Scheduling Oriented Improvement of Kanban Card Resupplying In Logistic Systems at Automotive Industry

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ABSTRACT
Kanban is a pull production system that is very useful in Automotive Production Industry. Logistic systems in automotive industry, tries to apply the best system of logistic to supply the production lines and stations by bringing the parts and all requirements in best quantity and timing in order to come off the JIT specifications. In this article we try to exert a sequencing concept in Kanban card rotations to minimize the line shortage of parts causes stop in production procedure. Minimizing the Resupplying Cycle Times in production lines lead to less quantity of shortages that's one important purpose of lean production. We introduce an appropriate sequencing and scheduling objective function related to Kanban card rotations to minimize some criteria affects the line inventories and causes some improvements on probable shortages. To know the weights of each job we used the Shannon's Entropy method combined with SAW decision making method and we solved the sequencing and scheduling problem with total weighted tardiness objective function, using VNS heuristic method. To show the improvement and positive effects of our method we presented a real world case study and applied our model to a real world case study to observe the improvements in backlogs and tardiness in Kanban resupplying. Finally we presented the achieved improvements.

General Terms
Sequencing and scheduling, Shannon's Entropy, Pull production systems.

Keywords
Kanban, Just-in-Time, Production Systems, Scheduling, WSPT

1. INTRODUCTION
Kanban is originated from the Toyota Production Systems (TPS) which its purpose is to control the inventory levels, raw materials and supply the component parts. Kanban cards are key parts of a Kanban system that uses cards as a signal that determines need to move materials inside a production facility or move materials from a supplier to the production facilities. Gravels et al. (1995) [1] , defines the kanban as Material Flow Control Mechanism that controls the appropriate quantity and time of production of necessary products. Framinan et al. (2006) [2] presented a card controlling procedure for constant work in process systems.Pettersen and Segerstedt (2009) [3] evaluated the differences between Kanban and CONWIP with a simulation study over a small supply chain with restricted amount of work-in-process (WIP).Junior and Filho (2010) [4] searched variations of the kanban system and presented a review and classified the all kind of kanban in literature. Sipper and Bulfin (1997) [5] presented the kanban system with two communication signals or dual card kanban system. Rabbani et al.(2009) [6] evaluated the multi-stage supply chain system, controlled by kanban system .Tardif and Maaseidvaag (2001) [7], Assumed kanban with unstable demand and considered an adaptive kanban as an alternative to material flow control. Chaudhury and Whinston (1990) [8] proposed an auto adaptive kanban production system which is a similar to kanban system in its structure.Yang and Zhang (2009) [9] studied the performance and parameter design optimization of a Kanban system in a multi-stage and mixed-model assembly line without stockouts. Mohanty et al. (2003) [10] presented a reconfigurable kanban system with lower inventory costs. Andijani (1998) [11] presented a multi-criterion approach for kanban allocations in a single-item, multi-stage, serial production system.Shahabudeen and Sivakumar (2008) [12] presented an algorithm for the design of single-stage adaptive kanban system because he considered that the traditional kanban system with fixed quantity of cards work disappointing in unstable environments.Turner et al.(2012) [13] proposed a general case for solving the problem of Effective application of systems engineering in rapid response environments by combining a services approach with a kanban-based scheduling system to systems engineering. Al-Tahat and Mukattash (2006) [14] tried to create a scheme for production control in Kanban-based JIT environment and developed a synchronized mechanism for a single stage and single product kanban in production line. Hou and Hu (2011) [15] developed an integrated MOGA approach that determined the Pareto-optimal kanban size for Just-in-time systems considering that the kanban size and determine the inventory level of WIP or purchasing parts and they wanted to define the feasible kanban size and number.

What we want to prove in this article is how changing the sequences of each kanban card may lead to less quantity in probable shortages originated of variety problems and erratic delays in feeding and supplying procedure. We must choose an appropriate scheduling objective function to minimize a parameter is very impressive on kanban resupplying cycle time. In this text we will show that this problem is a single machine scheduling process minimize the total weighted tardiness for each parts and kanban card.

Wang et al. (2010) [16] considered the single machine scheduling and sequencing problems with sum of processing times that are based learning effect. They used the weighted processing time rule and earliest due date rule as heuristics.

Li et al. (2011) [17] investigated how to sequence jobs with fuzzy processing times and predict their due dates on a single machine such that the total weighted possibilistic mean value of the weighted earliness-tardiness costs is minimized. Cheng and Lio (2010) [18] proposed a coordinated scheduling of customer orders (CSCO) system, with the purpose of improving customer order flow time for the order-based

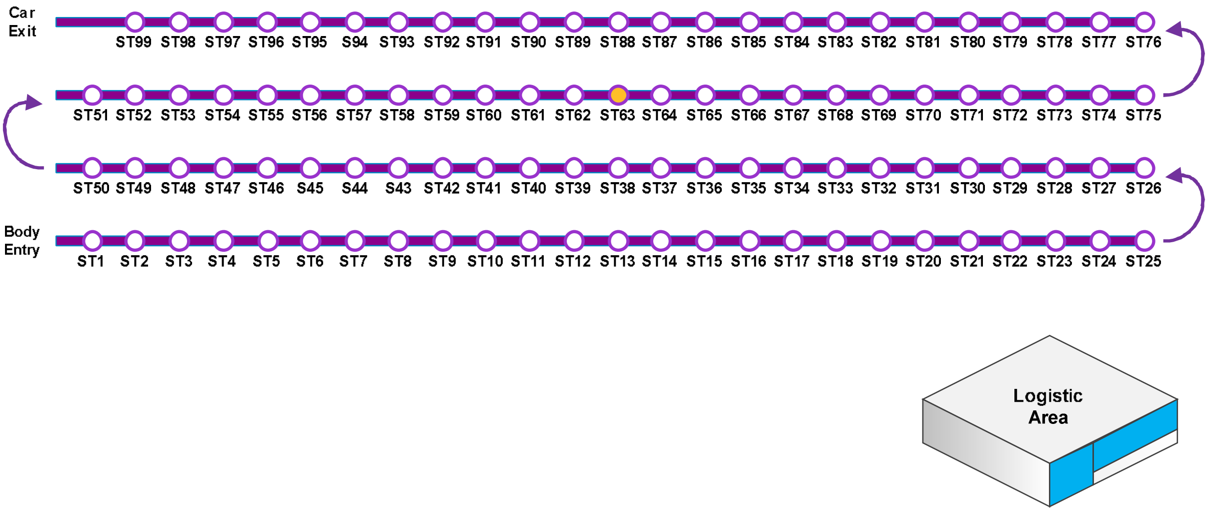


Fig 1: Station sequencing and layout in production area

production system. Erel and Ghosh (2007) [19] generated the algorithms and complexity of customer order scheduling on single machine with family setup times. Sheng and Liu (2009) [20] worked on improving the delivery efficiency of the customer order scheduling problem in a job shop. Wang and Cheng (2007) [21] considered the problem of scheduling customer orders on multiple facilities to minimize the weighted order completion time. Chou (2009) [22] presented an experienced learning genetic algorithm to solve the single machine total weighted tardiness scheduling problem. Wang (2009) [23] developed a population based variable neighborhood search (PVNS) for the single machine total weighted tardiness problem and compared that with the basic VNS. We use VNS algorithm because it is a simple general heuristic algorithm help us to show the objective function alterations.

We want to prove the improvements and we don't need solve the problem in global optimum so even if the model has solved in local optimum, it can be a useful solution helps us to understand the improvement in objective function. Taherian et al. (2011) [24] presented a scheduling based backlog reduction by minimizing the total tardiness in constant work in process systems.

In this article we will introduce the kanban resupplying cycle time and explain our model to improve the kanban resupplying cycle time and backlogs originated of resupplying tardiness using sequencing and scheduling objective function in Section 2. In section 3 we presented a weighting method to calculate the weight or importance of each Kanban Card and finally in section 4 we applied our model to a real world case study and solved the problem using VNS algorithm has been programmed via Delphi Programming Language and the results have been mentioned.

1. MODEL DESCRIPTION

In this article we assume an automotive factory assembly line via definite stations of work. The main body enters to first station and some parts available in the store of station 1 will be assembled to the main body and then the body moves the present station to the next and the assembly process continues through the stations one by one, respectively. The automotive assembly line follows the flow shop production and start from first station and move through next stations respectively without any backflow. The kanban is a pull system that has a broad usage in all manufacturing sections. For example kanban can work as a pull system in relationship between customers, manufacturer and supplier in a supply chain. Also we can use it in a production line that brings about a pull system between downward and upward stations. In other form and in logistic systems we can consider a pull relationship between the production line stations and logistic areas to feed required parts under JIT considerations. In this paper we study the kanban in logistic usage to feed the parts in best quantities and timing and develop a method to minimize unpredictable shortages in production lines. There are some allocated jobs to assemble on main body of cars within some seriate stations. The body movement starts at first station and it continues to be completed gradually during stations and exits from last station as a complete car. The example for stations layouts has shown in Fig1.

In each station, some parts are assembled to the output of former station so what is very important in logistic activity is to supply the parts to their prepared palaces and locations in racks in appropriate quantity and time no facing to any shortage. Because the stations are blow by blow or in series thus if one station faces any backlog, all of former stations will be impressed and production line might be stopped. The stations are as a corridor wherever part pallets are located in both left and right sides of its station aisle as it's shown in Fig2. Each part is known with its kanban cards that determine the quantity and timing of each material feeding.

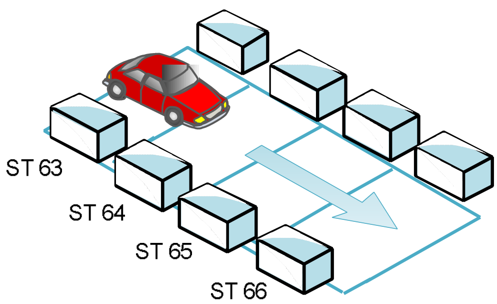


Fig 2: Racks are located in right and left hands of each station aisle

There are two systems that a kanban can implement it in feeding procedures: Fixed-order-size (FOS) and Fixed-interval-system (FIS). The differences between two mentioned systems are not the purpose of our paper so we assume kanban cart rotation using FOS system. Kanban Cards are used as a sign that specify needs of some parts or materials. Because in many manufacturing industries such as automotive, the variety and quantity of parts can be high, lots of Cards can be released and putted in supplying status at the same time or a very small time interval. Preparing parts takes variable time related to their type, weight, quantity and etc. so we can consider the Kanban Cards as some jobs with their process time (provision time). We can consider the logistic unit as a single machine provides the requested parts signed by Kanban Cards. So we can model the kanban card rotations as a scheduling and sequencing model. To find the objective function and making some improvements, at first, we have to introduce some Kanban calculation formulas:

D: Tact Time Rate
T: Cycle Time (Waiting time for resupplying)
α: Management Coefficient
C: Standard Pallet Capacity

The number of Kanban Pallets (N) is calculated as following:

$$N = \frac{D.T\ (1+\alpha)}{C} \qquad (1)$$

As it has shown in Formula 1, α is a coefficient that effects on safety stock quantities and is multiplied to the cycle time. This coefficient makes the cycle time greater. It shows the important role of Cycle Time alteration in Kanban Calculations.

Assume that there are many varieties and quantity of parts must be assembled together to make one unit of final product. For example in automotive industry it can exist above two thousands of different type of parts, so it is possible to be released many kanban cards that must be resupplied in a short duration of time. It makes one sequencing and scheduling problem. Minimizing the Cycle time prevent any probable shortage in production lines. Changing the sequences of jobs (kanban Cards) can make improvement in some scheduling objective functions. We calculate the suitable number of kanban pallets considering that the lead time required to resupplying the parts are equal to $\mathrm{T} \times (1+\alpha)$. The shortage happens if the real time for resupplying the kanban takes more than $\mathrm{T} \times (1+\alpha)$. In this form, the shortages causes interruption in production line, so what is main cause of this occurrence is the tardiness of resupplying procedure. The tardiness is the difference between the real supply time and forecasted time. So if we look this problem as a scheduling model, we can consider the forecasted resupplying time $(\mathrm{T} \times (1+\alpha)$ as a due time and supplying times as process times. In this case, all kanban cards are presumed as jobs. We choose the total weighted tardiness to minimize as objective function. Because the weights and importance of each part can be different to others so we can exert a weighting method to scheduling model and alter our objective function to average weighted Flow-time. To be more clear an example has represented. To be easier, we assume all weights for this example equal to 1. Table 1, shows the kanban cards as jobs and their sequencing parameters. Calculating the Supply Time and Due Time according to the mentioned formula in table 1 and 2, the Tardiness would be calculated by subtracting the Supply time from the Due Time. The Positive Tardiness happens when Due time is less than the Supply Time and otherwise the Tardiness is equal to zero. Shortages caused by the tardiness are related to the Tact Time Rate and its quantity equals the Tardiness value multiplied by Tact Time Rate.

Table 1. Example 1, Kanban cards and scheduling parameters information in original sequence

Kanban released	Part numbers	Part Names	Supply Time (Min)	Due Time = $\mathrm{T} \times (1+\alpha)$	Tardiness	Shortages
1	00042681940E	bracket	7	6	1	D
2	00077043860E	lock	12	19	0	0
3	00464491910E	Clip	3	21	1	D
4	00824568640E	Insulation	5	45	0	0
5	00500001610E	Screw	20	42	5	5D

As it has shown in Table 1, if the released kanban are resupplied via 1 worker, we can see 7 minutes of tardiness as resupplying time or 7.D units of shortages. Now we change the sequencing of jobs via changing the sequence of 4th and 5th kanban card.

Table 2. Example 1, Kanban cards and scheduling parameters information in custom sequence

Kanban released	Part numbers	Part Names	Supply Time (Min)	Due Time = $\mathrm{T} \times (1+\alpha)$	Tardiness	Shortages
1	00042681940E	bracket	7	6	1	D
2	00077043860E	lock	12	19	0	0
3	00464491910E	Clip	3	21	1	D
5	00500001610E	Screw	20	42	0	0
4	00824568640E	Insulation	5	45	2	2D

As the new result from custom sequence of jobs we found in new sequence of jobs, we have only 4 unit of time as tardiness so we made 3.D unit of thriftiness in shortages. It shows that if we continue to rearrange the jobs we can be hopeful more diminishing in shortages and tardiness. The comparison between completion time and due date for each Card has shown in Fig 3 and Fig 4.

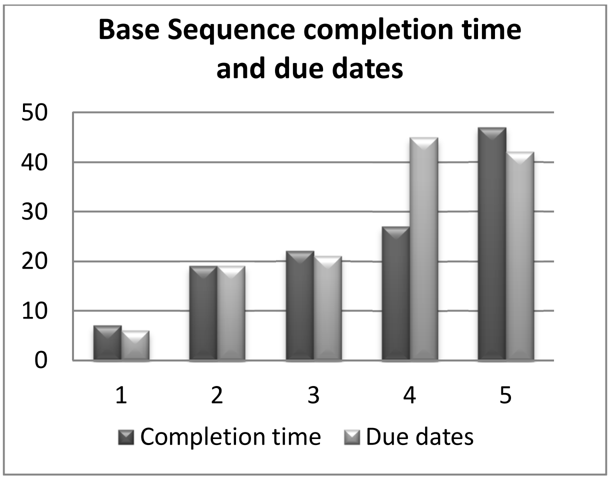


Fig 3: Primary Sequence Completion time and due dates

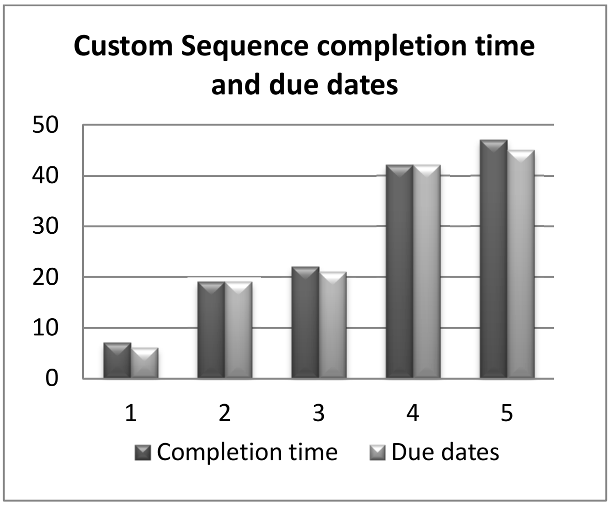


Fig 4: Custom Sequence Completion time and due dates

3. WEIGHT CALCULATION

As we mentioned in last part, the emphasis of each job is not equal so they have different types of weight thus we should calculate the weights for alternatives to use them as Tardiness Weights. In decision making techniques, we usually calculate the weights of criteria and according to the yielded weights; we sort the alternatives and make new decision. In this problem, we need the importance of each order that is our alternative. We mix Shannon's Entropy weighting method with SAW technique to calculate the appropriate weights. Each kanban card can be different to another within some criteria such requirement urgency, weight and etc.

Table 3. Decision Making Matrix

DM MATRIX	Criterion 1	Criterion 2	...	Criterion n
Alt 1	x_{11}	x_{12}	...	x_{1n}
Alt 2	x_{21}	x_{22}	...	x_{2n}
⋮	⋮	⋮	⋮	x_{n1}
Alt m	x_{m1}	x_{m2}	...	x_{mn}
weights	w_1	w_2	...	w_n

To calculate the weights for each item, it should be followed at following formulas and procedure:

a. Normalize the decision matrix like following formula

Set $p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}$ $\quad j = 1, \ldots, n, \quad i = 1, \ldots, m$ (2)

b. Compute entropy h_j as $h_j = -h_0 \sum_{i=1}^{m} p_{ij} . \ln p_{ij}$ (3)

Where h_0 is the entropy constant and is equal to $(\mathrm{Ln}\ m)^{-1}$ and $p_{ij}.\ln p_{ij}$ is defined as 0 if $p_{ij} = 0$.

c. Set $d_j = 1 - h_j, \quad j = 1, \ldots, n$ as the degree of diversification. (4)

d. Set $w_j = \frac{d_j}{\sum_{s=1}^{n} d_s}, \quad j = 1, \ldots, n$ as the degree of importance of attribute i. (5)

e. The values for all alternatives can be calculated as follow:

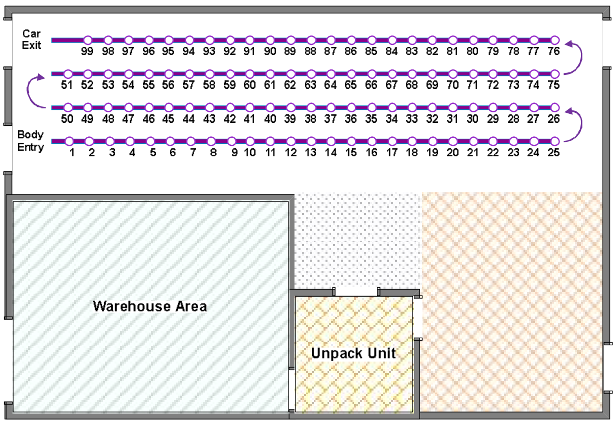
$$A_i = \sum_{j=1}^{n} w_j . x_{ij} \tag{6}$$

f. All the weights for alternatives can be calculated as next formula:

$$w_i = \frac{A_i}{\sum_{i=1}^{m} A_i} \tag{7}$$

4. CASE STUDY

To apply our method to a real world case study, we study the BonroCo Automotive Factory production line that produces Fiat Siena. BonroCo is a company in southern countryside part of Saveh City in Iran. It is located 7 kilometers far from the central part of the city. This company makes the Fiat Cars; just Siena model within a process includes 99 production line stations. The painted body entered to station 1 in trim-line and the parts are assembled to the main body and the cars are being completed gradually and exeunt the last station. The parts are carried from Fiat Company in Italy and Tofas Company in Turkey to Saveh in cases. The cases are kept and maintained in warehouse and are waited until the unpack list is issued. When the unpack list is prepared, all the parts required are identified in cases and are carried to the Unpack Unit. After unpacking the cases, the parts are labeled and counted and are placed in appropriate pallets and are put to Logistic Area racks by supply-feeding unit. This unit receives the parts and organizes them in their predefined locations and waits for part requests. Part requests, are the released kanban cart put in supply-box.

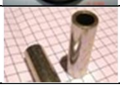


There are 4 teams with 3 members that have responsibility of supplying and feeding the parts to the stations according the Kanban System. One team for massive parts are just carried by lift trucks and three teams for other parts could be carried easily. The supply-Logistic Layout has shown in Fig 5.

The problem is that, in one moment or a little period of time, there are several released Kanban cards must be resupplied. As we mentioned former, we have 4 groups numbered 1 to 4, 3 people in groups that each group could only supply maximum 5 Card at one time. Group 4 is used just for massive parts needs lift truck to carry. Kanban cards are distributed to groups according to their size and weight. Finally there will be some Cards must resupplied in each group. As we mentioned in section 2 we saw that lateness in resupplying time increases the estimated standard resupplying time was equal to $T \times (1+\alpha)$ which leads to shortage in production line. So what we are going to do is minimizing the lateness of resupplying procedure using sequencing and scheduling method. On other hand, we want to show, changing the sequences of works leads to less average tardiness causes shortages.

We tried to collect the required data to show the result. We chose 40 samples of data of different days in two weeks. The weights are calculated by formula presented in section 3, and we used the VNS algorithms to solve the Total Weighted Tardiness objective function. We programmed the VNS algorithm and put our data as input and obtained the results.it this case we assume all weights equal to 1.

Table 4. Kanban cards and scheduling parameters information in primary sequence for group 1

Cards Allocated to Group 1								
Kanban released	Pic	Part Numbers	Station	Part Names	Supply Time (Min)	Due Time = $T \times (1+\alpha)$	Tardiness	Shortages
F0042		00130461110E	3RH	NUT M6	7	16	0	0
F0501		00130971900E	51LH	COLLAR	8	19	0	0
F1052		07353027430E	23LH	MIRROR LT	3	23	0	0
F1559		07354487590E	65RH	LOGO	5	18	4	4D
F0996		00517144960E	10LH	ABSORBER BUSHING	7	14	15	15D

In primary sequences of cards like F0042, F0501, F1052,F4559 and F0996, the total tardiness is equal to 19 thus total shortages in this sequence will be equal to 19D.After running the VNS by our computer program, the new sequencing has obtained with minimum total tardiness, F0042, F0996, F1559, F1052 and F0501. Results have shown in Table 5.

Table 5. Optimal sequences of cards with minimum total tardiness for group 1

Cards Allocated to Group 1							
Kanban released	Part Numbers	Station	Part Names	Supply Time (Min)	Due Time = $T \times (1+\alpha)$	Tardiness	Shortages
F0042	00130461110E	3RH	NUT M6	7	16	0	0
F0996	00517144960E	10LH	ABSORBER BUSHING	7	14	0	0
F1559	07354487590E	65RH	LOGO	5	18	1	D
F1052	07353027430E	23LH	MIRROR LT	3	23	0	0
F0501	00130971900E	51LH	COLLAR	8	19	11	11D

Fig 6: Optimal Sequences of orders

As we see, the new sequences of Cards made 8 unit diminutions in total tardiness make 8D unit diminutions in shortages. If we change this optimal sequence of Cards, total tardiness will increase anyway. You can see the optimal sequences of Cards in Fig 6. Because for group 2 & 3 we have the same method we only bring their results at final part, but because group 4 is for massive parts, so we will present the Cards and the sequencing result in Table 5 and Table 6 like we presented for group1.

Table 6. Kanban cards and scheduling parameters information in primary sequence for group 4

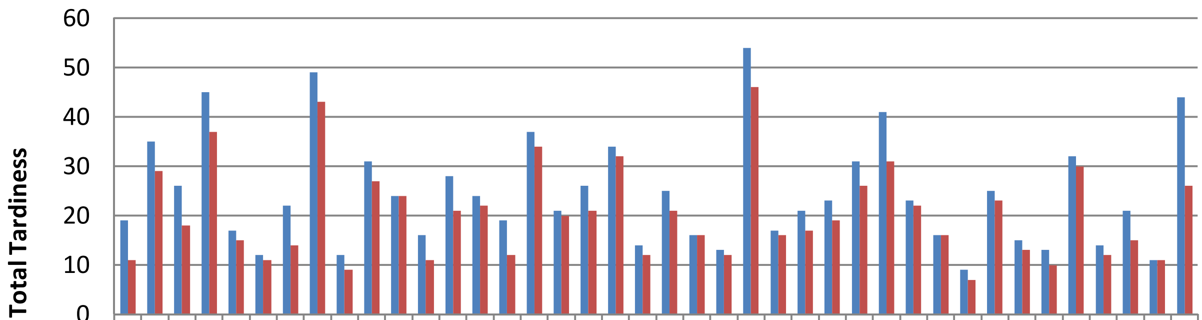
Cards Allocated to Group 4								
Kanban released	Pic	Part Numbers	Station	Part Names	Supply Time (Min)	Due Time = $T \times (1 + \alpha)$	Tardiness	Shortages
F1197		00517386620E	77RH	HEATED REAR WINDOW	16	36	0	0
F1135		07354079590E	83LH	REAR SEAT	14	41	0	0
F1039		00517377230E	22RH	RR. LAMP	20	49	1	D
F1175		00517921180E	70LH	COMPLETE TYRE	12	48	14	14D
F1090		07354082640E	86RH	RR. RT. DOOR PANEL	15	46	31	31D

In basic and primary sequences of Cards like F1197, F1135, F1039, F1175and F1090, the total tardiness is equal to 45 thus total shortages in this sequence will be equal to 45D.After rerunning the VNS, the new result with minimum total tardiness, F1135, F1197, F1090, F1175and F1039. Results have shown in Table 7 and changing the sequences of Cards will diminish total tardiness to 37 so the shortages will decrease within 8D units. Table 7 show the sequencing of Cards and calculation results after optimization.

Table 7. Optimal sequences of Cards with minimum total tardiness for group 4

Cards Allocated to Group 4							
Kanban released	Part Numbers	Station	Part Names	Supply Time (Min)	Due Time = $T \times (1 + \alpha)$	Tardiness	Shortages
F1135	07354079590E	83LH	REAR SEAT	14	41	0	0
F1197	00517386620E	77RH	HEATED REAR WINDOW	16	36	0	0
F1090	07354082640E	86RH	RR. RT. DOOR PANEL	15	46	0	0
F1175	00517921180E	70LH	COMPLETE TYRE	12	48	9	9D
F1039	00517377230E	22RH	RR. LAMP	20	49	28	28D

We chose 40 samples of data in different days. Each sample is related to one group and we tried to gather 4 samples, one for each group, in a day, so we have the data in a period of time in each day for all groups. We ran our Computer program on all samples of data and calculated the total tardiness and total reduction of shortage per group. Total tardiness calculated in both primary and optimal sequencing of all 40 samples is available in Fig 7.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Primary Seq	19	35	26	45	17	12	22	49	12	31	24	16	28	24	19	37	21	26	34	14	25	16	13	54	17	21	23	31	41	23	16	9	25	15	13	32	14	21	11	44
Optimal Seq	11	29	18	37	15	11	14	43	9	27	24	11	21	22	12	34	20	21	32	12	21	16	12	46	16	17	19	26	31	22	16	7	23	13	10	30	12	15	11	26

Fig 7: Total Tardiness Calculated in Primary and Optimal Sequence of Cards

Table 8. Tardiness Reduction Percent due to changing sequences of Cards, using VNS programming

Day		Group	Part Numbers					%Tardiness Reduction
1	Sat	1	00130461110E	00130971900E	07353027430E	07354487590E	00517144960E	42.1
		2	00044465460E	00467815390E	00076226060E	00156878010E	00076352330E	17.1
		3	00076877080E	00988122200E	00464016570E	00988124920E	00141441910E	30.8
		4	00517386620E	07354079590E	00517377230E	00988228680E	07354082640E	17.8
2	Sun	1	00144964010E	00145084870E	00145602870E	00143085240E	00464093170E	11.8
		2	00464231210E	00464205180E	00464190760E	00464187470E	00162871210E	8.3
		3	00464176830E	00464183800E	00464281570E	00464227650E	00464345840E	36.4
		4	00464190360E	00518209760E	00517386350E	00517377220E	00551864410E	12.2
3	Mon	1	00464255700E	00464359470E	00146313870E	00077463090E	00464093050E	25.0
		2	00464598700E	00517232640E	00104457210E	00517502080E	00465491140E	12.9
		3	00077398010E	00075685870E	00467847660E	00111907740E	00467366100E	0
		4	07352878000E	07353973680E	00988143940E	00467903990E	00464152100E	31.3
4	Tue	1	00126425240E	00551961910E	00517200700E	00551999590E	00157834070E	25.0
		2	00467827310E	00517075810E	00517821880E	00077967930E	00468301490E	8.3
		3	00465367330E	00465328550E	00126378040E	00116124240E	00551824600E	36.8
		4	00467922750E	00517712250E	00464108540E	07352961590E	07353757200E	8.1
5	Wed	1	00517029910E	00467640500E	00988126180E	00517556960E	00605766400E	4.8
		2	00126471240E	00464169600E	00517868300E	00044465460E	00111094900E	19.2
		3	00518087000E	00076478050E	00464804510E	00009949220E	00468346280E	5.9
		4	00468470560E	07353005820E	00517200700E	00517029910E	00077323540E	14.3
6	Sat	1	00467597100E	00517712250E	00517522420E	00464108540E	00517712250E	16.0
		2	00468272540E	00517747390E	00140594110E	07353597940E	00517721900E	0
		3	00551816320E	07353615670E	00988221290E	00162861240E	07353606700E	7.7
		4	00077323540E	07353627400E	00517915230E	00464363860E	07354050040E	14.8
7	Sun	1	00467586290E	00077140650E	07353164690E	00465446620E	00077648220E	5.9
		2	00518044880E	00517627560E	07353999070E	00077408820E	00468173740E	19.0
		3	00517160650E	00138374140E	00517356170E	00467584270E	00076766140E	17.4
		4	07354088530E	00464469110E	07353982520E	07354081910E	00468373170E	16.1
8	Mon	1	00467632630E	00517747380E	00077223760E	00464304740E	00076003910E	24.4
		2	00464445650E	00465162090E	00126544210E	00464443730E	00606070240E	4.3
		3	07353627400E	00075149210E	00464345840E	00146476900E	00468131690E	0
		4	00517515240E	07354016980E	07353973650E	00551864410E	00076874260E	22.2
9	Tue	1	00517159930E	00468129900E	00115684240E	00517747520E	00141441910E	8.0
		2	00464721260E	07353981410E	00125740110E	00076478750E	00161008150E	13.3
		3	00467906980E	00518237870E	00140396110E	00824910460E	00467922740E	23.1
		4	07354050680E	00467467570E	07179538010E	00517473180E	07354418810E	6.3
10	Wed	1	00988124930E	00467430340E	00517747480E	00141158850E	00076226060E	14.3
		2	07179548010E	00138321010E	00468478460E	07353757200E	00142154800E	28.6
		3	00126477040E	00468330760E	00464755830E	00145740800E	00517515270E	0
		4	07353608510E	00467647400E	00988143940E	07354088860E	00468186010E	40.9

Table 8, shows the Tardiness Calculations and Tardiness Reduction Percentage. As it has shown in Table 8, tardiness reduction of each sample of data has calculated. Using the Data Input Analyzer Software, the tardiness reductions are fitted to Triangular distribution with parameters 0, 5.78 and 43 separately. Chi Square and Kolmogorov-Smirnov Tests results are as following:

Table 9. Input Analyzer Results

Chi Square Test	Kolmogorov-Smirnov Test
Number of intervals = 5 Degrees of freedom = 3 Test Statistic = 0.459 Corresponding p-value > 0.75	Test Statistic = 0.0773 Corresponding p-value > 0.15

The mean and standard deviation of distribution are 16.26 and 11.29 respectively that means changes in primary sequences of Kanban Cart resupplying could cause improvement in quantity of possible shortages. The histogram of tardiness reductions figured by Minitab has shown in Fig 8.

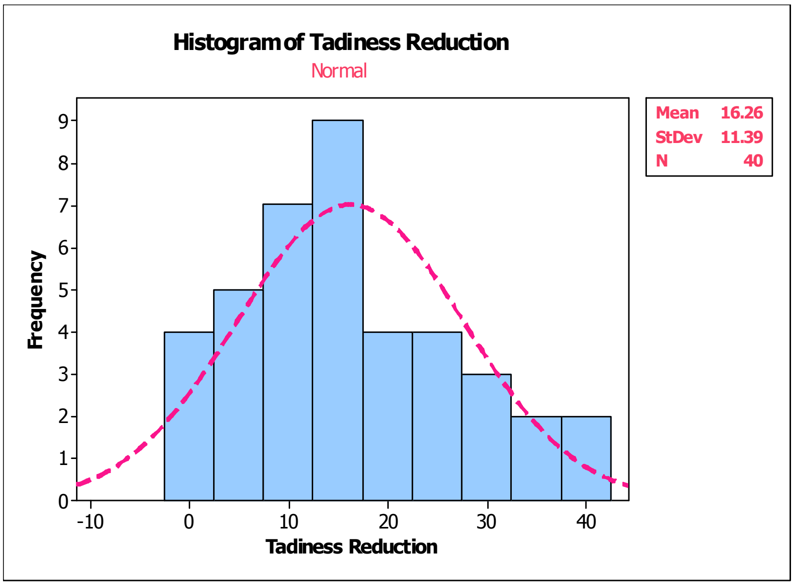


Fig 8: Histogram of Tardiness Reduction

According to this triangular distribution we can find that the tardiness reductions have positive skewness that means most tardiness reductions are less than the mean. Anyway, we can assume average shortage reductions for all parts will be calculated by the Master Production Schedule quantities multiplied by the Tardiness Reduction Percent has brought about in table 8. The MPS for 10 sampling days has shown in Table 10.Considering "%Tardiness Reduction" field of Table 8 and MPS quantities of Table 10, total shortage for all items is calculated as follows:

Table 10. MPS quantities for the 10 sampling days and shortage reduction calculations

Week Days	Group	Day	MPS quantity	MPS quantity × %Tardiness Reduction	Day	MPS quantity	MPS quantity × %Tardiness Reduction
Sat	1	1	32	14	6	28	5
	2			6			0
	3			10			3
	4			6			5
Sun	1	2	32	4	7	28	2
	2			3			6
	3			12			5
	4			4			5
Mon	1	3	30	8	8	28	7
	2			4			2
	3			0			0
	4			10			7
Tue	1	4	30	7	9	30	3
	2			3			4
	3			11			7
	4			3			2
Wed	1	5	28	2	10	32	5
	2			6			10
	3			2			0
	4			4			14
Total Shortage Reduction							211

5. CONCLUSION AND FUTURE STUDY

Nowadays, changing the production system from Make-to-stock to Make-to-order is very vital in all industries. In order to achieve the JIT concepts, Kanban is a pull system that is very familiar in industries especially automotive industry. Changing the sequencing and scheduling of Kanban Cards make some new attribute alteration for Logistic Systems. So we tried to show the effect of this matter on possible shortages may happen in a pull system. We chose the total tardiness objective function to solve our model and find the effect of the sequence alteration in total tardiness of Cards and shortages.in this article we only studied the Kanban in Logistic Systems while it is possible to assess the Kanban in all supply chain starts from suppliers and ends to customers. In future we can study another pull and push systems and apply the scheduling specifications on them and also we can evaluate Kanban in all supply chain include manufacturing, customers and suppliers.

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