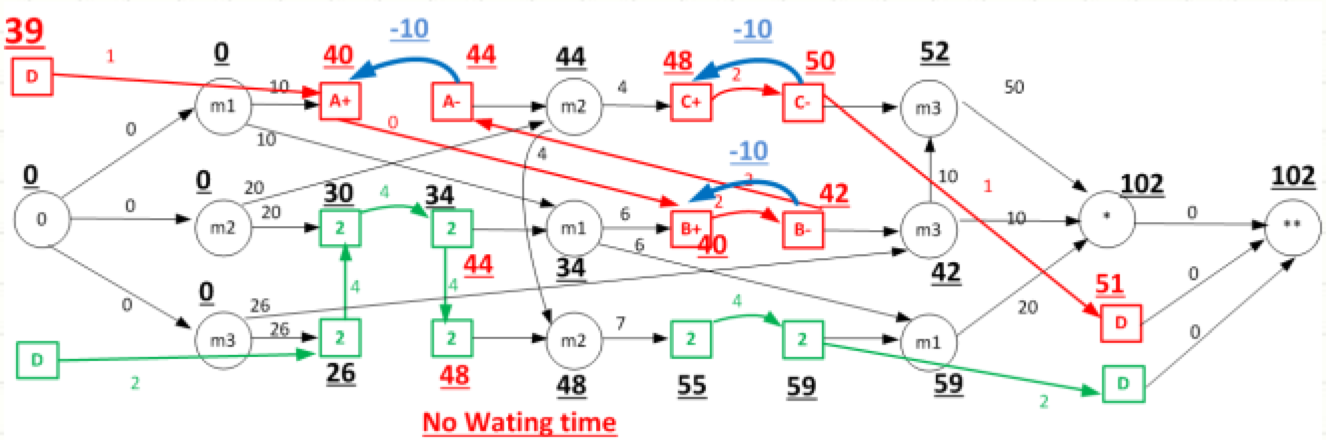


	Initial	Type	Fenêtre	final	Type	Fenêtre
dep 1	D	Vide		A+		[-∞;∞]
dep 2	A+	P	[10;∞]	B+	P	[-∞;∞]
dep 3	B+	P	[40;∞]	B-	D	[-∞;42]
dep 4	B-	D	[-∞;∞]	A-	D	[-∞;44]
dep 5	A-	D	[-∞;∞]	C+	P	[-∞;∞]
dep 6	C+	P	[48;∞]	C-	D	[-∞;52]
dep 7	C-	Vide	[-∞;∞]	D	vide	[-∞;102]

III. First trend : disjunctive….

- Challenging problems ?





IV. Second trend : specific problems….

- Scheduling with specific approach….

- RCPSP
  - Scheduling + resource management
  - Resource management => flot problem
  - High quality specific methods

- Under study with **Marina Vinot (LIMOS)**

IV. Second trend : specific problems….

Data :

R set of resources, limited constant availability $B_k \geq 0$ for $\mathrm{k} \in R$,

A set of activities (tasks),

duration $p_i \geq 0 , i \in A$,

resource requirement $b_{ik} \geq 0 , \mathrm{k} \in R$,

E set of precedence constraints (i, j), avec $i, j \in A, \ i < j$

T time interval (scheduling horizon)

Constraints :

$S_i \geq 0$ start time of activity i

$S_j \geq S_j + p_i$, *with* $(i, j) \in E$

Precedence constraints

$\sum_{j \in A(t)} b_{ik} \leq B_k$, *with* $t \in T, \ \mathrm{k} \in R$

Resource constraints

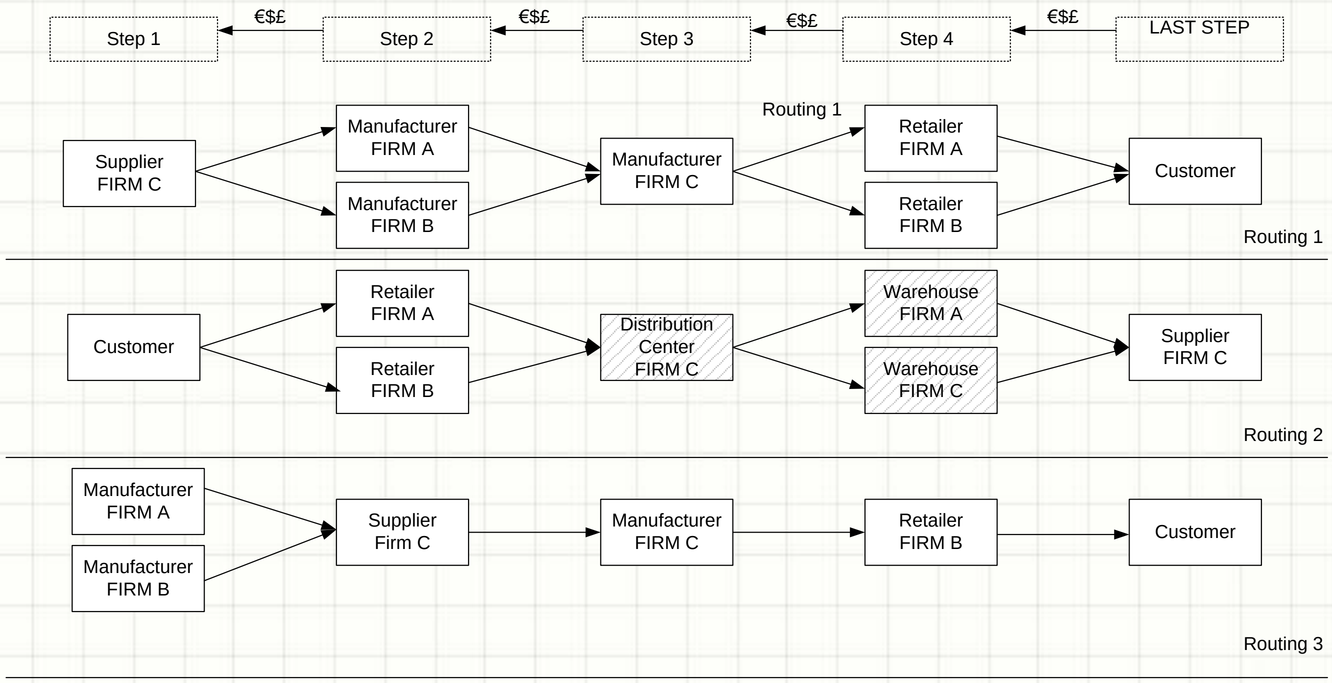
IV. Third trend : divide to conquer….

- Scheduling with specific approach….

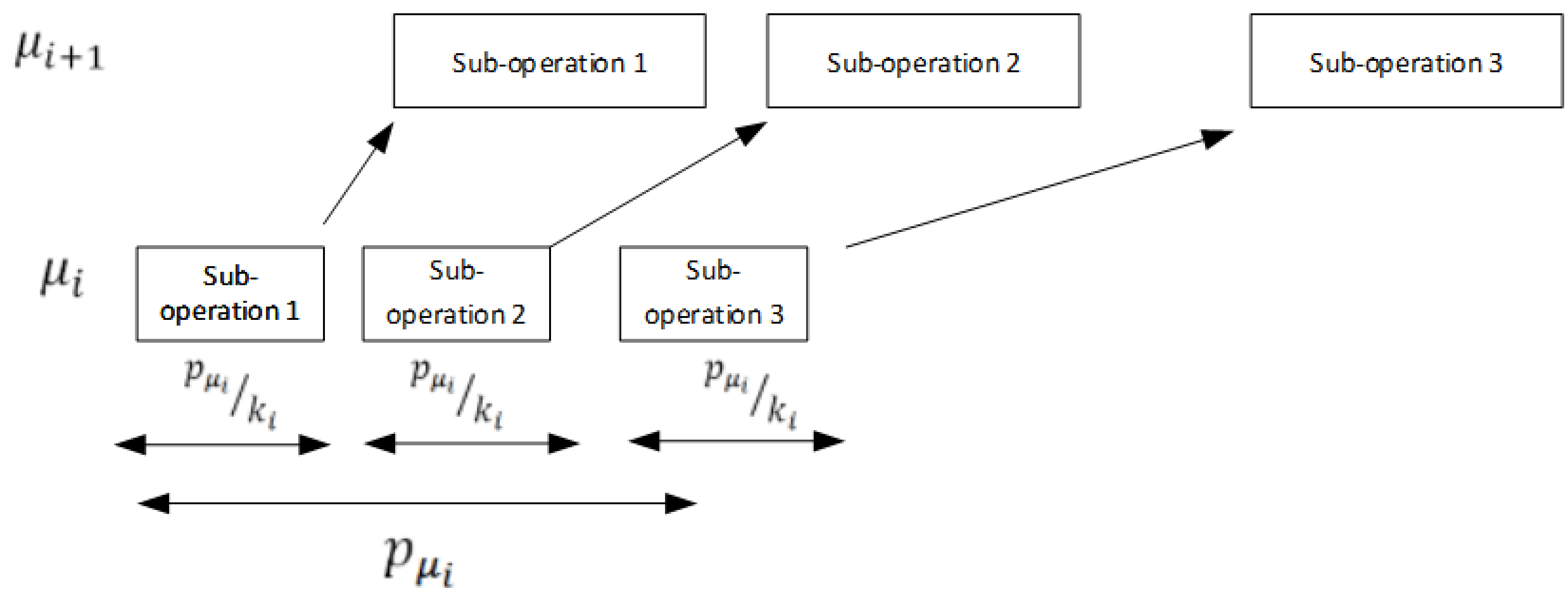
- ~~Transport~~ routing

- Under study with **Caroline Prodhon, Ren Libo and Daniele Vigo.**

IV. Third trend : divide to conquer….



IV. Third trend : divide to conquer….



A job :

number of parts batched together (*ni*)

(Adacher and Cassandras, 2014)

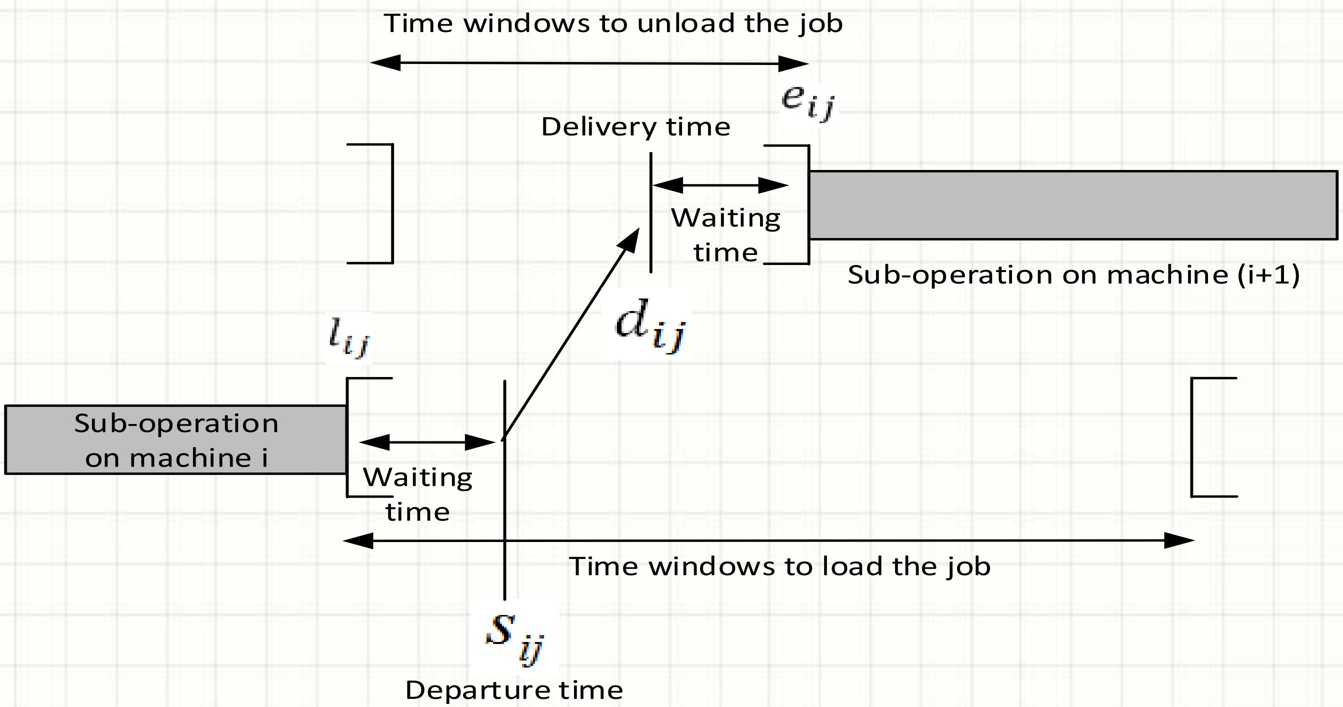
Lot size : $k_i = {}^{n_i}/_{n'_i}$

Processing time of batch : $p_{\mu_i} = \sum_{j=1}^{k_i} {}^{p_{\mu_i}}/_{k_i}$

IV. Third trend : divide to conquer….

	Scheduling	Nb vehicle	Vehicle Capacity	Specific constraint
(Chang and Lee , 2004)	Single machine	1	limited	
(Chen and Vairaktarakis , 2005)	Single machine	Infinite	limited(2)	
(Li and Vairaktarakis, 2007)	Single machine			
(Garcia et al., 2002)	Two stage scheduling problem		=1	Due Date Nowait(1)
(Garcia et al., 2004)	Parallel Machine	1		Due Date Nowait(1)
(Ullrich, 2013)	Parallel Machine	>1	>1	Heterogonous fleet
(Mahavi-Mazdeh et al. 2007)	Single machine	>1	>1	
(Mahavi-Mazdeh et al. 2008)				
(Mahavi-Mazdeh et al. 2011)				
(Rasti-barzoki and Hejazi,2013)	Single machine	>1	>1	Heterogonous fleet
(Karimi and Davoudpour, 2015)	Serial machine	>1	>1	

IV. Third trend : divide to conquer….



- A_{ij} The delivery time of a vehicle at the node v_i ;
- B_{ij} The beginning of service at the node v_i ;
- S_{ij} The departure time of a vehicle at the node i with $S_{ij} = B_{ij} + \partial_{ij}$ where ∂_{ij} is a service duration ;
- W_{ij} The waiting time before beginning of service at node v_i , $W_i = B_i - A_i$;

I. The problem description : batch job-shop

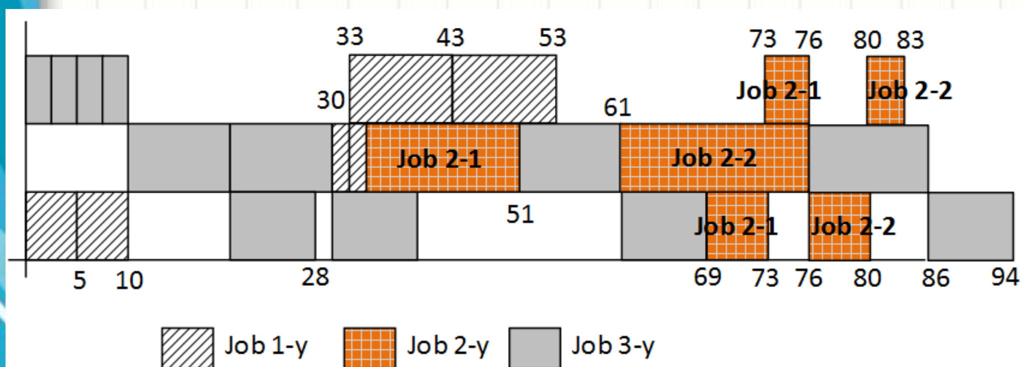
- 3 jobs, 3 machines, 2 vehicles

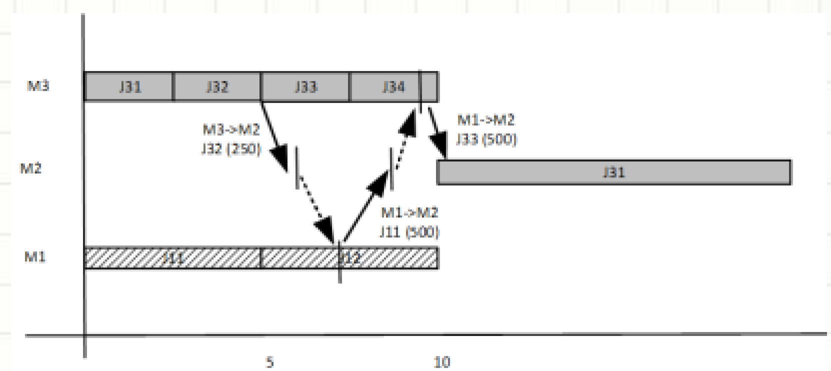
	Batch size	Lot size	Operation 1	Operation 2	Operation 3
Job 1	1000	500	$\mu_{11}=1$; $t_{11}=10$	$\mu_{12}=2$; $t_{12}=6$	$\mu_{13}=3$; $t_{13}=20$
Job 2	600	300	$\mu_{21}=2$; $t_{21}=30$	$\mu_{22}=1$; $t_{22}=8$	$\mu_{23}=3$; $t_{23}=6$
Job 3	1000	250	$\mu_{31}=3$; $t_{31}=20$	$\mu_{32}=2$; $t_{32}=40$	$\mu_{33}=1$; $t_{33}=32$

	Lot size	Operation 1	Operation 2	Operation 3
Job 1-1	500	$\mu_{11}=1$; $t_{11}=5$	$\mu_{12}=2$; $t_{12}=3$	$\mu_{13}=3$; $t_{13}=10$
Job 1-2	500	$\mu_{11}=1$; $t_{11}=5$	$\mu_{12}=2$; $t_{12}=3$	$\mu_{13}=3$; $t_{13}=5$
Job 2-1	300	$\mu_{21}=2$; $t_{21}=15$	$\mu_{22}=1$; $t_{22}=4$	$\mu_{23}=3$; $t_{23}=3$
Job 2-2	300	$\mu_{21}=2$; $t_{21}=15$	$\mu_{22}=1$; $t_{22}=4$	$\mu_{23}=3$; $t_{23}=3$
Job 3-1	250	$\mu_{31}=3$; $t_{31}=5$	$\mu_{32}=2$; $t_{32}=10$	$\mu_{33}=1$; $t_{33}=8$
Job 3-2	250	$\mu_{31}=3$; $t_{31}=5$	$\mu_{32}=2$; $t_{32}=10$	$\mu_{33}=1$; $t_{33}=8$
Job 3-3	250	$\mu_{31}=3$; $t_{31}=5$	$\mu_{32}=2$; $t_{32}=10$	$\mu_{33}=1$; $t_{33}=8$
Job 3-4	250	$\mu_{31}=3$; $t_{31}=5$	$\mu_{32}=2$; $t_{32}=10$	$\mu_{33}=1$; $t_{33}=8$

I. The problem description : batch job-shop

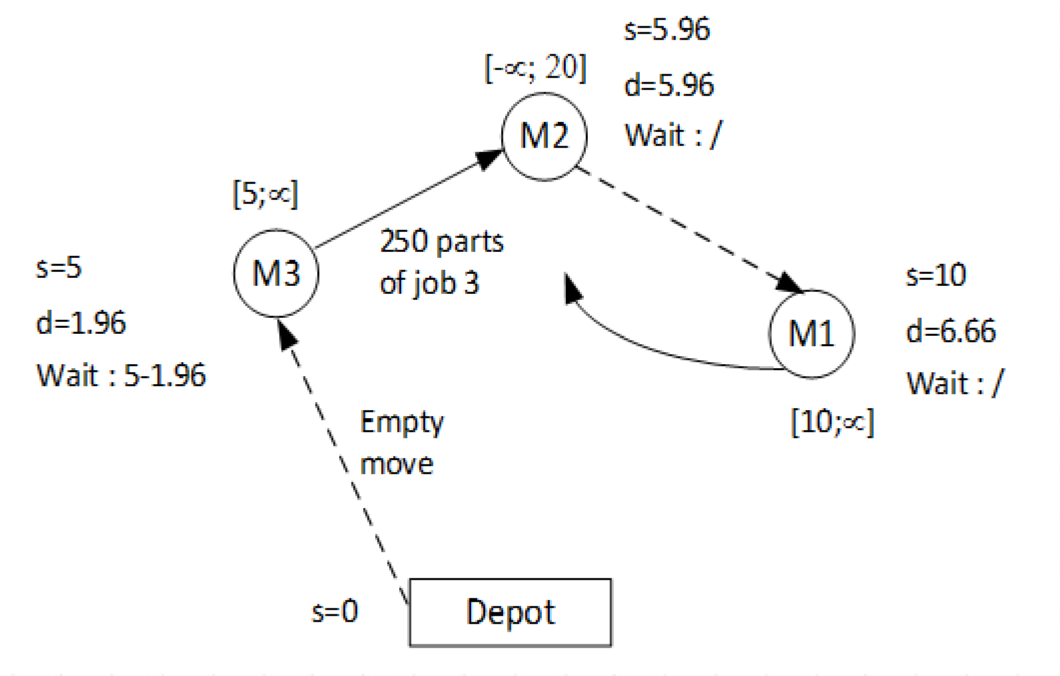
- A two parts solution



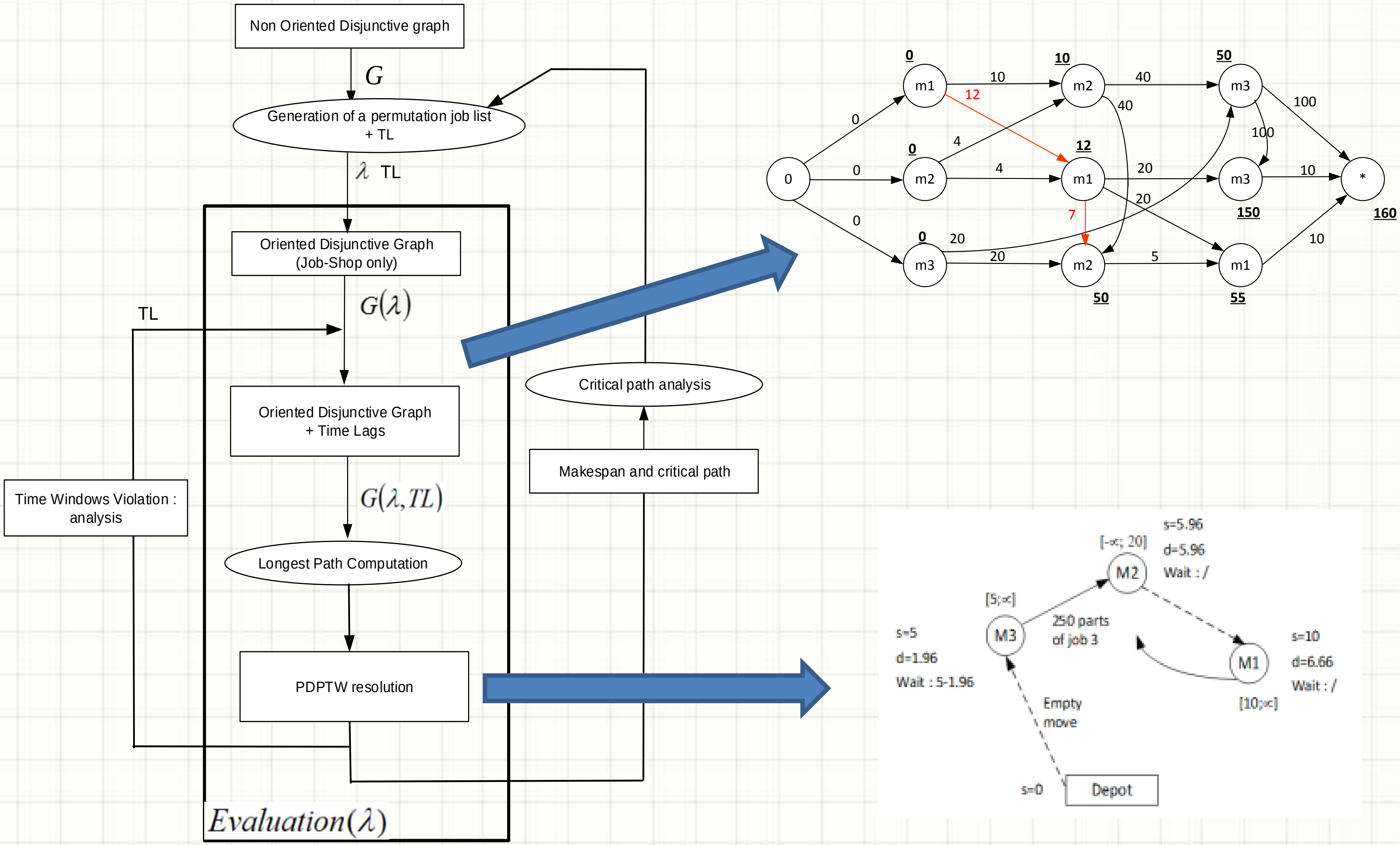


IV. Third trend : divide to conquer….

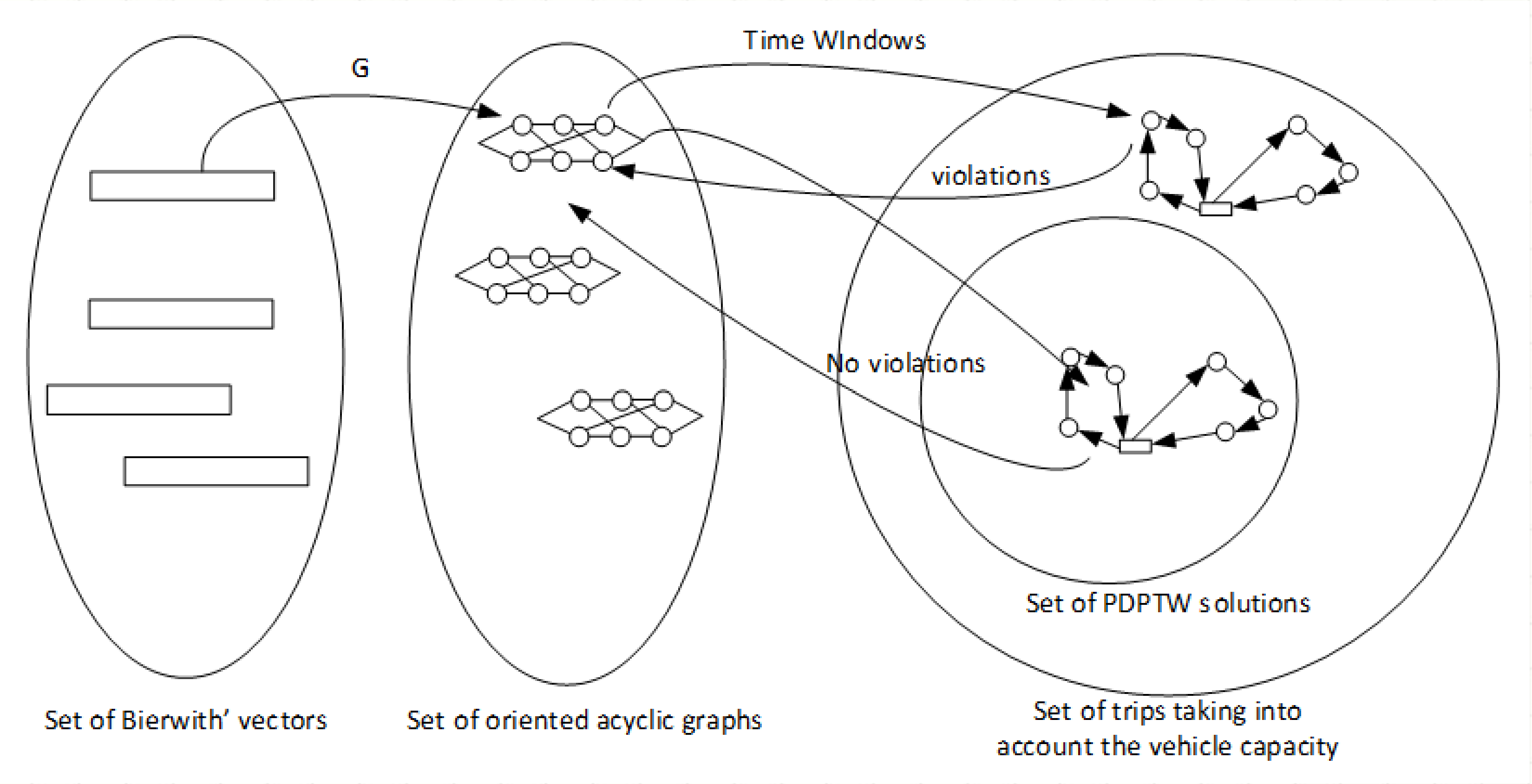
- A two parts solution



IV. Third trend : divide to conquer….



IV. Third trend : divide to conquer….



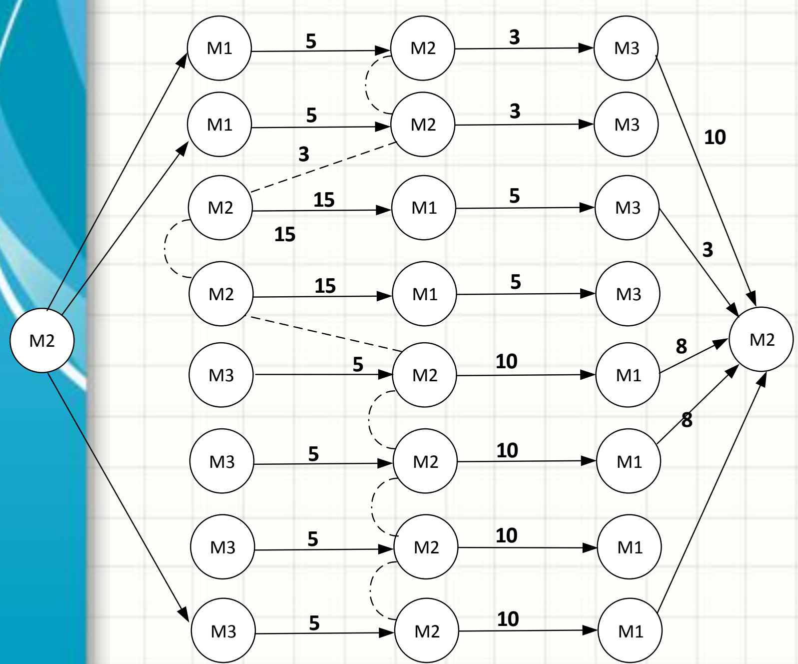
IV. Third trend : divide to conquer….

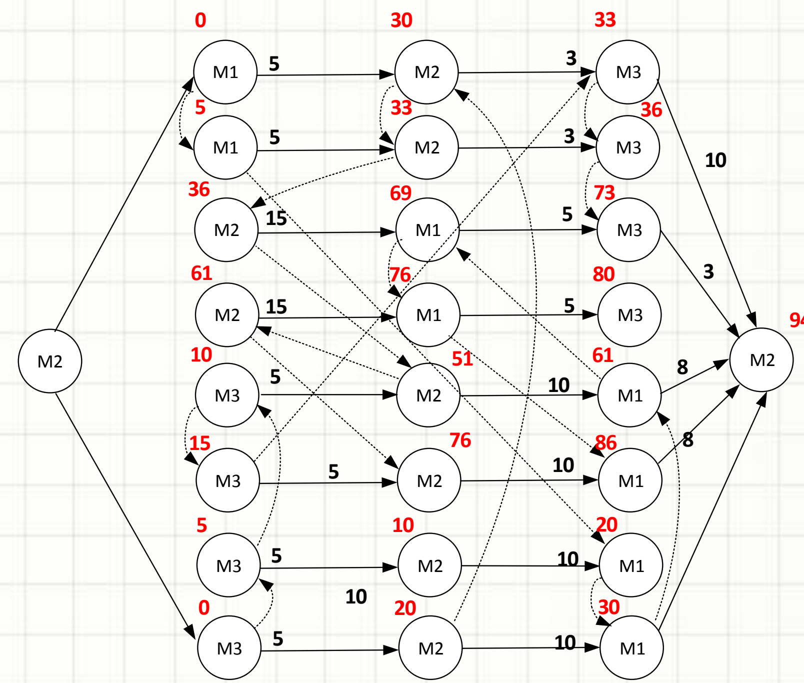
Algorithm 2. Evaluation of one solution

```
procedure Evaluate_Bierwith_Sequence
  input parameters
    λ: Bierwith' sequence
  output parameters
    (S,R) : the scheduling/routing solution
  local parameters
    TL_ij : time-lag min inserted in the disjunctive graph
    ES_ij: earliest starting time in the scheduling solution
    EF_ij: earliest starting time in the scheduling solution
    P_ij: father array for shortest path
    (l_ij,e_ij) : time windows definition
  global parameters
    n'_i : number of parts to service for job i (batch size)
    d_ij : distance between machine i and j
    imax: maximal number of attemps
begin
   //Part 1: Initialization
   ∀i∀j TL_ij := 0
   (ES_ij,EF_ij,P_ij) := Evaluate_Job_Shop(λ,TL)
   S:=Set_scheduling_solution(ES_ij,EF_ij)
   (l_ij,e_ij) := Create_Constraints_for_Routing(ES_ij , EF_ij )
   (γ,A_ij,B_ij,D_ij,W_ij) := Solve_Routing((l_ij,e_ij))
    R:=Set_routing_solution(A_ij,B_ij,D_ij,W_ij)
   Total_Violation := check_constraints(A_ij,B_ij,D_ij,W_ij)
   //Part 2: iterative evaluation
   while ((i<imax) and (Total_Violation≠0)) do
    (l_ij,e_ij) := Create_Constraints_for_Routing(ES_ij , EF_ij )
    (γ,A_ij,B_ij,D_ij,W_ij) := Update_Routing(γ,(l_ij,e_ij))
     R:=Set_routing_solution (A_ij,B_ij,D_ij,W_ij)
     Total_Violation := check_constraints(A_ij,B_ij,D_ij,W_ij)
     i++;
     if (Total_Violation<delta) then
        (γ,A_ij,B_ij,D_ij,W_ij) := Local_Search(γ,(l_ij,e_ij))
        Total_Violation := check_constraints(A_ij,B_ij,D_ij,W_ij)
     endif
     if (Total_Violation≠0) then
       (TL_ij):=Create_Constraints_for_Scheduling(A_ij,B_ij,D_ij,W_ij)
     endif
   End while
   return (S, R);
 end
```

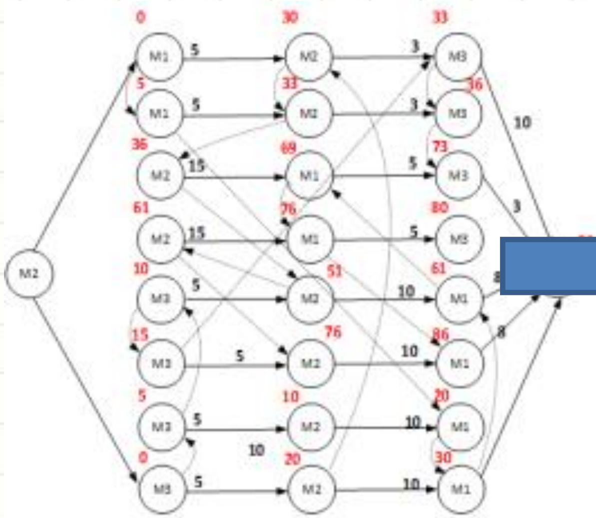
IV. Third trend : divide to conquer….

8	7	5	7	6	1	8	1	2	7	2	8	3	1	2	5	5	4	3	4	3	4	6	6
m3	**m3**	**m3**	**m2**	**m3**	**m1**	**m2**																	

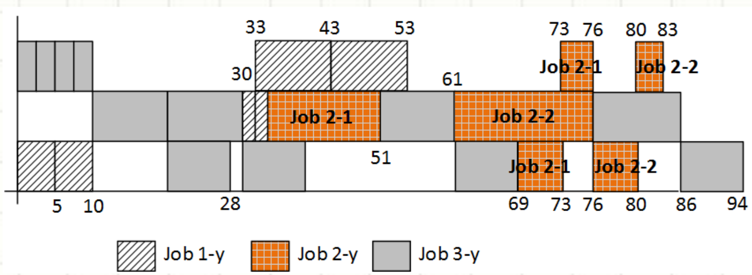




IV. Third trend : divide to conquer….

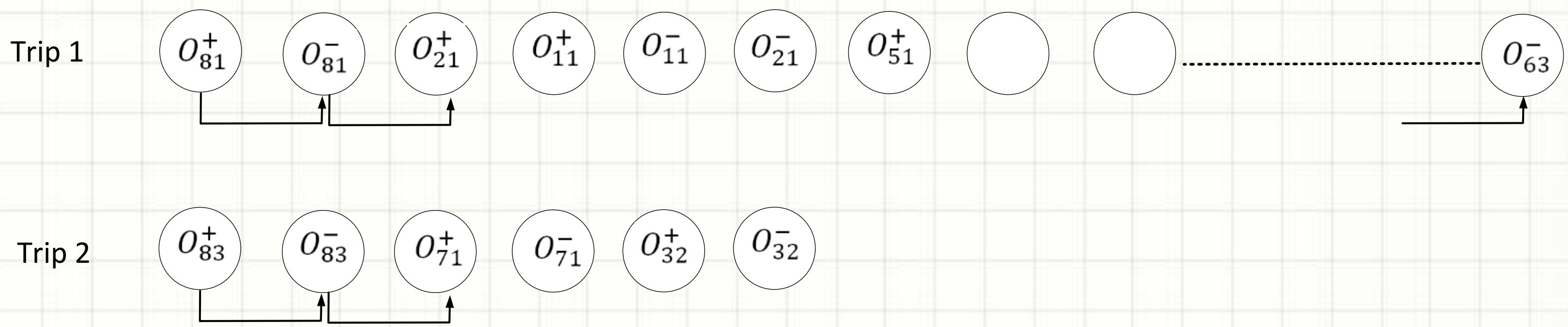


	Pick up node	Time Windows	Volume	Delivery Node	Time Windows
Job 1-1	M1	[5; ∞]	500	M2	[-∞; 30]
	M2	[33; ∞]	500	M3	[-∞; 33]
Job 1-2	M1	[10; ∞]	500	M2	[-∞; 33]
	M2	[36; ∞]	500	M3	[-∞; 43]
Job 2-1	M2	[51; ∞]	300	M1	[-∞; 69]
	M1	[73; ∞]	300	M3	[-∞; 73]
Job 2-2	M2	[76; ∞]	300	M1	[-∞; 76]
	M1	[80; ∞]	300	M3	[-∞; 80]
Job 3-1	M3	[15; ∞]	250	M2	[-∞; 51]
	M2	[61; ∞]	250	M1	[-∞; 61]
Job 3-2	M3	[20; ∞]	250	M2	[-∞; 76]
	M2	[81; ∞]	250	M1	[-∞; 86]
Job 3-3	M3	[10; ∞]	250	M2	[-∞; 10]
	M2	[20; ∞]	250	M1	[-∞; 20]
Job 3-4	M3	[5; ∞]	250	M2	[-∞; 20]
	M2	[30; ∞]	250	M1	[-∞; 30]



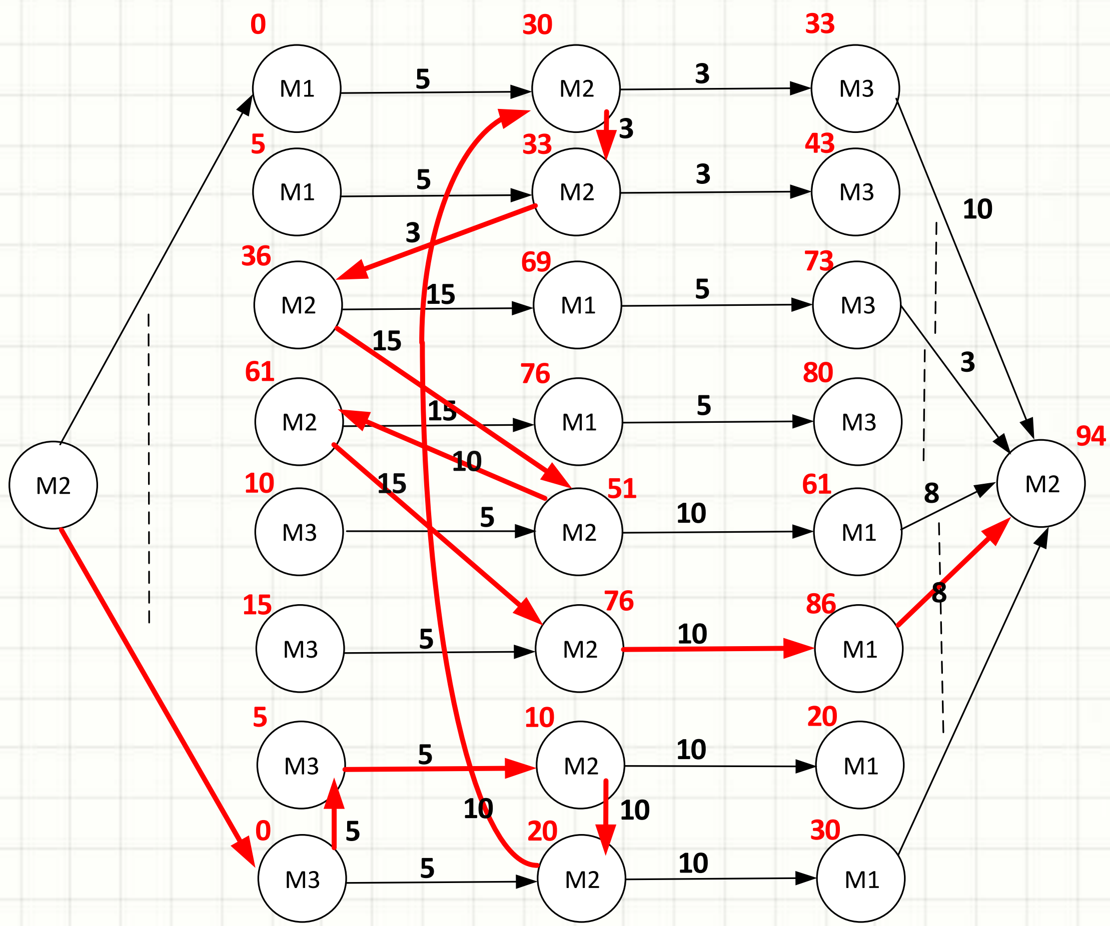
IV. Third trend : divide to conquer….

- Resolution of the PDPTW



See (Cordeau and Laporte, 2005)

IV. Third trend : divide to conquer….



Use the longest path in 2 ways…….

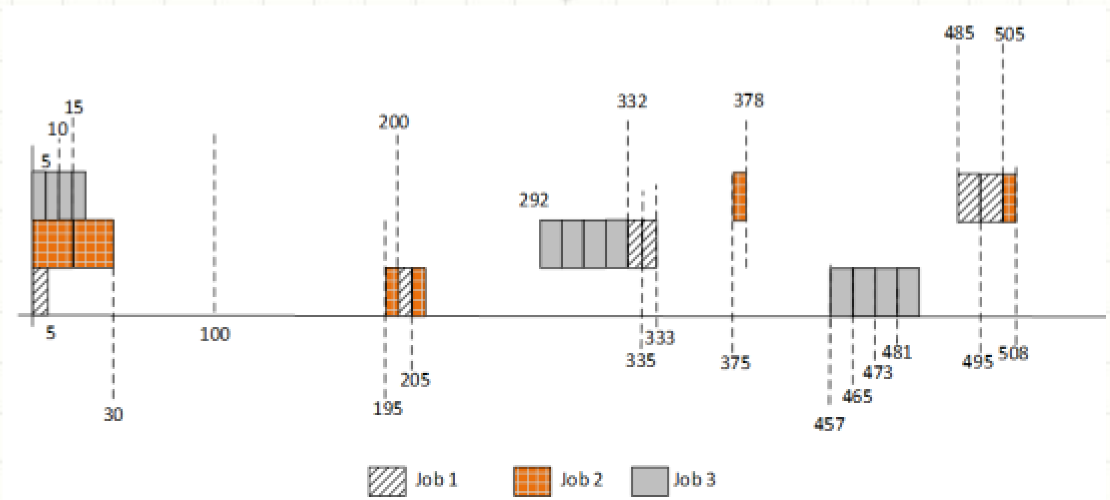
IV. Third trend : divide to conquer….

- Resolution of the PDPTW

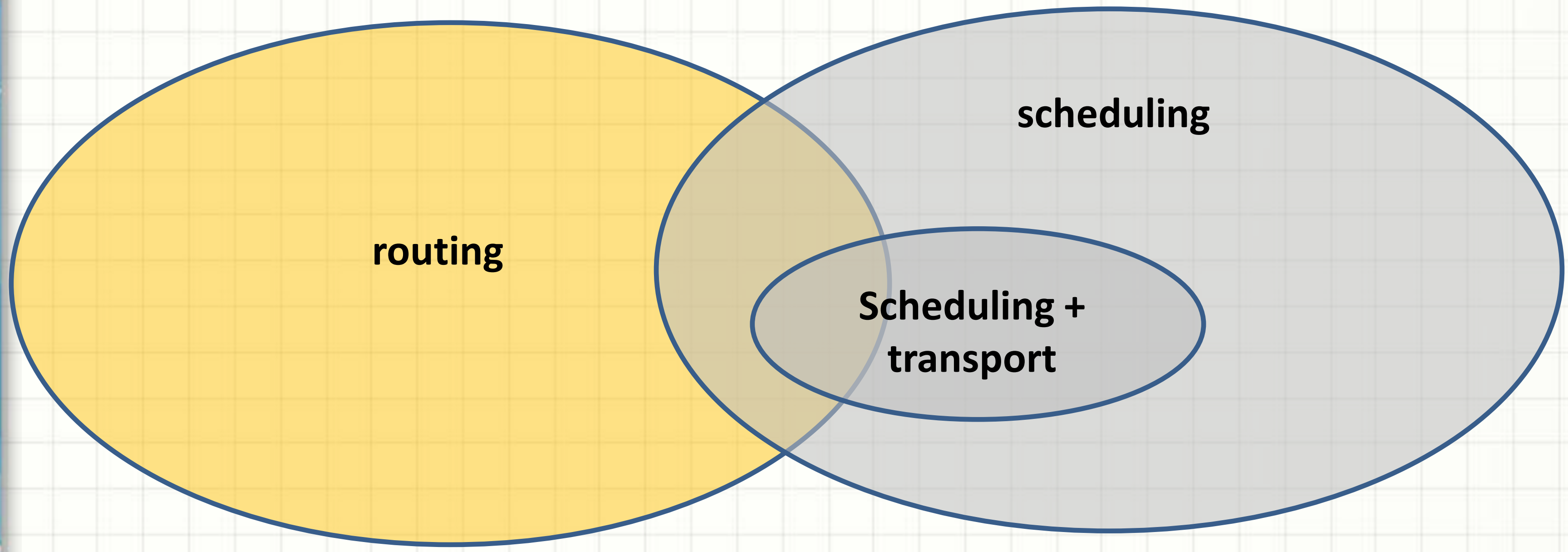
	Machine	Type of operation	Time Windows	Volume	Delivery time A_{ij}	Beginning of service B_{ij}	Departure time S_{ij}	Waiting time W_{ij}	Constraint violation
	Depot								
Job 3-4	M3	pickup	[5; ∞]	+250	1.96	5.00	5.00	3.04	0.00
Job 3-4	M2	delivery	[-∞; 20]	-250	5.97	5.97	5.97	0.00	0.00
Job 1-2	M1	pickup	[10; ∞]	+500	6.66	10.00	10.00	3.34	0.00
Job 1-2	M1	pickup	[5; ∞]	+500	10.00	10.00	10.00	0.00	0.00
Job 1-2	M2	delivery	[-∞; 30]	-500	10.69	10.69	10.69	0.00	0.00
Job 1-2	M2	delivery	[-∞; 33]	-500	10.69	10.69	10.69	0.00	0.00
Job 3-1	M3	pickup	[15; ∞]	+250	11.66	15.00	15.00	3.34	0.00
Job 3-1	M2	delivery	[-∞; 51]	-250	15.97	15.97	15.97	0.00	0.00
Job 3-3	M2	pickup	[20; ∞]	+250	15.97	15.97	15.97	0.00	0.00
Job 3-3	M1	delivery	[-∞; 20]	-250	20.69	20.69	20.69	0.00	0.69
Job 1-1	M2	pickup	[33; ∞]	+500	21.38	33.00	33.00	11.62	0.00
Job 1-1	M3	delivery	[-∞; 33]	-500	33.97	33.97	33.97	0.00	0.97
Job 3-2	M3	pickup	[20; ∞]	+250	33.97	33.97	33.97	0.00	0.00
Job 3-2	M2	delivery	[-∞; 76]	-250	34.94	34.94	34.94	0.00	0.00
Job 1-2	M2	pickup	[36; ∞]	+500	34.94	34.94	34.94	0.00	0.00
Job 1-2	M3	delivery	[-∞; 43]	-500	36.97	36.97	36.97	0.00	0.00
Job 2-1	M2	pickup	[51; ∞]	+300	37.94	51.00	51.00	13.06	0.00
Job 2-2	M1	delivery	[-∞; 69]	-300	51.69	51.69	51.69	0.00	0.00
Job 3-1	M2	pickup	[61; ∞]	+500	52.38	61.00	61.00	8.62	0.00
Job 3-1	M1	delivery	[- ∞;61]	+250	61.69	61.69	61.69	0.00	0.69
Job 2-2	M2	pickup	[76; ∞]	+300	62.38	76.00	76.00	13.62	0.00
Job 2-2	M1	delivery	[-∞; 76]	-300	76.69	76.69	76.69	0.00	0.69
Job 2-2	M1	pickup	[80; ∞]	+300	76.69	80.00	80.00	3.31	0.00
Job 2-2	M3	delivery	[-∞; 80]	-300	81.28	81.28	81.28	0.00	1.28
Job 3-2	M2	pickup	[81; ∞]	+250	82.25	82.25	82.25	0.00	0.00
Job 3-2	M1	delivery	[-∞; 86]	-250	86.69	/	/	/	/

IV. Third trend : divide to conquer….

		Problem with batch size		Problem with lot size			Solution		
	cv	Nb job	Nb machine	Nb jobs	Nb machine	Total number of op. to Schedule	Cmax	T*	TT
JS_1	0.01	3	3	8	3	24	85	<1	1
JS_2	0.1	3	3	8	3	24	96	<1	1
JS_3	1	3	3	8	3	24	508	<1	2
JS_4	0.01	8	3	20	3	[illegible]	187	<1	12
JS_5	0.1	8	3	20	3	60	197	<1	28
JS_6	1	8	3	20	3	60	626	<1	50
JS_7	0.01	3	5	8	5	40	96	<1	7
JS_8	0.1	3	5	8	5	40	182	<1	7
JS_9	1	3	5	8	5	40	1771	<1	7



Conclusion



- Scheduling with transport
- Scheduling with routing