



An Analytical Approach to Automotive Industry

İlayda Ülkü¹, Serol Bulkan², Fadime Üney-Yüksektepe³

Abstract

Inventory control helps to manage or locate materials and any information through the processes in the company. The aim of the inventory management in the companies is to optimize inventory control. Especially, for the manufacturing companies, inventory control has an important goal which satisfies the product to the customer on time. Therefore, the system in the production processes should not have any trouble during the production. This study aims to optimize the production system of a two stage production processes where the bumpers are produced for different type of cars and different colors due to the model of the car. In the first stage there is three injection machines which are parallel, and in the second stage, there is a dying station. A mixed-integer linear programming model is proposed to optimize the production process. With the proposed model, the production of the injection processes is optimized and the lot sizes for each stage is determined. Also, front and back bumpers for each same model is dyed concurrently which prevents the color difference for the same model of each type of car.

Keywords: Inventory Control, Lot Size, Mixed-Integer Linear Programming

Introduction

Inventory control helps to manage or locate materials and any information through the processes in the company. The aim of the inventory management in the companies is to optimize inventory control. Especially, for the manufacturing companies, inventory control has an important goal which satisfies the product to the customer on time. The motivation behind this study is to see the inventory control, when some important constraints are changed, such as inventory balance equation. The obtained data [3] is used in an automotive manufacturer that produces bumpers for different type of car models and different colors. The problem has two stages, in the first stage there is three injection machines with unequal production rates, and the dying station is the second stage. In the first stage, there are different moulds used by injection machines. Different than the study in the literature, we try to use the dying station for the same type of bumpers to prevent color differentiation between bumper types which are front and back. This proposed model helps to increase the customer satisfaction at the same time with the balancing the inventory.

Inventory control has an important goal which satisfies the product to the customer on time for the manufacturing companies. Therefore, the system in the production processes should not have any trouble during the production. This study aims to optimize the production system of a two stage production processes where the bumpers are produced for different type of cars and different colors due to the model of the car. In the first stage there is three injection machines which are parallel, and in the second stage, there is a dying station.

¹İlayda ÜLKÜ, Istanbul Kültür University, Faculty of Engineering, Department of Industrial Engineering, Istanbul, Turkey, <mailto:i.karabulut@iku.edu.tr>

²Serol BULKAN, Marmara University, Faculty of Engineering, Department of Industrial Engineering, Istanbul, Turkey, <mailto:sbulkan@marmara.edu.tr>

³Fadime ÜNEY-YÜKSEKTEPE, Istanbul Kültür University, Faculty of Engineering, Department of Industrial Engineering, Istanbul, Turkey, <mailto:f.yuksektepe@iku.edu.tr>



In this study, a mixed-integer linear programming model is proposed to optimize the production process. With the proposed model, the production of the injection processes is optimized and the lot sizes for each stage are determined. Also, front and back bumpers for each same model is dyed concurrently which prevents the color difference for the same model of the car. The remaining part of this paper is organized as follows. In the methodology part, proposed optimization model is described in detail. In comparison study part, data related to the compared study is used and the proposed study results are compared with the current study. Paper concludes with conclusion and suggestions in conclusion part.

Methodology

The parameters below are used to solve the mixed-integer linear programming model. The demand for model i in color k for day g is d_{ikg} , required setup time for injection machine r to produce model i of type j is defined as s_{ijr} . Available time of injection machine r in micro period t is at , available time of dying station in micro period t is atd . Dying time of model i with color k is td_{ik} , required process time for unit product of model i of type j by injection machine r is defined as tp_{ijr} , inventory cost and setup costs are ic and sc respectively. Backlogging costs and idleness cost of dying station are bc and idc respectively. Maximum number of products that can be kept in available inventory $MaxINX$.

The following decision variables are used to solve the two-stage production processes to find optimal lot sizes for each stage.

X_{ijrt} is the number of products of model i of type j produced by injection machine r in micro period t ,
 Y_{ikt} is the number of products of model i dyed by dying station with color k in micro period t , INY_{ikg}
is the number of products of model i with color k held in buffer stock II at the end of day g , INX_{ijt} is
the number of products of model i of type j held in buffer stock I at the end of in micro period t , BL_{ikg}
is the number of backlogged products of color k of model i in day g , IDL_t is the idle time of the dying
station in micro period t .

$$S_{ijrt} = \begin{cases} 1 & \text{if model } i \text{ of type } j \text{ is produced by machine } r \text{ micro period } t; \\ 0 & \text{otherwise} \end{cases}$$
$$SI_{ijrt} = \begin{cases} 1 & \text{setup for model } i \text{ of type } j \text{ is produced by machine } r \text{ micro period } t; \\ 0 & \text{otherwise} \end{cases}$$

The following the mixed-integer linear programming model is used to solve the optimal lot sizes for two stages production problem.

$$\min z = \sum_i \sum_j \sum_t INX_{ijt} + \sum_i \sum_j \sum_r \sum_t sc.SI_{ijrt} + \sum_t \sum_k \sum_g bc.BL_{ikg} + \sum_t idc.IDL_t + \sum_i \sum_k \sum_g ic.INY_{ikg} \quad (1)$$



Subject to

$$X_{ijrt} \leq M \cdot S_{ijrt} \quad \forall ijrt \quad (2)$$

$$S_{ijrt} - S_{ijr(t-1)} \leq SI_{ijrt} \quad \forall ijrt \quad (3)$$

$$\sum_r S_{ijrt} \leq 1 \quad \forall ijt \quad (4)$$

$$\sum_i \sum_j S_{ijrt} \leq 1 \quad \forall rt \quad (5)$$

$$\sum_i \sum_j (tp_{ijr} \cdot X_{ijrt} + st_{ijr} \cdot SI_{ijrt}) \leq at \quad \forall rt \quad (6)$$

$$\sum_i \sum_j INX_{ijt} \leq MaxINX \quad \forall t \quad (7)$$

$$INX_{ij(t-1)} + \sum_r X_{ijrt} - INX_{ijt} = \sum_k Y_{ikt} \quad \forall ijt \quad (8)$$

$$INY_{ik(g-1)} + \sum_t Y_{ikt} + BL_{ikg} = d_{ikg} + INY_{ikg} + BL_{ik(g-1)} \quad \forall ikg \quad (9)$$

$$\sum_i \sum_k td_{ik} \cdot Y_{ikt} + IDL_t \leq atd \quad \forall t \quad (10)$$

$$INX_{\max_{it}} \geq INX_{ijt} \quad \forall ijt \quad (11)$$

$$X_{\max_{irt}} \geq X_{ijrt} \quad \forall ijrt \quad (12)$$

$$INX_{\max_{i(t-1)}} + \sum_r X_{\max_{irt}} - INX_{\max_{it}} = \sum_k Y_{ikt} \quad \forall ijt \quad (13)$$

$$X_{ijrt}, Y_{ikt} \geq 0 \quad \forall ijrt \quad (14)$$

$$INX_{ijt}, INY_{ikg}, BL_{ikg}, IDL_t \geq 0 \quad \forall ikgt \quad (15)$$

$$SI_{ijrt}, SI_{irt} \in 0,1 \quad \forall ijrt \quad (16)$$

The objective function (1) is to minimize the total cost which includes inventory cost, setup cost, backordering cost, and idleness cost. Inventory cost includes number of products held in inventory after injection process and number of products held in inventory after the dying process. There are i type of car models and j type of bumpers on each injection machine, therefore, if there is any production S_{ijrt} will take 1 value in the equation, if there is no production then S_{ijrt} value will take 0 for constraint (2). Constraint (3) helps to determine number of setups for each micro period t . Constraint (4) is used to show that each model has one mould to be used. That is each injection machine has different mould to produce different type of bumpers in each micro period. This restriction is given by constraint (5). Constraint (6) is valid to see the capacity constraint where total available time should not exceed total process and setup time. Constraint (7) represents that total inventory level after injection process should not be exceeded. Constraint (8) gives the production



balance equation of injection processes for dying station. In constraint (9) demand is balanced with both stages injection and dying. Also, available time of dying station is restricted with constraint (10). Constraint (11), (12), and (13) give restriction for bumpers in dying station. To prevent color differentiation for each model i , each model's bumpers-front and back should enter at the same time in the dying station in each micro period t . Therefore, it is important to held in inventory both type j of model i . Constraint (14), (15), and (16) satisfy the non-negativity of the decision variables.

Comparison Study

In this study, real data is used to see the efficiency of the model. [3] There are five different type of bumpers with front and back for each model. The problem has two stages, in the first stage there is three injection machines with unequal production rates. For defined models the production rates are 45, 57, 56, 45, 45 unit/hour respectively. Setup time is considered as one hour and setup cost is 600 TL, for the injection machines. The dying station is the second stage where the production rate is 70 bumpers, front and back. In the literature [3] bumpers are put on the hangers and dyed on the hangers. If a color change is occurred a single hanger stays empty. In this study, to reduce the color differentiation between front and back bumpers, the bumper pairs are dyed at the same time together. Therefore, there is no need to leave a hanger empty. The dying station will be used efficiently with this approach. The setup time is ignored, because the production rate of dying station is higher than the setup time. Moreover, setup cost related to the color change is not necessary to be included in the model at the dying station. Idleness cost is taken as 80 TL, as it is not preferred to be idle at the dying station. Also, there is a capacity for 2472 unit products after the injection processes. Inventory holding cost is 10 TL/day both for the products after injection process which are not finished and for the products after dying station. As backlogging is not preferred, the backlogging cost is 1000 TL per day. In addition, there are nineteen types of colors for the bumpers. There is a daily demand value which is obtained before the start of a week. Proposed model is formulated in GAMS 23.1.2 and solved by using CPLEX 11 solver in order to obtain the optimal results. The runs were executed on a 1.70GHz Intel Core i5 notebook with 6 GB of RAM. The micro period lengths of 4 hours that is 36 micro period length is obtained in a day. [3].

Table 1 gives a brief information about the number of products of model i of type j produced by injection machine r .

Table 1. Number of products of model i of type j produced by injection machine r for the proposed model

		Injection Machine						Total Production	
		1		2		3			
		Bumper 1	Bumper 2	Bumper 1	Bumper 2	Bumper 1	Bumper 2	Bumper 1	Bumper 2
Model	1	500	500	600	500	300	400	1400	1400
	2	400	800	300	100	500	300	1200	1200
	3	200	0	200	800	500	100	900	900
	4	400	400	200	0	0	200	600	600
	5	400	0	300	700	0	300	700	1000
	Total Production	1900	1700	1600	2100	1300	1300		



For each model i , in each injection machine r , total number of produced bumpers are shown in Table 1. For instance, for model 1

- ✓ The production amount for bumper 1 and bumper 2 for injection machine 1 is 500 units.
- ✓ For injection machine 2, the production amount for bumper 1 is 600 units, and for bumper 2 is 500 units.
- ✓ For injection machine 3, the production amount for bumper 1 is 300 units, and for bumper 2 is 400 units.

Figure 1 represents a detailed histogram of each model i produced by each injection machine r .

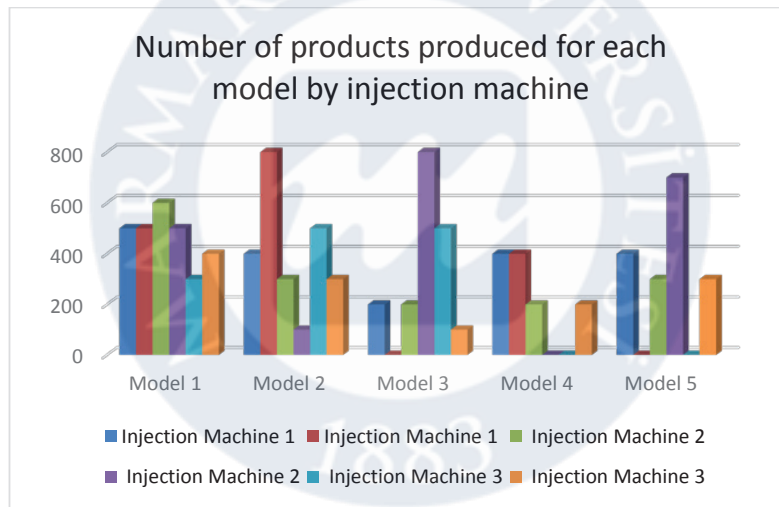


Figure 1. Number of products of model i of type j produced by injection machine r for the proposed model

When the model is compared with the current study [3] the following production rates are obtained. Table 2 represents the production amount of model i of type j produced by injection machine r for the current model.

Table 2. Number of products of model i of type j produced by injection machine r for the current model

		Injection Machine							
		Injection Machine 1		Injection Machine 2		Injection Machine 3		Total	
		Bumper 1	Bumper 2	Bumper 1	Bumper 2	Bumper 1	Bumper 2	Bumper 1	Bumper 2
Model	Model 1	1100			500	700	1300	1800	1800
	Model 2	600	100	300	900	200	100	1100	1100
	Model 3	500	400	100	300	100		700	700
	Model 4	100			100	100	100	200	200
	Model 5	600	200	500	900	500	500	1600	1600
Total		2900	700	900	2700	1600	2000		

Figure 2 shows a detailed histogram of each model i produced by each injection machine r . When proposed model and current model is compared, proposed model has significant effect in the production amount of model 2, 3 and 4.

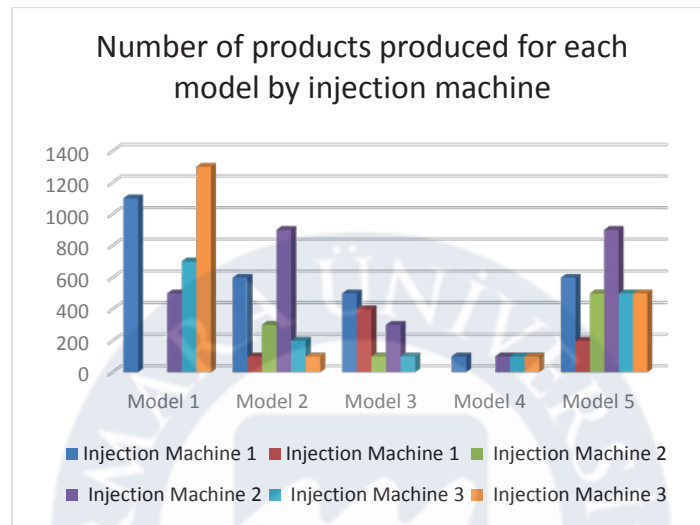


Figure 2. Number of products of model i of type j produced by injection machine r for the current model

Table 3 shows the comparison of number of products of each model i of type j from injection machines held in inventory for the proposed model. After the production process in injection machines, semi-products for model 1 is as follows, for the first type of bumper 500 units and for the second type of bumper 600 units are held in inventory for the dying station.

Table 3. The comparison of number of products of model i of type j from injection machines held in inventory

		Bumper	Proposed Model	Current Model
Model	1	Bumper 1	500	200
		Bumper 2	600	100
	2	Bumper 1	200	200
		Bumper 2	1300	400
	3	Bumper 1	500	0
		Bumper 2	200	900
	4	Bumper 1	100	0
		Bumper 2	700	200
	5	Bumper 1	31	718
		Bumper 2	1131	1518

Figure 3 gives an information to see easily each type of model i and j type of bumpers held in inventory. When the proposed situation is compared with the current situation, the bumper pairs-front and back are dyed together for each model. Therefore, there are both front and back bumpers together as the semi-products in the inventory.

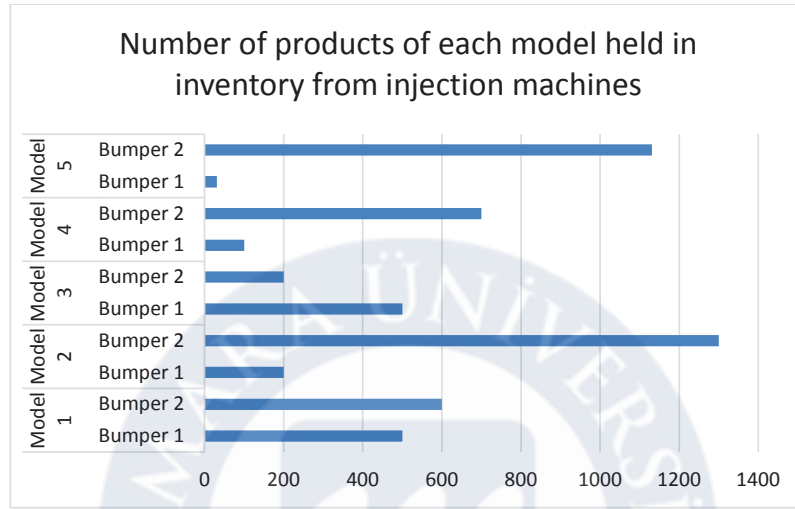


Figure 3. The comparison of number of products of model i of type j from injection machines held in inventory for the proposed study

Table 4 represents number of products of each model dyed by painting station with nineteen different color. For instance, for model 1,

- ✓ There 75 units dyed by color number 3,
- ✓ 10 unit dyed by color 18 etc.

Table 4. The comparison of number of products of model i dyed by painting station with color k

		Proposed Model					Current Model				
		1	2	3	4	5	1	2	3	4	5
Color	1				8	57					57
	2				120	185				23	288
	3	75	137	141	118	105	108	167	124	47	178
	4	297	388	112	12	6	287	486	110		7
	5	53			19	5	53			10	5
	6	9	83	22	71	167	70	83	18	20	214
	7	71					58			16	
	8				9	48					60
	9	28			92	347	43			17	413
	10	726	142	213			957	185	121		
	11		9	5	31	90			4	11	108
	12	108	29	135			158	22	80		
	13		68	47	32	158			43	32	200
	14	16	100	150	61	33	35	71	134	28	10
	15	7	46	38			16	35	29		
	16		37	13				31	13		
	17		23	24	25	23		20	24	13	62
	18	10			2	8	15				8
	19										

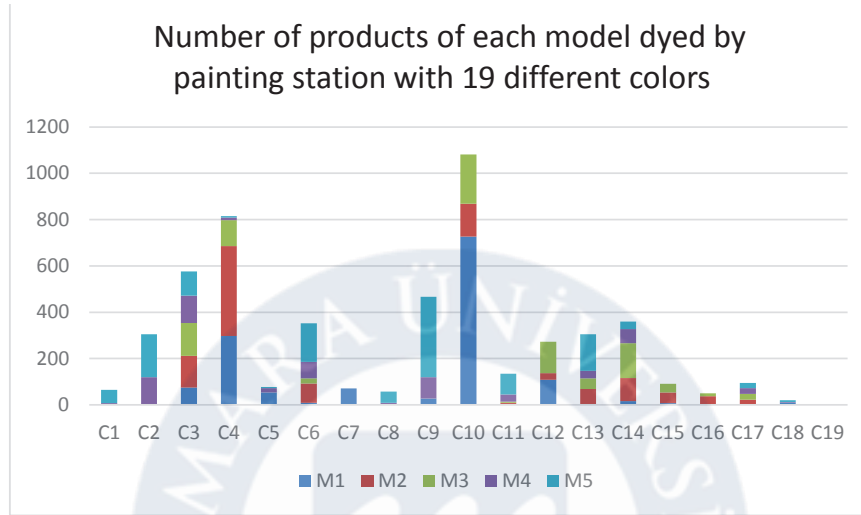


Figure 4. Number of products of model i dyed by painting station with color k for the proposed study

In Figure 4, number of products of each model dyed by painting station with different colors for the proposed study are represented. In the proposed model, bumper pairs are dyed for model 1, 2, and 3 in eleven different colors, and for model 4 and 5, thirteen different colors bumper pairs are dyed. On the other hand in the current study, for model 1 and 3-eleven different colors, for model 2-nine different colors, for model 4-ten different colors, and for model 5-thirteen different colors are dyed. In the proposed study, the color type is enlarged 18.18% for model 2, and also for model 4 dyed different color types are increased in 23.08%.

Table 5. Daily Idle Time (min.)

Daily Idle Time (min.)	Day 1	11.689
	Day 2	12.227
	Day 3	9.833
	Day 4	11.250
	Day 5	11.250
	Day 6	11.250
	Total Idle Time	67.499
	Average Idle Time	11.250

Table 5 shows the summary information about the proposed model. Idle time for dying station of each day is given in minutes. For instance, at the end of day 1, dying station is idle 11.689 minutes, and the average idle time of dying station is 11.250 minutes. Also, in figure 5, idle time for dying station of each day is given as percentages. For instance, minimum daily idle day is day 3 with 14%.

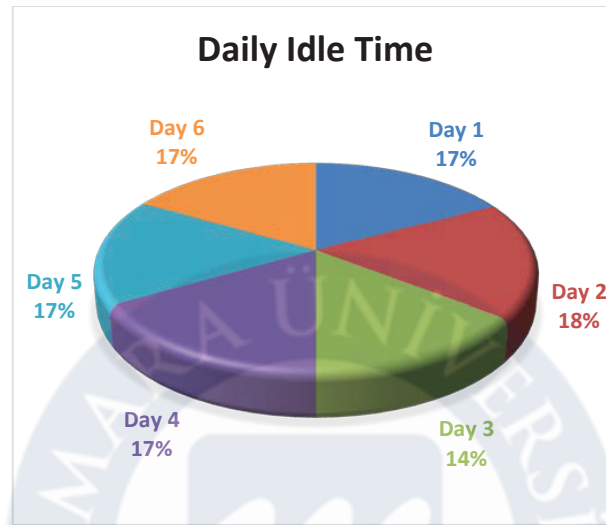


Figure 5. Daily Idle Time (%)

Conclusion

In this paper, real data from an automotive supplier is used. A mixed-integer linear programming model is proposed to optimize the production process. With the proposed model, the production of the injection processes is optimized and the lot sizes for each stage is determined. Also, front and back bumpers for each type of model is dyed concurrently which prevents the color difference for the same model of the car. This study helps to increase the customer satisfaction at the same time with the balancing the inventory. Moreover, the characteristics of the proposed model are given. As the possible future work, micro period lengths can be changed instead of using a fixed micro period. In addition, as comparison the run time of the model can be changed to see the effects to the model. Also, objective function can be changed to see the influence to the proposed model.

References

- [1] Brooke, A., Kendrick, D., Meeraus, A., Raman, R., 1998. GAMS:A User's Guide. GAMS, Development Co., Washington, DC.
- [2] Ilog, 2010. CPLEX 12.0 User's Manual , ILOG S. A. See website www.cplex.com
- [3] Uney, Yuksektepe, F., Ozdemir, R., G., 2011, Synchronized Two-Stage Lot Sizing and Scheduling Problem in Automotive Industry, *Operations Research Proceedings*, 477.