DISTRIBUTION AND INVENTORY POLICIES FOR RAW MATERIALS IN A PROCESS INDUSTRY

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DISTRIBUTION AND INVENTORY POLICIES FOR RAW MATERIALS IN A PROCESS INDUSTRY

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Approval of the Graduate School of Natural and Applied Sciences

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ABSTRACT

DISTRIBUTION AND INVENTORY POLICIES FOR RAW MATERIALS IN A PROCESS INDUSTRY

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In this study, we aim to manage the raw material transfer between the central warehouse and the floor stock areas. Floor stock areas are the places next to production units that are used for stocking items, especially floor stock items. Floor stock items are the materials for making adjustments in a batch being produced. Halts during production occur due to the lack of these materials. We decide which materials should be stocked at which floor stock area at which quantity via an (*s,Q*) inventory policy for these materials.

Our objective is to reduce the order to delivery cycle time by reducing the number and duration of halts. For this purpose, we propose the introduction of a production logistics department that organizes the material transfer by implementing the milk run concept according to the vendor managed inventory principle with the goal of minimizing the number of halts during the production and maximizing the overall equipment and work force efficiency.

Keywords: production logistics, floor stocks, milk run, vendor managed inventory, (*s,Q*) inventory policy, paint production, process industry

ÖZ

PROSES ENDÜSTRİSİNDE HAM MADDELER İÇİN DAĞITIM VE ENVANTER POLİTİKALARI

Dalgıç, Burcu

Akıllı Mühendislik Sistemleri Yüksek Lisans Programı
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Bu çalışmada, ana ambar ile koltuk ambarları arasındaki ham madde transferinin yönetimi hedeflenmektedir. Koltuk ambarları, üretim tesislerinin yanında bulunan malzeme (özellikle koltuk malzemeleri) stoklamak için kullanılan yerlerdir. Koltuk malzemeleri, üretilmekte olan partiyle ilgili ayar yapmak için kullanılan malzemelerdir. Bu malzemelerin eksikliği sebebiyle üretim esnasında duruşlar yaşanmaktadır. (s,Q) envanter politikası ile hangi malzemeden hangi koltuk ambarında ne kadar stok tutulması gerektiğine dair kararlar verilmektedir.

Hedef, duruş sayısını ve süresini azaltarak siparişten sevkiyata olan çevrim süresini kısaltmaktır. Üretim esnasındaki duruşları en aza indirgeme ve toplam ekipman ve işgücü verimliliğini en fazlaya çıkarmak amacıyla, malzeme transferini milk run yöntemi ile (tedarikçi kontrollü envanter yönetimi prensibine göre) düzenleyen bir üretim lojistiği bölümü kurulması önerilmektedir.

Anahtar kelimeler: üretim lojistiği, koltuk malzemeleri, milk run, tedarikçi kontrollü envanter yönetimi, (s,Q) envanter politikası, boya üretim, proses endüstrisi

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CHAPTER 1

INTRODUCTION

In today's world, companies need excellent distribution networks both inside and outside the organization in order to survive in the rapidly changing, global competitive environment. The lead times in business process are shortened taking advantage of the rapidly evolving information technologies. A requisite to satisfy today's impatient customers is investing in logistics strategies. APICS (American Production and Inventory Control Society) defines logistics strategies as the planning activities related with warehouse, information systems, and transportation and remarks them as the crucial components of the overall business strategy. [1]

In a plant, logistics activities are divided into 3 groups that are inbound logistics, production logistics and outbound logistics. APICS defines inbound logistics as the transportation activities originating from the suppliers and ending inside the facilities and defines outbound logistics activities as the transportation activities taking place between the end of production and the receipts' of the customers and processes such as shipping and storing. As regards to production logistics, it is the part of logistics that takes place within the confines of the production facility after the inbound logistics activities and before the outbound logistics activities. [1]

This study which is focused on production logistics is conducted in a multinational coating company. The company produces a wide range of automotive and general industrial coatings. According to data of year 2013, there are 1,302 active raw materials and 8,166 active end products. Approximately 60,000 tons of raw materials are consumed while approximately 58,000 tons of end products are produced.

The production in the company consists of four main processes namely pre-dispersion, dispersion, let-down and filtering & packaging: [2]

1) During the pre-dispersion process, polymers and raw materials like pigments are mixed in determined proportions and a homogeneous solution is obtained.
2) Homogeneous and stable mixture is obtained at the end of the dispersion process by scattering of one substance into another in small particles.
3) Let-down is the third step at which other input materials in the paint formulation are added to the pigment paste.
4) Solid particles are separated mechanically from fluid medium through a sieve which limits certain particle size to pass by filtering. Finally, the related coatings are filled into the determined packages and by this operation the products become ready for being delivered to the customer.

The products need not to go through all of the above four steps. Each product has a specific sequence of the four steps as determined by the R&D department, i.e., there exists a job shop system. Some of the steps can be omitted for some of the products as in the case of the thinners that are only processed through the third and the fourth steps.

In producing coatings, the three material groups that may be used are raw materials, polymers and semi-finished products. Polymers are special semi-finished products. Semi-finished products may consist of raw materials, polymers or other semi-finished products. This study focuses on the raw materials' internal transfer. Inbound and outbound logistics activities are beyond the scope of our thesis. In this work we assume that the raw materials that are needed at the floor stock areas are always stocked at the central warehouse. The raw material transfer is of crucial importance for the company since their shortages cause halts in the production and these halts result in inefficiencies and delays in the production schedule.

In this general setting, the objective of this study is defined as minimizing the number of unexpected halts during production and maximizing the overall equipment and work force efficiency. Via the optimization of these designated objectives, the order-to-delivery cycle time is reduced and customer satisfaction rate is increased. In order to achieve these objectives in a sustainable fashion, a new department namely "production logistics department" is proposed.

In the spirit of the vendor-managed inventory concept, the proposed department will be the internal customer of the warehouse department as well as the internal supplier of the production department. Furthermore, the production department will be the internal customer of all other departments while the warehouse department will be the internal supplier of the other departments. The flow chart is given in Figure 1.1.

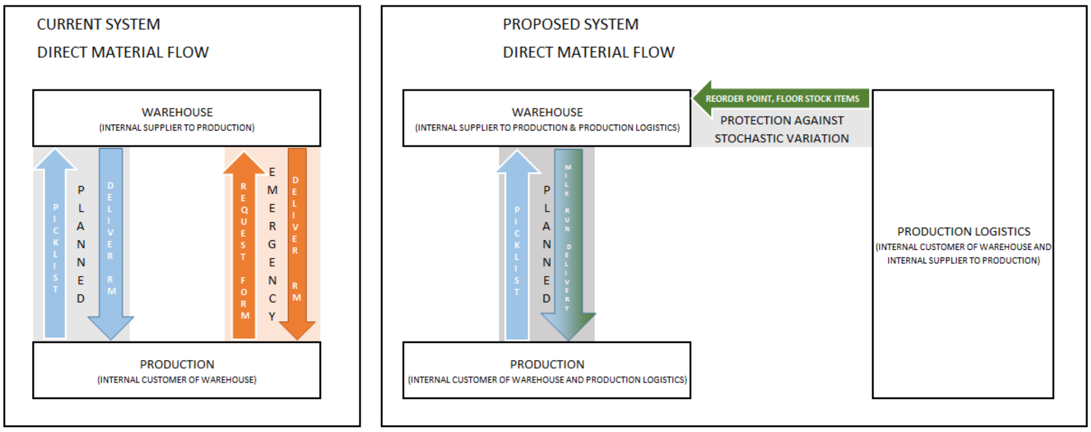


Figure 1.1 Flow chart of information and direct material

The tasks of the production logistics department are as follows:

- Determining the floor stock items and valid inventory policies for them. Floor stock items are inventory items that are stored in particular areas adjacent to production sites. They are used for adjusting the color and other characteristics of the produced paints. When a production batch is not approved by the quality and color laboratories, raw materials outside the bill of materials need to be added into the batch for attaining the required color or characteristic.
- Coordinating the material flow between production and warehouse departments.
- Sustaining the system and revisiting the floor stock item replenishment policies regularly.

Currently, whenever an ingredient has to be added after the mixing of the original formula ingredients, the production halts. Then the production operator rushes to the warehouse and requests the material from the warehouse operator. It takes time for the warehouse operator to prepare and transfer the requested material. Due to the lack of production logistics department, these departments need to perform additional tasks that are not in their original job definitions. This policy causes erratic material flow, lengthens the production time and decreases the proportion of on-time deliveries.

In the proposed solution, the material transfer between the warehouses and the floor stock areas will be coordinated by the means of a milk run concept. Milk run concept is based on the principle of replenishing the raw materials in a planned manner with the help of simple material handling equipment. It is frequently applied in internal plant logistics for the transportation of raw materials. In this system, vehicles circulate between the warehouse and the production facilities according to a pre-defined schedule (Kovács, 2011). [9]

The rest of this thesis is organized as follows. Chapter 2 provides the literature review on milk runs and inventory policies that can be applied to floor stock items. Chapter 3 presents the current system and the problems in the company. Chapter 4 introduces how the raw material transfers can be coordinated via milk run concept in the setting considered. This chapter does not give an answer for the major problem, i.e., the halts during production. In this chapter, analyses about an alternative transportation method are made according to the current system. If our major problem was high transportation costs, more analyses would need to be done related with especially routing issues. Chapter 5 provides an analysis of the (*s,Q*) inventory policy for the floor stock items. By adopting the appropriate inventory model, the number and duration of halts during production is aimed to be minimized. Via milk run concept, all the raw materials (except pipeline) will be transferred. But in this chapter we do not develop inventory policies for each raw material. We develop inventory policies only for the raw materials that usually cause halts during production due to their shortages due to their unplanned consumptions. In fact, chapter 4 and chapter 5 are associated with each other. Because after developing inventory policies for the floor stock items, we will be prepared for their unplanned usages before their occurrences. Hence, the requisites related with these extra consumptions due to the developed inventory policy will be transferred via the milk run vehicle before the period they are consumed in the current system (Total amount transferred via the milk run vehicle will not change too much during a year due to the inventory policy, only the periodic transfer amounts will change.) Chapter 6 concludes the work by a discussion of the contribution to the literature and possible future directions.

CHAPTER 2

LITERATURE REVIEW

In this chapter, we give the theory and methodology related with the transportation and inventory control of the floor stock items. The literature review is surveyed in two categories namely milk run and inventory policies. APICS defines milk run as “a regular route to pick up mixed loads from several suppliers. A combined or consolidated delivery from multiple suppliers often is a part of milk runs.” [1]

The milk delivery system is provided by a milkman delivering on a predetermined schedule, called a milk run. The milkman collects the empty milk bottles and puts full milk bottles in place of empty ones. Although nowadays such a distribution method for milk is scantly used (most milk is sold through supermarkets and stores), “milk run” is still used in the trucking industry meaning a routine trip involving stops at many places. In this method, the empty bottle is the signal or Kanban for the milkman (Leone, G. and Rahn, R. D. ,2011). [3]

Durmusoglu et al. (2012) develop a model for in-plant milk run distribution systems. They aim to standardize the material handling system and eliminate waste for getting through to lean manufacturing. They mention that in the case that an effective material handling system is designed, the cost will decrease between 10% and 30%. The authors indicate that lean logistics consists of three groups namely in-bound, in-plant and out-bound logistics. In the scope of their study, they put emphasis on in-plant logistics similar to our study.

They differentiate from our study due to the determination of milk run routes and vehicle cycle time. Rather than these decisions, single milk run route and fixed vehicle cycle time is used in our study. They state that their problem has similarities with the capacitated vehicle routing problem and inventory routing problem in which the quantities to be delivered are determined. [4]

Tanrikulu et al. (2010) concern about stochastic joint replenishment problem by determining the replenishment policy. They aim to minimize the total expected ordering, inventory holding, and backordering costs. They propose an (*s,Q*) inventory policy. With respect to this policy, in case of dropping of the inventory position of any item to its reorder point s, the replenishment order of a constant size of *Q* is allocated to multiple items for equalizing their inventory positions as much as possible. This policy is then compared with the (*Q,S*) policy. It is reported that (*s,Q*) inventory policy works better. (*Q,S*) policy is another continuous review policy in which, as soon as the total demand since the last order reaches *Q*, a joint order of *Q* units is given for raising the inventory position of all items to S. This (*Q,S*) policy is more preferable when the fixed ordering cost is high and the shortage cost is low. Similar to the explanations of the authors, this (*Q,S*) policy is not convenient for the company due to the significant shortage costs. For this reason, we propose an (*s,Q*) policy for the company.

Replenishing a single item in multiple locations is also related with joint replenishment. For taking advantage of economies of scale, shipments to multiple locations are combined via usage of a milk run vehicle. This situation is similar to our study as we also collect the necessary raw materials from the central warehouse, put them to the milk run vehicle and then transfer to the floor stock areas. Furthermore, the authors mention about vendor-managed inventory (VMI) contract. VMI contract is advantageous in reducing inventory and transportation costs via joint replenishment of multiple retail locations. [5]

Zerman (2007) considers an inventory replenishment problem of a company operating in fast moving consumer goods (FMCG) by taking the transportation costs between regional warehouses and customer depots into consideration. In this study, some questions like serving time to the customers, amount of delivery, the route of deliveries are tried to be answered. Milk run approach is used while delivering the orders placed by different customers by the same truck. Minimizing the number of trips and distances covered by the milk run vehicles are the primary objectives. Furthermore, VMI approach is used for the inventory control. [6]

Çay et al. (2010) conduct a study for a washing machine factory at which milk run approach is already being used. They intend to improve the performance of the milk run system by developing a SYMECA system that integrates a mathematical, a heuristic and a simulation model. By implementing this system, the distances travelled by the milk run vehicles decrease by 11%, the need for operators and vehicles decrease by 20% and 33% respectively. [7]

Öztürk et al. (2011) implement the pull and milk run system at an automotive supplier firm in their study. By the proposed system, they manage to decrease the transportation time by 49.85%, increase the utilization of man power by 83.35% and decrease inventory holding costs by 13.23%. Similar to our study, they determine a fixed milk run route. [8]

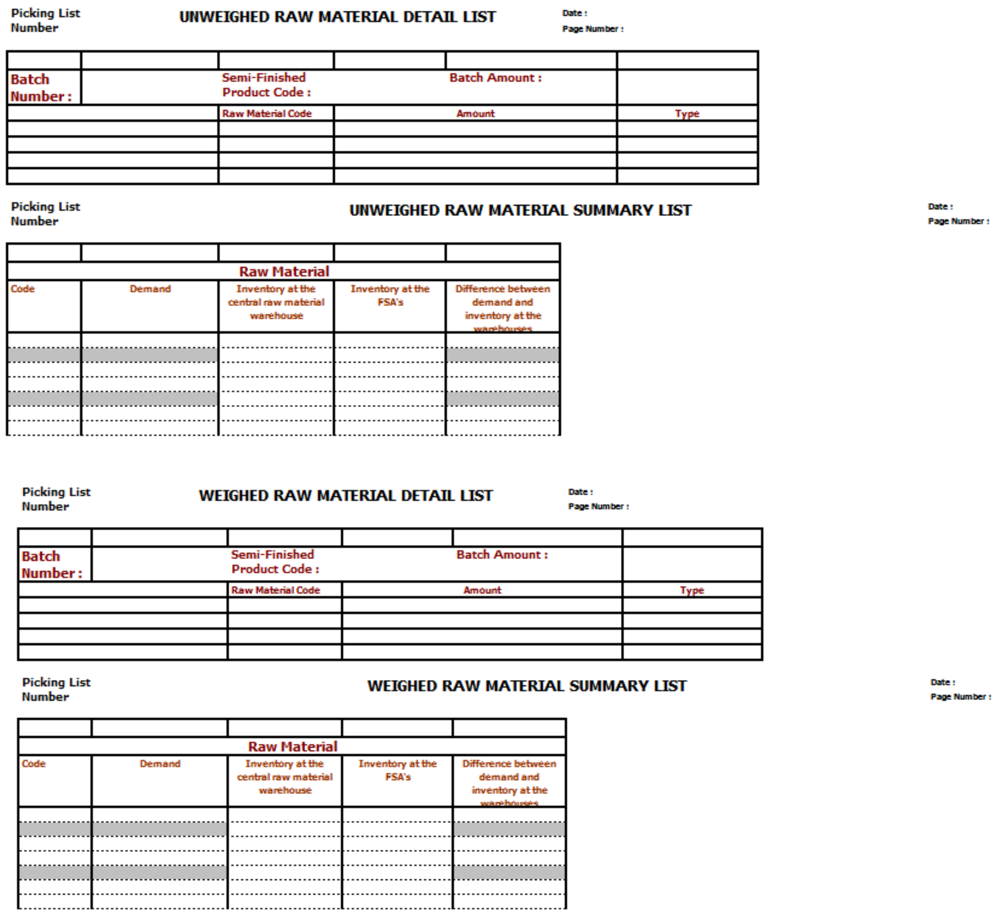
Production logistics is formerly disregarded and it is an emerging concept recently. For this reason, there are very few references in the literature and very few companies have production logistics department. This thesis is one of the rare studies that deals with the internal logistics activities in two dimensions, i.e., distribution and inventory management issues. Furthermore, as we are able to work with real data of the company in which we conduct this thesis, our study becomes more realistic and applicable in the process industries.

CHAPTER 3

CURRENT SYSTEM

In this chapter, we describe the current distribution system inside the company and its inherent problems.

In the company, there is one central raw material warehouse and there are five floor stock areas (FSA). Each FSA has a limited storage capacity. The central warehouse keeps the bulk of the inventory and transfers the needed one-shift raw materials to the FSAs according to the picking lists. The capacity of each FSA is dedicated to these materials that will be used in the coming shift and safety stock for any raw material is not kept at the FSAs. Currently, no inventory policy having a part in the literature is applied for the raw materials. With respect to the inbound logistics activities, the purchasing department orders the raw materials by only taking the lead time and standard package sizes of each raw material into consideration. No more raw material is purchased due to holding safety stock in the central raw material warehouse. With respect to the production logistics activities, the warehousing department brings the orders of the production department by only taking the required amounts in the picking lists and standard package sizes of each raw material into consideration. No more raw material is brought due to holding safety stock in the FSAs. APICS defines the picking list as “A document that lists the material to be picked for manufacturing or shipping orders”. [1] The FSAs are replenished at the beginning of each shift. A picking list is illustrated in figure 3.1.



Picking List Number — UNWEIGHED RAW MATERIAL DETAIL LIST — Date : Page Number :

Batch Number :	Semi-Finished Product Code :	Batch Amount :	
	Raw Material Code	Amount	Type

Picking List Number — UNWEIGHED RAW MATERIAL SUMMARY LIST — Date : Page Number :

Raw Material				
Code	Demand	Inventory at the central raw material warehouse	Inventory at the FSA's	Difference between demand and inventory at the warehouses

Picking List Number — WEIGHED RAW MATERIAL DETAIL LIST — Date : Page Number :

Batch Number :	Semi-Finished Product Code :	Batch Amount :	
	Raw Material Code	Amount	Type

Picking List Number — WEIGHED RAW MATERIAL SUMMARY LIST — Date : Page Number :

Raw Material				
Code	Demand	Inventory at the central raw material warehouse	Inventory at the FSA's	Difference between demand and inventory at the warehouses

Figure 3.1 A picking list form

The planning department prepares a 2-week production plan for the finished products after checking the current inventory levels, sales forecasts, current manufacturing and customer orders. On a daily basis, the production department produces a daily production plan for the next day. This plan includes both finished and semi-finished products and is based on the planning department’s production plan. When the daily production plan is ready, the production department issues the production orders. This order sheet also includes production information (formula, process) for the product. After this stage, the raw materials and the semi-finished products that are needed and their necessary quantities are determined. Firstly, the materials are checked whether they are available at the FSAs or not. If required quantities are available, they are not ordered. If stock at the FSAs is less than the required quantity, the close-planning group within the production department checks via the ERP system whether the necessary material is available at the central warehouse or not. If they are not, the production orders containing these materials are extracted from the daily production plan and another production order is issued instead of this one. But sometimes these shortages do not necessarily cause a change in the daily production plan as some materials can be substituted by another material. APICS defines substitution as “the use of a nonprimary product or component, normally when the primary item is not available.” [1] The production department decides which materials will be used in place of the absent materials according to the previously identified substitution table, marks the committed changes on the picking lists and the warehousing department is informed. In the case that the absent materials cannot be substituted, the order has to be taken out of the daily plan and the picking lists need to be updated. Sorting the production orders according to their priorities, the production department consolidates the orders into three shifts and prepares a picking list for the needs of each production area at each shift. These are the orders to be delivered by the warehousing department. The flow chart is given in Figure 3.2.

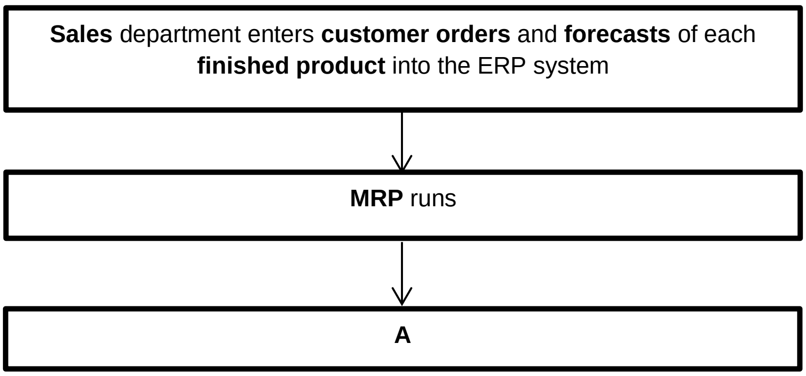


Figure 3.2 Flow chart about weekly and daily plan procedure

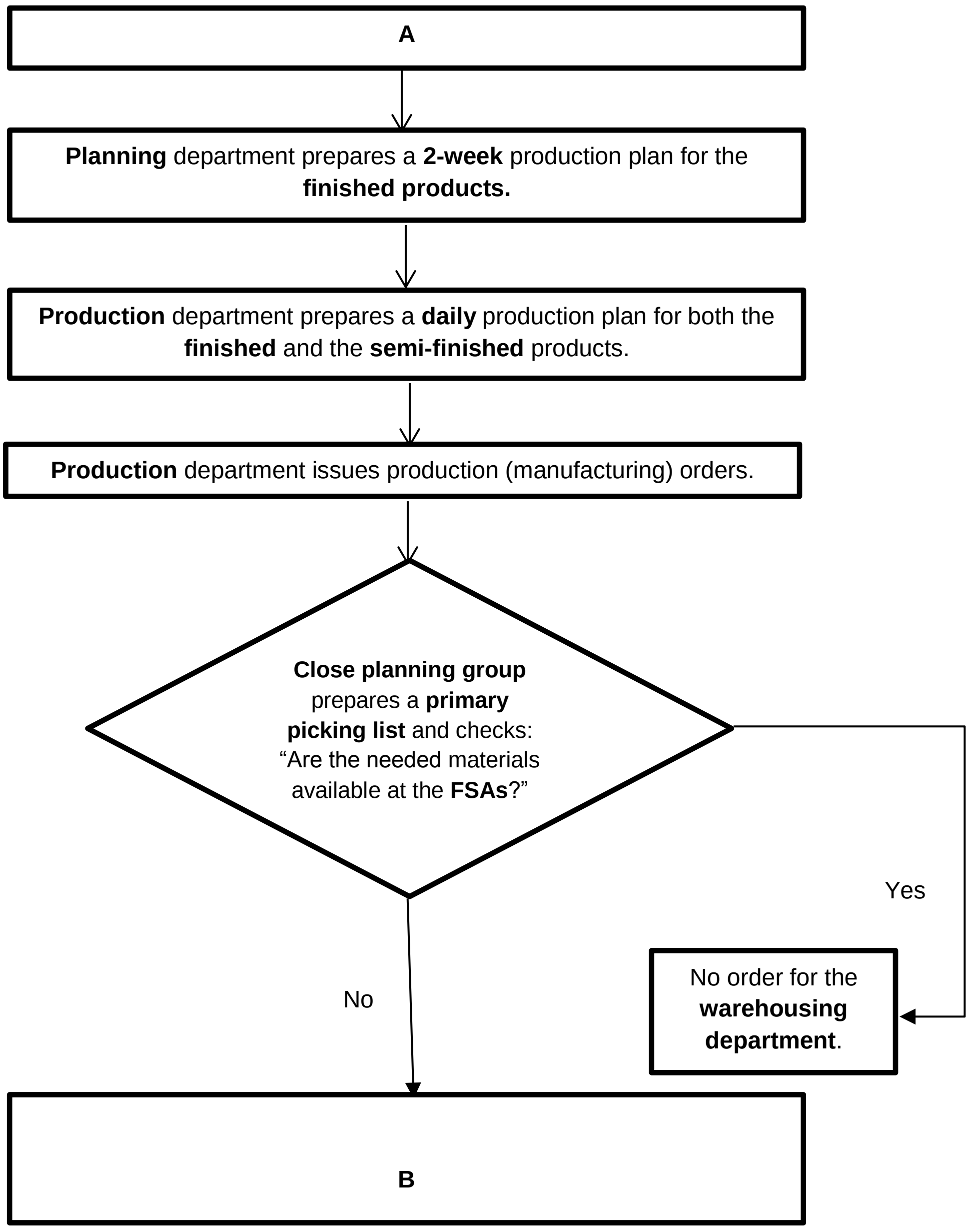


Figure 3.2 (cont.) Flow chart about weekly and daily plan procedure

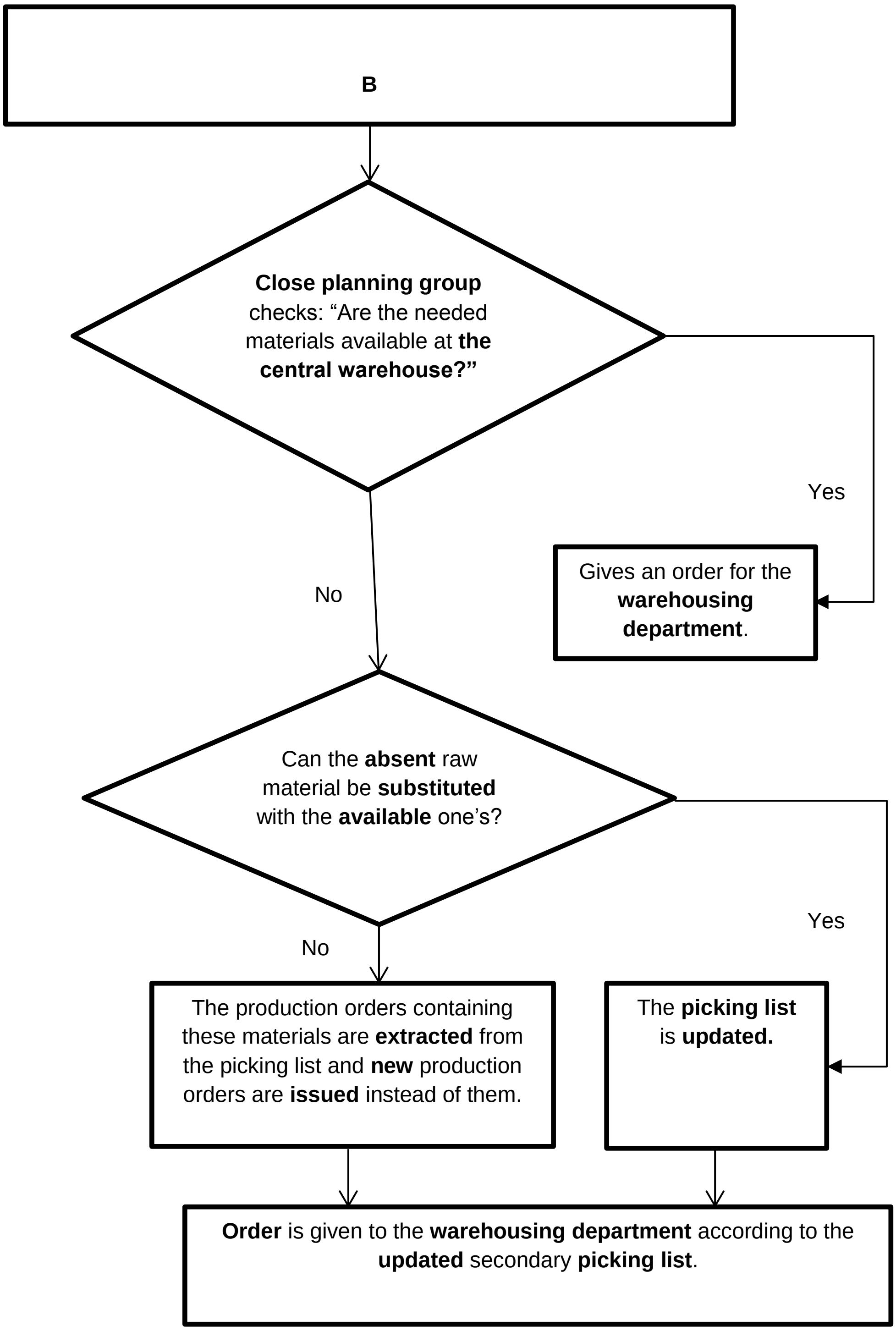


Figure 3.2 (cont.) Flow chart about weekly and daily plan procedure

Currently, the warehousing department dispatches the exact amounts of raw materials as given in the picking lists. However, due to the nature of the paints, the amount of each material used in a batch may differ from the corresponding quantity in the picking list. This is usually due to problems in meeting the criteria of the specifications set by the engineering department and controlled by color and quality control laboratories. In the case when the additional raw materials needed for adjustment are not ready at the FSAs, the production halts to fetch materials. We classify the raw materials that can cause this kind of interruptions as the floor stock items (FSI). When FSI's are not available, the production stops and waits until the needed raw materials are brought from the warehouse. According to 2013 data, this happened on the average 900 times a month.

Whenever the production operator cannot find the necessary raw materials at the FSA, he fills in a raw material request form indicating the code and quantity of the desired material and submits this form to the warehouse operator. Then the warehouse operator picks the desired raw materials from the shelves and transfers it to the intended FSA. This causes an interruption in the production batch of approximately 45 minutes. Sometimes instead of filling in the form, the operator calls the warehouse operator and asks for the necessary materials on the phone. This mode of verbal communication, i.e., informal system, may often cause misunderstandings and ends up prolonging the duration of the production halt.

The information and material flow following the halt of production due to the lack of raw materials is illustrated in Figure 3.3.

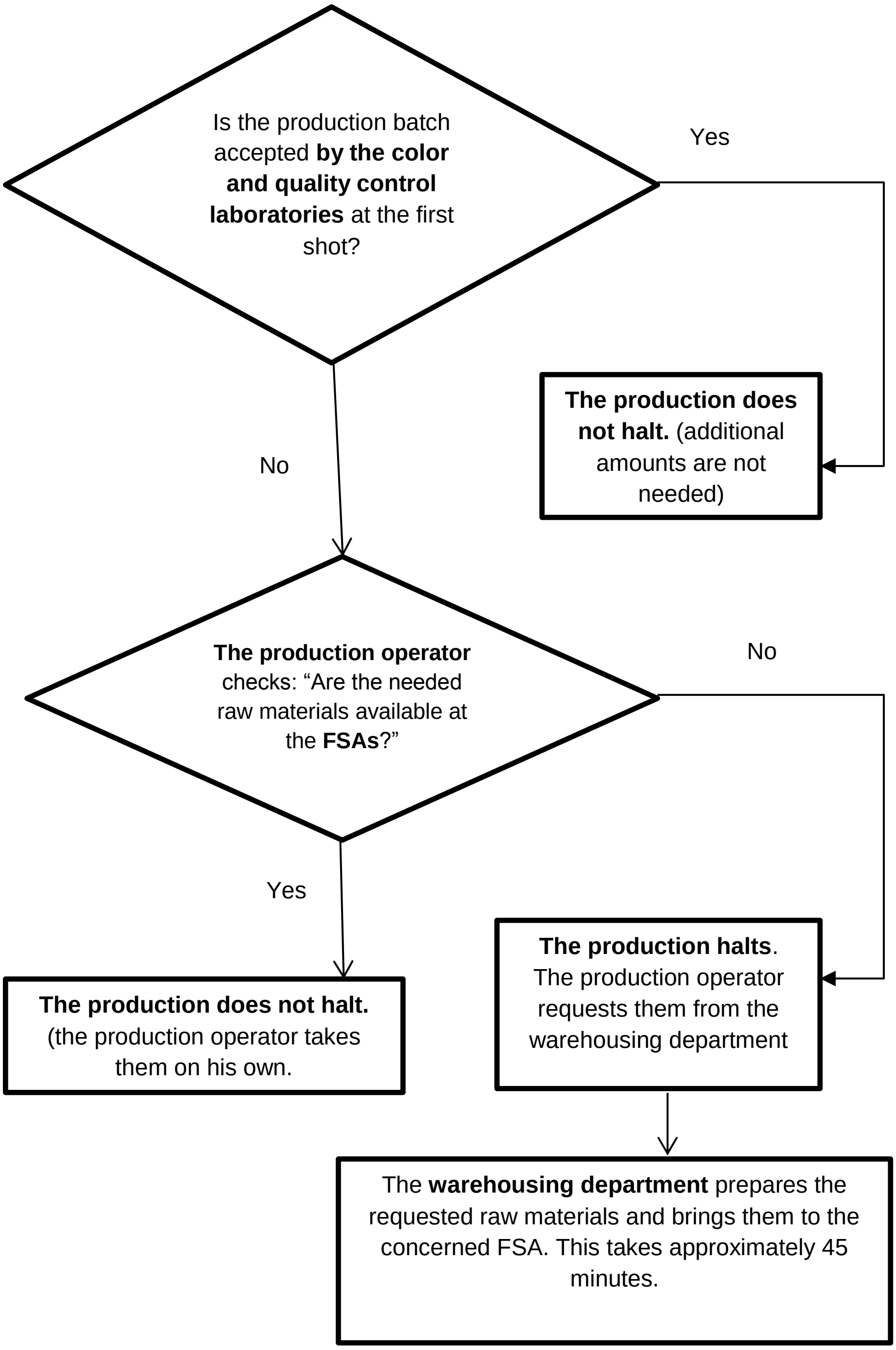


Figure 3.3 Material and information flow due to the lack of FSIs

In order to decrease the number of these halts as well as to decrease the order-to-delivery cycle time, we propose the introduction of a production logistics department. This department is to be responsible for coordinating the proposed milk run system and for developing inventory policies for the FSIs and revisiting them when necessary.

CHAPTER 4

MILK RUN

In this chapter, we recommend a milk run system to solve the problems mentioned in Chapter 3 and quantify its potential benefits.

A milk run logistics system is proposed for the internal material transfer of the company. The main purpose of this new system is the reduction of the inventories at the FSAs and of the transportation costs by assuring the continuity of the production process. In the proposed milk run system, there will be five stations (FSAs) that have limited storage capacities. Capacity of each station is given in Table 4.1 in terms of pallets (We do not determine these values. Currently, the shelves are ready at each FSA and pallets are put onto these shelves). A pallet can approximately contain 1,000 kg of material.

Table 4.1 Capacity of FSAs (limited)

Station (FSA)	Capacity (pallets)
Dispersion	36
Waterbased	18
Wood	57
Common	66
Coil	12
Total	189

Company own two milk run vehicles of 10 tons capacity and these vehicles will be used for the transfer of the needed raw materials. The management would like the cycle times to be one hour for operational simplicity. Thus, the first milk run vehicle will be used for transferring each FSAs orders for the coming hour while the second one will be used for the preparation of the next order needed two hours from that point in time. Loading, unloading and transportation times are not quantified but they should be taken into consideration. We would also like the materials bound to the last station of the milk run to be ready before the corresponding production period starts. For all these reasons, we plan to introduce a safety lead time of one period in transferring the raw materials (according to the following analyses and the method that we propose at the end of this chapter, we decide to neglect it as the required transportation amounts are not affected too much due to the mentioned reasons). The management would like to have a single fixed milk run route in order to eliminate complications due to routing, thus we do not deal with routing issues. Hence, the designed milk run route starts from the raw material warehouse, visits each of the five stations and ends at the raw material warehouse completing a ring. Collecting wastes and leftovers is also beyond the scope of our thesis.

We classify the raw materials into three groups: weighed, unweighed and pipeline. Most frequently used liquid raw materials are stored in big tanks with 30 or 50 tons capacity and are transferred through the pipelines in order to minimize labor due to the barrelling process of the fluids and the transportation process. The raw materials transferred through the pipelines are excluded from the milk run as they will be transferred via pipes. To meet the demand in the picking lists, unweighed raw materials are transferred in amounts equal to the multiples of their standart package sizes while weighed raw materials are transferred in the exact amount specified in the picking lists.

We first analyzed the consumption between November 2012 and October 2013 in order to determine demand variability and to check whether the planned transfer capacity would be sufficient. The consumption data is obtained via real time shop floor data capturing system. In the company, a barcode system that is being used enables quality control, item and quantity control from manufacturing order and lot traceability at all levels.

We then grouped the consumption data hourly, two-hourly and shiftwise. Here, one shift corresponds to company specified period of eight hours. The average, maximum, standard deviation and coefficient of variation values are calculated. In Table 4.2, consumption statistics are given considering hourly consumptions.

Table 4.2 Hourly consumption statistics

Period	Average consumption, kg	Standard deviation, kg	Max consumption, kg	CV
0	1,283	1,675	9,712	130.60%
1	1,303	1,517	8,935	116.40%
2	884	1,211	7,443	137.06%
3	872	1,407	10,244	161.42%
4	988	1,344	8,951	136.04%
5	724	1,002	6,084	138.38%
6	566	810	4,516	143.19%
7	8,547	7,750	46,724	90.68%
8	2,361	4,565	38,065	193.32%
9	5,458	9,472	50,964	173.54%
10	5,197	9,889	40,495	190.31%
11	9,903	11,957	46,846	120.74%
12	7,188	10,933	51,187	152.09%
13	2,311	3,793	35,349	164.13%
14	770	1,633	14,853	212.09%
15	17,546	8,463	37,534	48.23%
16	1,251	2,558	23,858	204.47%
17	1,504	2,231	14,025	148.41%
18	1,495	3,144	31,265	210.33%
19	1,483	3,304	45,575	222.80%
20	1,067	1,631	12,305	152.89%
21	856	1,131	9,096	132.16%
22	487	968	6,993	198.68%
23	1,687	2,288	10,553	135.60%

Via the coefficient of variation (CV) values, i.e., the ratio of standard deviation and mean, it can be concluded that the variability of the raw material consumption is very high, i.e., is usually greater than one.

Furthermore, the consumption at the beginning of each shift is very high, while it is very low at the end of each shift. The average consumption attains its maximum value at hour 15 (the beginning of the second shift) and get the minimum value at hour 22 (the end of the second shift). This is because the production volumes decrease towards the end of the shifts.

For the periods in which one milk run vehicle is not enough, i.e., the consumption is greater than 10,000 kg; new strategies need to be devised. The maximum value of the maximum consumption is approximately 50 tons indicating that five milk run vehicles are necessary to meet the hourly demands if we opt to transfer the needed materials on the period they are used.

In Table 4.3, the consumptions are given for two-hour intervals. We consider this grouping process in order to smooth the fluctuations in consumption, to better use the milk run vehicle capacity. Otherwise, we need four emergency milk run vehicles with 10 tons capacity to satisfy the maximum hourly consumption amounts in Table 4.2. In Table 4.3, the first two-hour period designates the duration between 00:00 A.M. and 02:00 A.M. Although now periods are twice as long as the previous ones, the maximum of the maximum consumptions do not increase too much. This indicates that high consumptions are usually followed by low consumptions.

It looks like if we work with two-hour periods, the milk runs can be accomplished with fewer vehicles. While capacity is doubled along with the period length, maximum period consumptions increase considerably less than twice.

***Table 4.3 Two-hourly consumption statistics** (0 A.M. - 2 A.M., 2 A.M. – 4 A.M. ,…)*

Period	Average consumption, kg	Standard deviation, kg	Max consumption, kg	CV
1	2,381	2,251	10,582	94.55%
2	1,535	1,800	12,344	117.21%
3	1,536	1,671	10,925	108.83%
4	8,552	7,791	46,756	91.11%
5	7,643	10,098	51,158	132.12%
6	14,499	13,622	48,690	93.96%
7	9,222	11,458	62,306	124.24%
8	17,444	8,983	37,684	51.50%
9	2,613	3,334	26,346	127.60%
10	2,742	4,320	45,575	157.53%
11	1,801	2,022	14,755	112.22%
12	1,917	2,393	10,613	124.84%

In Table 4.4, again the consumptions are merged in order to provide two hour consumptions. However, in contrast to Table 4.3 two-hour periods have different composition. For example, the first two periods designate the duration between 01:00 A.M. and 03:00 A.M. Effectively, the periods are shifted by one hour.

***Table 4.4 Two-hourly consumption statistics** (1 A.M. - 3 A.M., 3 A.M. – 5 A.M. ,…)*

Period	Average consumption, kg	Standard deviation, kg	Max consumption, kg	CV
1	1,981	1,902	9,939	95.97%
2	1,657	1,898	15,525	114.52%
3	902	1,110	6,084	123.08%
4	10,240	8,674	46,835	84.70%
5	10,379	12,620	53,199	121.60%
6	16,547	13,725	54,041	82.95%
7	2,863	4,371	35,429	152.66%
8	18,426	8,823	38,576	47.89%
9	2,849	3,941	31,531	138.33%
10	2,379	3,492	45,575	146.80%
11	1,094	1,381	9,096	126.22%
12	2,383	2,650	14,031	111.20%

Comparing Tables 4.3 and 4.4 with Table 4.2, the variability decreases due to the merging process. For each period, the average consumption amount is less than 20,000 kg that represents the milk run vehicle capacity for two-hour duration.

In Table 4.5, each period corresponds to a shift, i.e., the consumptions are merged in order to provide eight hour consumptions.

Table 4.5 Shiftwise consumption statistics

Period	Average consumption, kg	Standard deviation, kg	Max consumption, kg	CV
1	38,700	17,115	77,397	44.23%
2	24,071	10,400	49,197	43.21%
3	6,041	4,309	25,645	71.34%

When consumptions of each shift are consolidated, Table 4.5 provides that the CV values are considerably smaller than CV values for one-hour and two-hour data (average of periodic CV values for hourly, two-hourly and shiftwise consumptions is 152%, 110% and 53% respectively, i.e., for shiftwise data it is approximately 52% and 65% less than the values for hourly and two-hourly data respectively). As mentioned before, high consumptions are usually followed by low consumptions and this situation creates imbalance. Hence, whenever we consolidate more data by lengthening the period length, CV values decrease as it is seen usually (aggregation decreases variability).

Considering maximum consumption, it can be concluded that one milk run vehicle of 10 tons capacity would be sufficient since maximum consumptions are all less than 80 tons. (One shift consists of eight hours and one milk run vehicle can convey 10 tons of raw materials per hour.)

The above analyses indicate that two milk run vehicles owned by the company are sufficient for the raw materials' transfer regardless of the length of the period.

Currently, in the company the needed raw materials are transferred to the FSAs before the beginning of the shifts according to the shiftwise demands in the picking lists. This policy has some disadvantages. As high amount of raw materials are transferred, capacity of the FSAs may be exceeded. Hence, the raw materials need to be stored outside the FSAs and this situation violates safety rules. Besides, as the raw materials are hilled, it takes the production operators more time to find the needed raw materials. Due to the request of the management and due to the safety risks mentioned above, we will deliver raw materials from the central raw material warehouse to the FSAs hourly.

In order to increase the utilization of the milk run vehicle while meeting the demands without causing halts in the production, we propose a transportation method in which necessary raw materials start to be transported a number of periods before their consumption. Looking into the one-hour consumptions, we prepone our material needs, so that the needed materials are present before their usage period. We call our proposed method as “1+N period method”. The number of periods by which the demand is preponed is determined by finding the smallest preponement amount (N) that is sufficient to keep up with the total periodic consumptions, i.e., the needed material is at the FSA before the production at each period. As the preponement increases, the FSA inventories also increase. But the number of periods in which an emergency transportation is needed decreases. Hence, we try to find the minimum preponement periods that would eliminate the need for emergency transportation.

As mentioned before, we deal with the hourly consumption data covering a year. We also check outliers in consumption and observe that these outliers always occur right after holiday periods. Since a special arrangement is obviously needed for these special periods, we opt to exclude these values from our analysis. Due to this process, we include only 331 days and 7,944 (331*24) periods in our analyses.

First of all, we check the feasibility of “1+2 period method” where N is equal to 2 by taking consumption data during 7,944 periods into consideration. According to this method, at each hour we transport the demands of that period and the subsequent two periods given that the capacity of milk run vehicle is sufficient and the demands of the periods have not been carried beforehand. Hence, this corresponds to the preponement (rescheduling for an earlier time) of two periods.

Table 4.6 Illustration of "1+2 period method"

Year	Month	Day	Hour	consumption, kg	carried - period1	carried - period2	carried - period3	total carried via milk run vehicle	total carried via milk run vehicle and emergency milk run vehicle	shortage? (0:no, 1:yes)
2012	11	10	4	3,823	0	0	150	150	150	0
2012	11	10	5	552	0	0	7,151	7,151	7,151	0
2012	11	10	6	150	0	0	2,206	2,206	2,206	0
2012	11	10	7	7,151	0	0	1,686	1,686	1,686	0
2012	11	10	8	2,206	0	0	10,000	10,000	10,000	0
2012	11	10	9	1,686	0	10,000	0	10,000	10,000	0
2012	11	10	10	35,770	10,000	0	0	10,000	15,770	1
2012	11	10	11	411	411	562	1,176	2,149	2,149	0
2012	11	10	12	562	0	0	0	0	0	0
2012	11	10	13	1,176	0	0	10,000	10,000	10,000	0

In Table 4.6, a 10-hour interval is given an example to illustrate "1+2 period method". 150 kg of raw materials needed for hour 6 have already been transported to the FSAs before hour 4, i.e., two periods before the raw materials are actually needed, to satisfy the consumption amounts at hour 6. Before the beginning of hour 4, as the demands during hour 4 and 5 are already satisfied, only the demands during hour 6 are transported. Although we have excess capacity equal to 9,850 kg for the transportation of hour 4, we do not start transporting the requirement of hour 7 since this would mean a preponement of three periods instead of two which is in use. Consequently, the requirements of period 10 cannot be transported in time, without resorting to an emergency mode. (Although we make this analysis covering 7,944 periods, we only illustrate 10 periods of 7,944 periods for exhibiting an example to the emergency mode.)

If the number of preponement periods is increased from 2 to 3, in this example, the need for an emergency mode to satisfy the consumption of hour 10 would be eliminated.

In the proposed method, whenever the capacity constraint of the milk run vehicle is violated, i.e, shortage occurs; the needed raw materials are transferred by the emergency milk run vehicles (with smaller capacities) before the beginning of the corresponding period in order to prevent halts during production. For this reason, it can be stated that backordering is not allowed and the setting can be categorized as a “lost sales” setting in the inventory literature. APICS defines cost of lost sales as “profit that is foregone because of a stock-out situation”. In our system, in response to the shortages, extra labor and equipment are utilized to fullfill the demand since not fullfilling the requirements is not an option. However, this results in higher transportation costs which can be classified as “lost sales” costs.

Table 4.7 Yearly performance measures for “1+2 period method”

total carried via (regular) milk run vehicle %	97.9%
total carried via emergency milk run vehicle %	2.1%
% of periods with shortage	1.3%
(regular) milk run vehicle utilization %	25.9%

For the selected transportation method, different performance measures are provided in Table 4.7. We calculate the first performance measure by dividing the summation of total carried via milk run vehicle during 7,944 periods by total consumption during 7,944 periods. The second performance measure is obtained by subtracting the value of the first performance measure from 1. By applying this method, 103 emergency milk run vehicle runs are required to satisfy the hourly demands. Hence, we calculate the third performance measure by dividing 103 by 7,944. As mentioned before, the capacity of the milk run vehicle is 10 tons. Thus, up to 79,440 tons of raw materials can be transferred. We calculate the last performance measure by dividing the summation of total carried via (regular) milk run vehicle by 79,440 tons.

Since there are periods in which we need an emergency mode of transportation, we introduce “1+3 period method”. A 10-hour interval is given as an illustration in Table 4.8 showing a case to the compulsory emergency milk run vehicle usage (the row marked with a color). Although the previous consumption pattern of Table 4.6 would not have caused a need for an emergency vehicle under the "1+3 period method", there is a need for the emergency vehicle even used this policy for the consumption pattern in Table 4.8.

Table 4.8 Illustration of "1+3 period method"

Year	Month	Day	Hour	consumption, kg	carried - period1	carried - period2	carried - period3	carried - period4	total carried via milk run vehicle	total carried via milk run vehicle and emergency milk run vehicle	shortage? (0:no, 1:yes)
2013	6	21	10	3,784	0	0	0	10,000	10,000	10,000	0
2013	6	21	11	992	0	0	10,000	0	10,000	10,000	0
2013	6	21	12	931	0	10,000	0	0	10,000	10,000	0
2013	6	21	13	35,349	5,349	80	4,571	0	10,000	10,000	0
2013	6	21	14	80	0	10,000	0	0	10,000	10,000	0
2013	6	21	15	29,839	10,000	0	0	0	10,000	15,267	1
2013	6	21	16	186	186	1,382	234	1,153	2,954	2,954	0
2013	6	21	17	1,382	0	0	0	740	740	740	0
2013	6	21	18	234	0	0	0	356	356	356	0
2013	6	21	19	1,153	0	0	0	0	0	0	0

Performance measures are given in Table 4.9 for "1+3 period method".

Table 4.9 Yearly performance measures for "1+3 period method"

total carried via (regular) milk run vehicle %	100.0%
total carried via emergency milk run vehicle %	0.0%
% of periods with shortage	0.0%
(regular) milk run vehicle utilization %	26.4%

When the "1+3 period method" is used instead of "1+2 period method", number of emergency milk run vehicle runs decreases from 103 to 1 in 7,944 periods. Hence, in just 1 (emergency run) / 7,944 (periods) = 0.01% of the periods, extra labor and equipment are used to satisfy all the requirements before the beginning of the corresponding period. Hence, a preponement of 3 hours would be sufficient to reduce the emergency runs to a minimum that is acceptable by the company.

We repeat this analysis by taking the consumption data between November 2013 and June 2014 into consideration. After excluding the extreme data, according to the proposed "1+3 period method", there is no need for the emergency milk run vehicle and the utilization of the regular milk run vehicle is 28.1%.

Using real consumption data, we simulate the system under our policy using a spreadsheet and obtain the amount of raw materials that are carried to each FSA at each period and the amount of inventory at each FSA at the end of each hour.

Table 4.10 Inventory Statistics of each station / FSA

Station	Average inventory, kg	Std deviation, kg	Maximum inventory, kg	Capacity (pallets)	% capacity violation
Dispersion	549	1,287	10,934	36	0.0%
Waterbased	1,205	3,555	25,974	18	1.1%
Wood	1,019	1,977	17,292	57	0.0%
Common	2,844	4,058	27,780	66	0.0%
Coil	820	1,909	18,510	12	0.3%

The inventory statistics as obtained from the simulation run are given in Table 4.10. At each FSA, there are shelves for storing the raw materials. For this reason, the capacity of each FSA is expressed in terms of pallets. As mentioned before, approximately 1,000 kg of material can be stored on each pallet. According to this, it is concluded that the capacity is exceeded in Waterbased and Coil FSA's in case of reaching maximum inventories in these places. In the rare occasions in which FSA capacity is not sufficient, the problem is only for a short duration since the excess material is to be immediately used in production. Currently, three shelves are put over and over. For handling the problem related with capacity violation, usage of four shelves over and over may be looked into or capacity of the nearest FSA may be used for a short duration.)

Table 4.11 Allocation of the milk run capacity between different stations

						Carriage amounts via milk run vehicle per station, kg				
Year	Month	Day	Hour	Consumption, kg	Total carriage amount, kg (milk run vehicle and emergency milk run vehicle)	Dispersion	Waterbased	Wood	Common	Coil
2013	6	21	0	143	1,503	0	0	0	1,503	0
2013	6	21	1	527	46	46	0	0	0	0
2013	6	21	2	0	1,179	0	0	0	1,179	0
2013	6	21	3	1,503	0	0	0	0	0	0
2013	6	21	4	46	1,066	661	106	7	243	49
2013	6	21	5	1,179	362	20	0	7	276	60
2013	6	21	6	0	3,154	40	0	357	2,758	0
2013	6	21	7	1,066	3,784	2,185	0	182	1,256	161
2013	6	21	8	362	992	0	0	350	641	0
2013	6	21	9	3,154	931	25	0	207	699	0
2013	6	21	10	3,784	10,000	7	5,016	718	49	4,209
2013	6	21	11	992	10,000	7	5,016	718	49	4,209
2013	6	21	12	931	10,000	7	5,016	718	49	4,209
2013	6	21	13	35,349	10,000	488	2,722	478	2,514	3,798
2013	6	21	14	80	10,000	1,060	84	204	5,279	3,372
2013	6	21	15	29,839	15,267	1,618	129	312	8,060	5,149
2013	6	21	16	186	2,954	130	0	0	2,824	0
2013	6	21	17	1,382	740	0	252	0	479	10
2013	6	21	18	234	356	0	180	0	170	6
2013	6	21	19	1,153	0	0	0	0	0	0
2013	6	21	20	740	3	0	0	0	3	0
2013	6	21	21	356	445	0	0	0	445	0
2013	6	21	22	0	252	0	252	0	0	0
2013	6	21	23	3	0	0	0	0	0	0

In Table 4.11, the illustration of what we propose in order to allocate the transported amounts among FSAs is given. If the capacity of the regular milk run vehicle is sufficient to satisfy the hourly demands completely, there isn't any allocation problem. However, when the capacity of the milk run vehicle is exceeded, we propose that the capacity is allocated between different FSAs considering the demand ratios.

In order to clarify our allocation scheme, we will focus on the consumption date 2013/6/21/10 (year/month/day/hour). As the hourly demand of periods 10, 11 and 12 are already carried at the previous periods, only the requirements of period 13 can be carried according to the 1+3 period transportation method. However, these requirements (35,349 kg) are greater than 10,000 kg. Thus, the capacity of the milk run vehicle is exceeded; and only 10,000 kg of 35,349 kg can be carried. We determine the distribution amounts in terms of stations by taking the total demands of each station at hour 13 into consideration. In Table 4.12, we show how the allocation quantities are determined for period 10.

Table 4.12 Illustration of rationing between FSAs

Station	Demand, kg	Demand, %	Carriage amounts, kg (according to 10,000 kg's capacity)
Dispersion	25	0%	7
Waterbased	17,732	50%	5,016
Wood	2,539	7%	718
Common	173	0%	49
Coil	14,880	42%	4,209
Total	35,349	100%	10,000

In the scope of this study, two groups of raw materials, namely weighed and unweighed are dealt with. We have three different transportation types for transfering these raw materials. The first transportation type is for unweighed raw materials and they are transferred in amounts equal to the multiples of their standart package sizes. For weighed raw materials, we have two different transportation types. If weighed raw materials are in the picking lists, they are brought to the FSAs in amounts exactly equal to the amounts in the picking lists. Weighed materials' ,i.e., that are one of the FSIs, demands are transferred again like the transportation type for unweighed raw materials.

As we have to transfer the raw materials more than their necessary amounts in two of the three transportation types, we update the consumptions according to the determined transportation type. In Table 4.13 an illustration is given for unweighed raw materials.

Table 4.13 Illustration to the transportation amount for unweighed RM

Raw Material Code	Planned, kg	Consumed, kg	Month	Day	Hour	Standard Package Size, kg	FSA	Cumulative consumed	Cumulative transported	Periodic transported	Periodic transported and consumed difference	Cumulative transported and consumed difference
RAW MATERIAL-00140	27.15	27.2	11	3	8	240	Common	27	240	240	213	2,571
RAW MATERIAL-00140	59.1	0	1	17	4	240	Common	27	240	0	0	2,571
RAW MATERIAL-00140	61.25	0	1	30	3	240	Common	27	240	0	0	2,571
RAW MATERIAL-00140	60.25	0	2	5	20	240	Common	27	240	0	0	2,571
RAW MATERIAL-00143	213.35	213.35	12	24	15	210	Wood	213	420	420	207	2,778
RAW MATERIAL-00143	187.25	187.25	1	10	18	210	Wood	401	420	0	-187	2,590
RAW MATERIAL-00143	183.55	183.55	1	11	15	210	Wood	584	630	210	26	2,617
RAW MATERIAL-00143	24.15	24.2	9	19	9	210	Wood	608	630	0	-24	2,593
RAW MATERIAL-00143	500	500	11	7	7	210	Coil	500	630	630	130	2,723
RAW MATERIAL-00143	520	520	11	7	17	210	Coil	1,020	1,050	420	-100	2,623
RAW MATERIAL-00143	520	520	11	7	19	210	Coil	1,540	1,680	630	110	2,733
RAW MATERIAL-00143	520	520	11	8	11	210	Coil	2,060	2,100	420	-100	2,633
RAW MATERIAL-00143	520	520	11	17	7	210	Coil	2,580	2,730	630	110	2,743
RAW MATERIAL-00143	520	520	11	17	11	210	Coil	3,100	3,150	420	-100	2,643
RAW MATERIAL-00143	520	520	11	17	18	210	Coil	3,620	3,780	630	110	2,753
RAW MATERIAL-00143	520	520	11	22	12	210	Coil	4,140	4,200	420	-100	2,653
RAW MATERIAL-00143	520	520	11	23	7	210	Coil	4,660	4,830	630	110	2,763
RAW MATERIAL-00143	500	500	11	23	8	210	Coil	5,160	5,250	420	-80	2,683
RAW MATERIAL-00143	520	520	11	23	18	210	Coil	5,680	5,880	630	110	2,793
RAW MATERIAL-00143	520	520	11	24	9	210	Coil	6,200	6,300	420	-100	2,693
RAW MATERIAL-00143	520	520	12	4	0	210	Coil	6,720	6,720	420	-100	2,593
RAW MATERIAL-00143	520	520	12	4	8	210	Coil	7,240	7,350	630	110	2,703
RAW MATERIAL-00143	1,026.55	1,027	12	4	22	210	Coil	8,267	8,400	1,050	23	2,726
RAW MATERIAL-00143	520	520	12	12	7	210	Coil	8,787	8,820	420	-100	2,626
RAW MATERIAL-00143	520	520	12	12	9	210	Coil	9,307	9,450	630	110	2,736
RAW MATERIAL-00143	520	520	12	13	7	210	Coil	9,827	9,870	420	-100	2,636
RAW MATERIAL-00143	500	600	12	17	20	210	Coil	10,427	10,500	630	30	2,666

Although the demand for the SKU of raw material-00140 at the Common FSA is equal to 27.2 kg, 240 kg (the standard package size of this SKU) of raw material are transported at the beginning of the 8th hour 03.11.2012, i.e., the first period. In the second period, nothing is transferred for this SKU as the remaining part from the 240 kg transported before the beginning of the first period compensates for the demands during the second period of this SKU.

According to the yearly data, 7,809 tons of unweighed raw materials are transported while 7,736 tons of them are consumed. Hence, 73 tons of unweighed raw materials will be stored at the FSAs if we do not remove the excess raw materials.

In Table 4.14 an illustration is given for weighed raw materials.

Table 4.14 Illustration to the transportation amount for weighed RM

Raw Material Code	Planned, kg	Consumed, kg	Month	Day	Hour	Standard Package Size, kg	FSA	Cumulative consumed	Cumulative unplanned consumptions	Cumulative transported	Periodic transported	Periodic transported and consumed difference	Cumulative transported and consumed difference
RAW MATERIAL-00882	363.05	363.05	11	13	15	25	Dispersion	363	0	363	363	0	84,543
RAW MATERIAL-00882	28.05	28.05	11	15	15	25	Dispersion	391	0	391	28	0	84,543
RAW MATERIAL-00882	0	52.55	11	17	7	25	Dispersion	391	53	466	75	22	84,566
RAW MATERIAL-00882	326.1	326.1	11	19	15	25	Dispersion	717	53	792	326	0	84,566
RAW MATERIAL-00882	28.05	28.05	11	21	15	25	Dispersion	745	53	820	28	0	84,566
RAW MATERIAL-00882	327.5	327.5	12	6	15	25	Dispersion	1,073	53	1,148	328	0	84,566
RAW MATERIAL-00882	186.95	186.95	12	10	15	25	Dispersion	1,260	53	1,335	187	0	84,566
RAW MATERIAL-00882	350	350	12	22	15	25	Dispersion	1,610	53	1,685	350	0	84,566
RAW MATERIAL-00882	2.6	2.6	1	12	15	25	Dispersion	1,612	53	1,687	3	0	84,566
RAW MATERIAL-00882	0	52.55	1	25	15	25	Dispersion	1,612	105	1,737	50	-3	84,563
RAW MATERIAL-00882	300	300	1	28	19	25	Dispersion	1,912	105	2,037	300	0	84,563
RAW MATERIAL-00882	300	300	1	30	14	25	Dispersion	2,212	105	2,337	300	0	84,563
RAW MATERIAL-00882	300	300	2	21	14	25	Dispersion	2,512	105	2,637	300	0	84,563
RAW MATERIAL-00882	300	300	2	27	15	25	Dispersion	2,812	105	2,937	300	0	84,563
RAW MATERIAL-00882	300	300	3	12	12	25	Dispersion	3,112	105	3,237	300	0	84,563
RAW MATERIAL-00882	300	300	3	23	15	25	Dispersion	3,412	105	3,537	300	0	84,563
RAW MATERIAL-00882	2.6	2.6	3	28	15	25	Dispersion	3,415	105	3,540	3	0	84,563
RAW MATERIAL-00882	300	300	4	5	15	25	Dispersion	3,715	105	3,840	300	0	84,563
RAW MATERIAL-00882	36.95	36.95	4	13	15	25	Dispersion	3,752	105	3,877	37	0	84,563
RAW MATERIAL-00882	300	300	4	16	7	25	Dispersion	4,052	105	4,177	300	0	84,563
RAW MATERIAL-00882	300	300	5	10	12	25	Dispersion	4,352	105	4,477	300	0	84,563
RAW MATERIAL-00882	34.9	34.9	5	14	15	25	Dispersion	4,387	105	4,512	35	0	84,563
RAW MATERIAL-00882	300	300	5	23	15	25	Dispersion	4,687	105	4,812	300	0	84,563
RAW MATERIAL-00882	70	70	5	24	7	25	Dispersion	4,757	105	4,882	70	0	84,563
RAW MATERIAL-00882	528.75	528.75	5	31	15	25	Dispersion	5,286	105	5,411	529	0	84,563

In Table 4.14, raw material-00082 at the Dispersion FSA is consumed more than its planned amount by 53 kg at the third period. The standard package size of this raw material is equal to 25 kg. As mentioned before FSIs that are consumed more than their planned amounts are transferred in amounts equal to the multiples of their standard package sizes. Thus, 75 kg of raw material-00082 are brought to the Dispersion FSA. The remaining 22 kg of raw material-00082 are seperated for the coming excess usages, i.e., each excess usage does not trigger an extra transportation.

According to the yearly data, 10,073 tons of unweighed raw materials are transported while 9,931 tons of them are consumed. Hence, 142 tons of unweighed raw materials will be stored at the FSAs if we do not remove the excess raw materials.

To sum up 215 tons of raw materials, i.e., both weighed and unweighed raw materials will be stored at the FSAs if we don’t remove the excess materials. As the total capacity of FSAs is approximately 190 tons, we do have to remove some of them, i.e., especially the ones that will not be used in the coming three months.

Due to the necessities mentioned above, we have to increase the transportation amounts by taking the standard package sizes of the raw materials into consideration. As the transportation amounts increase, we check whether our “1+3 period method” works well or not. Due to the stated change, number of emergency milk run vehicle runs increases from 1 to 20. In this case, a preponement of 3 hours would not be sufficient as number of 20 emergency milk run vehicle runs is greater than the acceptable runs determined by the company (at most %0.1 of the periods, i.e., 7,944*0.001 = ~8).

To handle these, we propose “1+4 period method”. By this method, number of emergency milk run vehicle drops to 1 again. The “1+4 period method” is illustrated in the following Table 4.15.

Table 4.15 Illustration of “1+4 period method”

Year	Month	Day	Hour	consumption, kg	carried - period 1	carried - period 2	carried - period 3	carried - period 4	carried - period 5	total carried via milk run vehicle	total carried via milk run vehicle and emergency milk run vehicle	shortage? (0:no, 1:yes)
2013	2	22	18	1,171	1,171	6,953	540	439	897	10,000	10,000	0
2013	2	22	19	6,953	0	0	0	1,383	1,336	2,719	2,719	0
2013	2	22	20	540	0	0	0	0	45	45	45	0
2013	2	22	21	439	0	0	0	0	285	285	285	0
2013	2	22	22	2,280	0	0	0	0	1,230	1,230	1,230	0
2013	2	22	23	1,336	0	0	0	0	0	0	0	0
2013	2	23	0	45	0	0	0	0	0	0	0	0
2013	2	23	1	285	0	0	0	0	0	0	0	0
2013	2	23	2	1,230	0	0	0	0	0	0	0	0
2013	2	23	3	0	0	0	0	0	10,000	10,000	10,000	0
2013	2	23	4	0	0	0	0	10,000	0	10,000	10,000	0
2013	2	23	5	0	0	0	10,000	0	0	10,000	10,000	0
2013	2	23	6	0	0	10,000	0	0	0	10,000	10,000	0
2013	2	23	7	53,749	10,000	0	0	0	0	10,000	13,749	1
2013	2	23	8	0	0	7,428	1,659	913	0	10,000	10,000	0
2013	2	23	9	7,428	0	0	39	4,525	440	5,004	5,004	0
2013	2	23	10	1,659	0	0	0	0	1,010	1,010	1,010	0
2013	2	23	11	952	0	0	0	0	2,948	2,948	2,948	0

It is obvious that the periodic consumptions of 50 tons or more always lead to an emergency milk run vehicle run due to the milk run vehicle capacity of 10 tons. Between November 2012 and October 2013, there is only one period with a consumption amount of 50 tons or more. Thus, we can conclude that other periodic consumptions of less than 50 tons do not lead to the usage of an emergency milk run vehicle.

Performance measures are given in Table 4.16 for “1+4 period method”.

Table 4.16 Performance measures for “1+4 period method”

total carried via (regular) milk run vehicle %	100.0%
total carried via emergency milk run vehicle %	0.0%
% of periods with shortage	0.0%
(regular) milk run vehicle utilization %	27.8%

Comparing with the performance measures for “1+3 period merhod” in Table 4.9, it is seen that regular milk run vehicle utilization ratio increases from 26.4% to 27.8%. This is due to the increase in both the preponement period and the transportation amounts.

While applying the “1+2 period method”, “1+3 period method” and “1+4 period method”, we consider the capacity constraint of the milk run vehicle in terms of kilograms. However, the raw materials are transferred on pallets. The weighed raw materials of each batch need to be transferred on separate pallets. Currently available tractors will be used as milk run vehicles. Although there is a spacial capacity of 10 pallets for the tractor trailers, the capacity that really matters is the weight capacity that is 10 tons. Even if the spacial capacity is exceeded, it is possible to accommodate this situation by adding another trailer to the tractor.

CHAPTER 5

INVENTORY POLICY

APICS defines inventory as “stock or item used to support production (raw materials and work-in-process items), supporting activities (maintenance, repair, and operating supplies), and customer service (finished goods and spare parts).” Demand for inventory may be dependent or independent. Many policies are developed to regulate inventories by determining inventory replenishment times and quantities. Four inventory control policies are widely scrutinized and analyzed in the literature. These are (*s,Q*), (*s,S*), (*R,S*) and (*R,s,S*) policies. (Silver, E. A., Pyke, D. F. and Peterson, R.,1998, 237-241). [10]

The (*s,Q*) policy is usually applied within a continuous review system where the review period *R* is equal to 0. Whenever the inventory position drops to the reorder point *s* or lower, a fixed quantity *Q* is ordered. The advantage of this policy arises from its simplicity. Whenever individual demands are larger than *Q*, inventory position could not be raised above *s*. However, to handle this disadvantegous situation, an integer multiple of *Q* could be ordered.

The (*s,S*) policy is a continuous review system where the review period *R* is equal to 0. Whenever the inventory position drops to the reorder point *s* or lower, it is raised to the order-up-to-level *S*. Whenever all individual demands are unit-sized, this system is the same with the previous (*s,Q*) policy. This policy is more preferable for managing the inventory of especially A items whose potential savings are appreciable. policy is more preferable for managing the inventory of especially A items whose potential savings are appreciable. However, usually (*s,*Q) policy is more favorite as it is an easier policy for the suppliers due to invariable and predictable order quantities.

(*R,S*) policy is a periodic review system. Every *R* units of time, the inventory position is raised to the level *S*. This policy is preferable when items are ordered from the same supplier. The advantage of this policy arises from the savings in the shipping cost and its capability for handling with the variable demand pattern. The disadvantage of this policy is higher carrying costs with respect to the continuous review systems.

(*R,s,S*) policy is a combination of (*s,S*) and (*R,S*) policies. Every R units of time, the inventory position is raised to the level *S* if it is at or below the reorder point *s*. If it is not, nothing is done. Especially for A items, this policy is better due its advantages in total costing issues for periodic review systems.

As mentioned before, the management would like a fixed cycle time of one hour for operational simplicity. Hence, we do not use *R* as a control parameter in our proposed system. For this reason, the third and the fourth control policies are not suitable for us. Besides, the warehousing department does not prefer variable order quantities due to long weighing processes. If fixed order quantity is used, the operator does not need to weigh any raw material to reach a determined exact amount and this provides the operator to use his labor in more fundamental areas.

For all the reasons mentioned above, in the scope of this thesis, an (*s,Q*) inventory policy is adapted for reducing the number of shortages during production. Although in the literature, this policy is usually associated with the continuous review model, we adapt this policy to the periodic review setting.

In the company, during the production of an order, some materials may be used more than the amounts determined according to the product formulas. But as mentioned before, with the help of substitution, this situation does not mean a definite halt. In order to observe this behaviour, we analyze the consumptions in terms of production batches. To that purpose, firstly we exclude the raw materials that are substituted by others from our excess usage data. Because when there is a shortage of the needed material at the central warehouse, this material is substituted by an equivalent material at the planning stage without causing an interruption during the production.

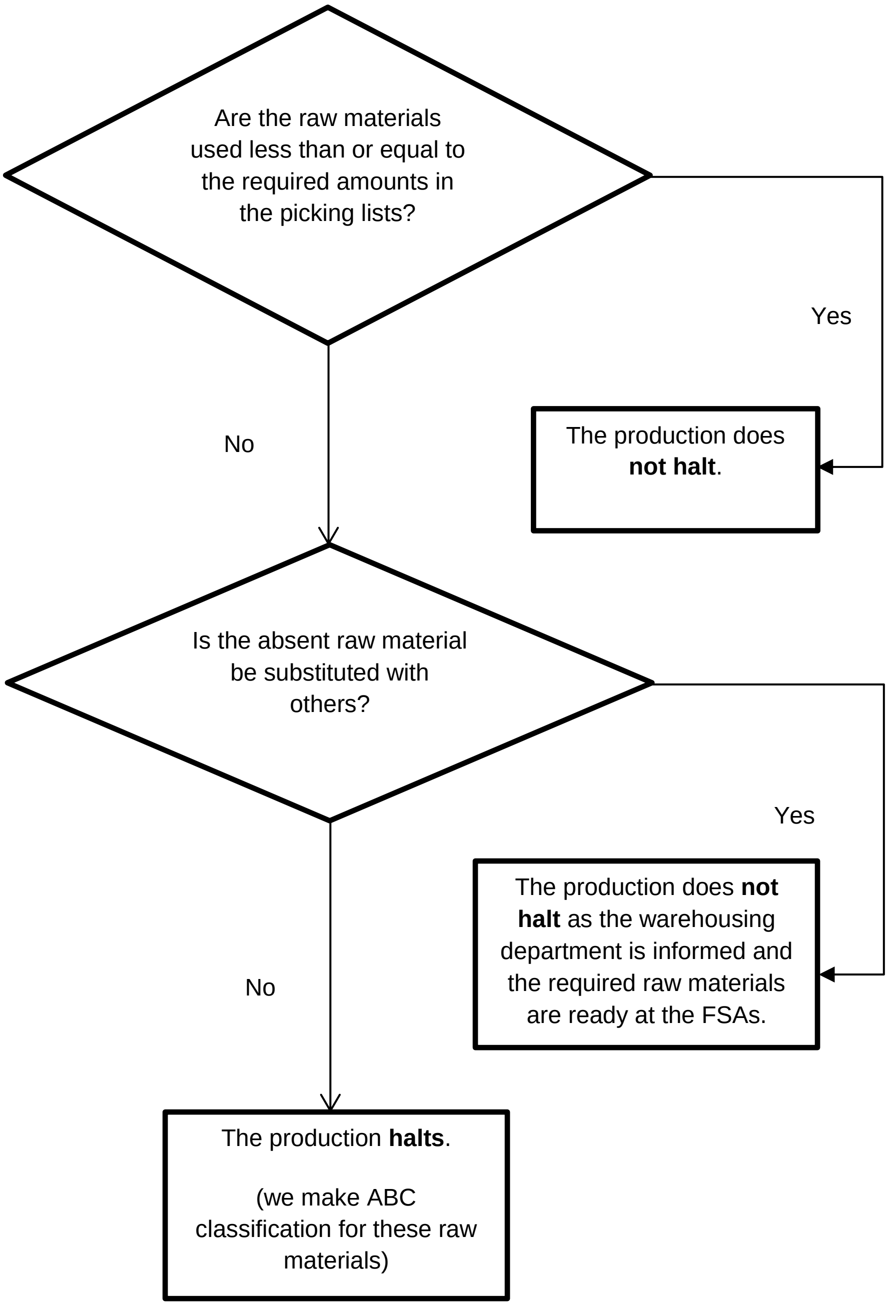


Figure 5.1 Flow chart about excess usage and substitution effect

We first present ABC classification for the raw materials that are used more than their planned amounts, without excluding the substitutions, considering the formula of the production batches. APICS defines ABC classification as, "The classification of a group of items in decreasing order of annual dollar volume (price multiplied by projected volume) or other criteria". [1] Here, as it is mentioned in the previous definiton, we determine other criterion (the number of excess usages) rather than using criterion related with value.

Firstly, the raw materials are sorted according to their number of excess usages from largest to smallest. Then we calculate the excess usage ratios of each raw material by looking at the overall excess usage occasions to understand which raw materials are more likely for being used more than their planned amounts. After this process, we obtain the cumulative excess usage ratios. The raw materials that are in the first 80% are classified as A class raw materials, the raw materials that are in the first 15% of the remaining 20% are classified as B class raw materials and the others are classified as C class raw materials.

Table 5.1 Excess usage for each raw material

Raw material code	Number of excess usages per production order	excess usage %	Cumulative excess usage %	ABC	Can be substituted?	Can substitute?
RAW MATERIAL-00165	1,165	4%	4%	A	YES	YES
RAW MATERIAL-00723	1,013	4%	8%	A	NO	NO
RAW MATERIAL-00697	932	4%	12%	A	NO	NO
RAW MATERIAL-00384	904	3%	15%	A	NO	YES
RAW MATERIAL-00442	720	3%	18%	A	YES	YES
RAW MATERIAL-03182	668	3%	21%	A	YES	YES
RAW MATERIAL-00135	616	2%	23%	A	YES	YES
RAW MATERIAL-00722	598	2%	25%	A	YES	YES
RAW MATERIAL-00425	581	2%	27%	A	YES	YES
RAW MATERIAL-00660	499	2%	29%	A	NO	NO
RAW MATERIAL-00389	467	2%	31%	A	NO	YES
RAW MATERIAL-00388	457	2%	33%	A	YES	YES
RAW MATERIAL-01230	430	2%	34%	A	NO	NO
RAW MATERIAL-00383	413	2%	36%	A	NO	NO
RAW MATERIAL-00382	377	1%	37%	A	NO	NO
RAW MATERIAL-00371	335	1%	39%	A	NO	NO
RAW MATERIAL-00701	328	1%	40%	A	YES	NO
RAW MATERIAL-03016	326	1%	41%	A	NO	NO
RAW MATERIAL-00631	312	1%	42%	A	YES	YES
RAW MATERIAL-00713	308	1%	44%	A	NO	NO
RAW MATERIAL-03018	295	1%	45%	A	NO	YES
RAW MATERIAL-00400	294	1%	46%	A	NO	NO
RAW MATERIAL-03035	280	1%	47%	A	NO	NO
RAW MATERIAL-00386	278	1%	48%	A	NO	NO
RAW MATERIAL-00611	263	1%	49%	A	NO	NO
RAW MATERIAL-00416	258	1%	50%	A	YES	YES

In Table 5.1, only the raw materials that are in the first 50% are tabulated since the full table consists of 641 raw materials. The excess usage ratio for raw material-00165 is obtained by dividing 1,165 by 26,281 which corresponds to the overall excess usage occasions. Here, 1,165 means that raw material-00165 is used more than its planned amount in 1,165 different production orders. Whereas 26,281 does not mean that one raw material is used more than its planned amount in 26,281 different production orders as more than one raw material can be used more than the planned amounts. Note that Table 5.1 does not exclude the substitution effect. But as mentioned before, some raw materials may be substitued by another raw materials as their chemical properties are similar with each other. As the warehousing department is informed about the substitution, this effect needs to be excluded and we update the table about excess usage occasions. In Table 5.2, the updated results are given.

Table 5.2 Excess usage for each raw material - Updated

Raw material code	Number of excess usages per production order	excess usage %	Cumulative excess usage %	ABC	Can be substituted?	Can substitute?
RAW MATERIAL-00165	1,122	5%	5%	A	YES	YES
RAW MATERIAL-00723	1,013	5%	10%	A	NO	NO
RAW MATERIAL-00697	932	4%	14%	A	NO	NO
RAW MATERIAL-00384	904	4%	18%	A	NO	YES
RAW MATERIAL-00722	593	3%	21%	A	YES	YES
RAW MATERIAL-00660	499	2%	24%	A	NO	NO
RAW MATERIAL-00389	467	2%	26%	A	NO	YES
RAW MATERIAL-00388	457	2%	28%	A	YES	YES
RAW MATERIAL-01230	430	2%	30%	A	NO	NO
RAW MATERIAL-00383	413	2%	32%	A	NO	NO
RAW MATERIAL-00382	377	2%	34%	A	NO	NO
RAW MATERIAL-00371	335	2%	35%	A	NO	NO
RAW MATERIAL-00701	328	2%	37%	A	YES	NO
RAW MATERIAL-03016	326	2%	38%	A	NO	NO
RAW MATERIAL-00713	308	1%	40%	A	NO	NO
RAW MATERIAL-03018	295	1%	41%	A	NO	YES
RAW MATERIAL-00400	294	1%	42%	A	NO	NO
RAW MATERIAL-00631	282	1%	44%	A	YES	YES
RAW MATERIAL-03035	280	1%	45%	A	NO	NO
RAW MATERIAL-00386	278	1%	46%	A	NO	NO
RAW MATERIAL-00611	263	1%	47%	A	NO	NO
RAW MATERIAL-00416	258	1%	49%	A	YES	YES
RAW MATERIAL-00220	252	1%	50%	A	NO	NO
				A		
				A		
				B		
				B		
				C		
				C		
RAW MATERIAL-00442	1	0%	100%	C	YES	YES

Comparing the results in Table 5.1 and 5.2, there is a remarkable change in the ABC class of raw material-00442. In Table 5.1, it is the fifth from the top raw material in the list of materials used more than their planned amounts with 720 excess usages. But after taking the substitution effect into consideration, excess usage decreases to just 1. This occurs as raw material-00442 substitutes raw material-01707 and raw material-01700 in 719 of the production orders. If this is not taken into account, the ABC class of the raw material-00442 will be A instead of C. The A class raw materials are defined as the potential FSIs as they are usually used more than planned (taking into account the substitutions) and hence we decide to develop inventory policies for these raw materials to reduce the number of halts during production. Following these analyses, we also check the results of another method, that is inspired by the company's practice, for the validation of our method while determining the FSIs. In the second method, we have three criteria. The first criterion is that the raw materials are counted minimum five times at minimum one of the FSAs during the last eight counting periods (every four months). The second criterion is that coefficient of variation values that are calculated according to the monthly consumptions of each raw material during a year are less than 1. The third criterion is that the raw materials are not transported through the pipelines since pipeline materials do not need to be stocked. Both methods (ABC classification according to the excess usages and the opinion of the experts in the company) yield similar results.

According to the periodic excess usage amounts after taking the substitution effect into consideration, we determine the parameters of the (*s,Q*) policy for each stock keeping unit (SKU) that is used more than planned at least at one of the production batches. Although two raw materials are the same in terms of their chemical properties, they are defined as two different SKUs if they are stored at different FSAs. APICS also defines SKU as "in a distribution system, an item at a particular geographic location". The excess usage amounts of each SKU in terms of kg's are sorted from smallest to largest per period. In the case that an SKU is not consumed more than its planned amount in a period, we take the excess usage amount as "0". As mentioned before, we propose the (*s,Q*) inventory policy adapted for the periodic review model. The FSIs are transported in their standard packages whose sizes are considerably higher than their periodic consumptions. Hence, we need to use a constant replenishment quantity, *Q*. We also have to trigger these constant size replenishments when the floor stock for the item goes below a level that may cause shortages. Here, s is the reorder point and *Q* is the standard package size of each SKU.

In the literature, there are two common types of service measures that are P_1 and P_2. P_1 service measure is the fraction of ordering cycles in which a stockout does not occur. Whenever the on-hand stock drops to zero, a stockout occurs. P_2 service measure is the fraction of customer demand that is met without experiencing a shortage. (Silver, E. A., Pyke, D. F. and Peterson, R. ,1998, 298-300). [10]

In our thesis, we propose a similar service measure that is more appropriate for the setting. This is the fraction of cycles without lost sales (since shortages are always satisfied through an emergency channel, these should be categorized as shortages from the perspective of the regular channel)). P_2 service measure is closely related with our measure. If the demand due to the excess usages was stationary, it would exactly fit P_2 service measure. However, our objective is intentionally based on shortage periods and not the quanties. Every shortage causes a halt in the production. Whether this is due to the lack of 0.1 kg of raw material or 10,000 kg of raw material does not make any difference from our perspective. Our service measure is basically the percentage of periods in which the SKU in question does not cause a halt in production.

We first experiment with service levels of 95% and 99% for each SKU for this policy. Table 5.3 illustrates how we calculate *s* value for the SKU raw material-00054common (raw material code and FSA name). *Q* (standard package size) is a parameter, hence we do not calculate it.

Table 5.3 Illustration of s value calculation

SKU	Excess usage amounts,kg (sorted)	Period (not sorted)	Month	Day	Hour
RAW MATERIAL-00054Common	0	1	1	1	0
RAW MATERIAL-00054Common	0	2	1	1	1
RAW MATERIAL-00054Common	0	.			
RAW MATERIAL-00054Common	0	.			
RAW MATERIAL-00054Common	0	7547	1	1	2
RAW MATERIAL-00054Common	0	.			
RAW MATERIAL-00054Common	0	.			
RAW MATERIAL-00054Common	0	7927	1	1	3
RAW MATERIAL-00054Common	0.05	7928	4	25	10
RAW MATERIAL-00054Common	0.05	7929	6	28	12
RAW MATERIAL-00054Common	0.05	7930	7	27	14
RAW MATERIAL-00054Common	0.05	7931	9	25	15
RAW MATERIAL-00054Common	0.25	7932	6	14	20
RAW MATERIAL-00054Common	0.55	7933	2	28	12
RAW MATERIAL-00054Common	0.75	7934	4	21	0
RAW MATERIAL-00054Common	2.55	7935	10	3	14
RAW MATERIAL-00054Common	4.2	7936	8	3	19
RAW MATERIAL-00054Common	15	7937	4	11	10
RAW MATERIAL-00054Common	20.2	7938	4	29	15
RAW MATERIAL-00054Common	35	7939	11	22	13
RAW MATERIAL-00054Common	39	7940	11	12	15
RAW MATERIAL-00054Common	43.2	7941	11	8	21
RAW MATERIAL-00054Common	50	7942	5	31	20
RAW MATERIAL-00054Common	50.05	7943	8	17	8
RAW MATERIAL-00054Common	50.4	7944	9	13	19

The analyzed horizon consists of 7,944 periods. In Table 5.3, excess usage amounts are greater than zero in only 17 periods while in the remaining 7,927 periods they are all zero. For attaining 95% service level, we should have inventory at least equal to the excess usage amount at the 7,547th (7,944*0.95=7,547) period (row). Thus, *s* value for this SKU is equal to zero. As no inventory is kept for this SKU, in 0.2% (17/7,944) of the periods, the production halts due to the shortage of this SKU.

We make such *s* value calculations for each SKU. The *s* values get zero values for the SKUs that are not used more than their planned amounts in more than 417 (7,944-7,547) periods. We do not keep inventory for each

SKU. Lack of inventory of the non FSIs, i.e., items having *s* values equal to zero, does not trigger the inventory replenishment, *Q*. Because, although no inventory is kept for the non FSIs, the determined service level is satisfied. The results for each SKU ,i.e., SKUs having nonzero *s* values, are given in Table 5.4.

Table 5.4 s and Q values for 95% service level

Raw Material (RM) Code	FSA	s value, kg	Q value, kg (standard package size)	Average inventory (s+Q/2)	Maximum inventory (s+Q)	ABC Class of RM
RAW MATERIAL-00165	Coil	0.002	240.000	120.001	240.002	A
RAW MATERIAL-00165	Common	0.050	240.000	120.025	240.050	A
RAW MATERIAL-00722	Common	0.017	20.000	10.009	20.017	A
RAW MATERIAL-00723	Common	0.010	190.000	95.005	190.010	A

After calculating *s* values for each SKU, average and maximum inventories are calculated for each FSA. The results are given in Table 5.5. The average inventory for each SKU and FSA is calculated with respect to the assumption of linear consumptions.

Table 5.5 Inventory statistics for 95% service level

FSA	Average inventory (s+Q/2)	Maximum inventory (s+Q)
Coil	120.001	240.002
Common	225.039	450.077

As mentioned before, the total capacity of five FSAs is approximately 190 tons. In Table 5.5, it is seen that approximately only 690 kg's of the total capacity (0.36%) is used for the FSIs. Hence, we can safely try to satisfy higher service levels. We next consider the policy under 99% service level. Here, for attaining 99% service level, we should have inventory at least equal to the excess usage amount at the 7,865th (7,944*0.99=7,865) period (row). We determine that we need to keep floor stocks for 50 SKU's to achieve a

99% service level. Inventory statistics for 99% service level at each FSA are given in Table 5.6.

Table 5.6 Inventory statistics for 99% service level

FSA	Average inventory,kg (s+Q/2)	Maximum inventory,kg (s+Q)	FSA Capacity, kg	FSA Capacity usage %
Wood	93.0	186.1	57,000.0	0.3%
Coil	418.0	836.1	12,000.0	7.0%
Dispersion	190.1	380.1	36,000.0	1.1%
Common	2,777.7	5,555.4	66,000.0	8.4%
Waterbased	515.0	1,030.0	18,000.0	5.7%

Considering the maximum inventories at each FSA, again the capacity usage ratios due to the inventory policies developed for the FSIs are still very low. For this reason, we next consider the implementation of 99.9% service level for each SKU. In this implementation, for attaining 99.9% service level, we should have inventory at least equal to the excess usage amount at the 7,937th (7,944*0.999=7,937) period (row).

Inventory statistics for 99.9% service level at each FSA according to the yearly consumptions are given in Table 5.7.

Table 5.7 Inventory statistics for 99.9% service level

FSA	Average inventory,kg (s+Q/2)	Maximum inventory,kg (s+Q)	FSA Capacity, kg	FSA Capacity usage %
Wood	4,484.8	8,969.6	57,000.0	15.7%
Coil	4,134.8	8,269.6	12,000.0	68.9%
Dispersion	2,649.7	5,299.4	36,000.0	14.7%
Common	15,526.0	31,052.0	66,000.0	47.0%
Waterbased	2,689.7	5,379.4	18,000.0	29.9%

As capacity usage ratios are substantial at this service level at each FSA, i.e., especially Coil FSA, we do not consider higher levels.

We develop inventory policies for only FSIs but we transport all the raw materials (except the pipeline raw materials) via milk run vehicle and store all the raw materials (except the pipeline raw materials), i.e., FSIs and the ones in the picking lists, at the FSAs. Hence, we also need to allocate some capacity at each FSA for the regular usage of the raw materials that are brought to FSAs according to their formulas (for the required amounts in the picking lists).

If we take up the capacity of each FSA just for the FSIs, then we cannot store the other raw materials at the FSAs. In order to prevent the capacity violation of each FSA, we will use the ABC class information (using the results of the ABC classification analysis done according to the number of excess usages) of each FSI for the storage.

First of all, we will store the necessary raw materials that are in the picking lists. Then, we will give priority to A class raw materials for the extra storage via taking the results of the proposed inventory policy into consideration.

For achieving 99.9 service level, we need to keep inventory at one of the FSAs for 344 FSIs. In Table 5.8, it is seen that 161, 165 and 18 FSIs are in the A,B and C class respectively. Considering the maximum inventory levels, i.e., the summation of *s* and *Q* values for each SKU, A, B and C class FSIs take up 59%, 38% and 3% of the total FSA usage amounts (capacity dedicated for excessively used raw materials)

Table 5.8 Inventory allocations to ABC Class of FSIs for 99.9% service level

ABC Class of FSIs	Maximum inventory allocation	Number of FSI's
A class FSIs	59%	161
B class FSIs	38%	165
C class FSIs	3%	18

In the scope of this thesis, number of halts during production is tried to be minimized. For this reason, in this chapter we propose inventory policies for the FSIs that are used more than the planned amounts and that usually cause halts due to shortages.

49,322 production orders are produced during November 2012 and October 2013. Currently, 9,506 of the 49,322 production orders is halted due to the shortages (19.3%). We check whether our proposed method gives better results or not.

Firstly, the periodic consumptions for each SKU are consolidated and SKU's whose consumptions are greater than their planned amounts, i.e., at least for one period, are filtered. Then, we check whether the determined *s* value fulfills the periodic excess usage amounts of each SKU or not. After this process, we filter the SKU's whose periodic excess usage amounts are not fulfilled completely by the proposed inventory policy as illustrated in Table 5.9.

Table 5.9 Inventory at the beginning and end of period

Raw Material Code	FSA	Planned-Consumed Difference, kg	month	day	hour	s	Q	inventory, at the beginning of period	inventory, at the end of period - final state	inventory, at the end of period - initial state	Does production halt?
RAW MATERIAL-00152	Coil	0.7	12	4	22	0.7	220	220.7	220.0	220	NO
RAW MATERIAL-00152	Coil	114	12	17	20	0.7	220	220	106.0	106	NO
RAW MATERIAL-00152	Coil	0.2	2	4	21	0.7	220	106	105.8	105.8	NO
RAW MATERIAL-00152	Coil	-0.45	3	15	19	0.7	220	105.8	106.3	106.25	NO
RAW MATERIAL-00152	Coil	69	4	3	13	0.7	220	106.25	37.3	37.25	NO
RAW MATERIAL-00152	Coil	0.3	5	18	19	0.7	220	37.25	37.0	36.95	NO
RAW MATERIAL-00152	Coil	0.7	6	14	20	0.7	220	36.95	36.3	36.25	NO
RAW MATERIAL-00152	Coil	0.4	6	26	11	0.7	220	36.25	35.9	35.85	NO
RAW MATERIAL-00152	Coil	0.05	6	26	12	0.7	220	35.85	35.8	35.8	NO
RAW MATERIAL-00152	Coil	71.3	7	3	21	0.7	220	35.8	184.5	-35.5	YES
RAW MATERIAL-00152	Coil	130	7	4	15	0.7	220	184.5	54.5	54.5	NO
RAW MATERIAL-00152	Coil	0.45	7	9	10	0.7	220	54.5	54.1	54.05	NO
RAW MATERIAL-00152	Coil	0.7	7	12	8	0.7	220	54.05	53.4	53.35	NO
RAW MATERIAL-00152	Coil	0.3	7	18	22	0.7	220	53.35	53.1	53.05	NO
RAW MATERIAL-00152	Coil	0.05	7	19	5	0.7	220	53.05	53.0	53	NO
RAW MATERIAL-00152	Coil	0.2	8	13	21	0.7	220	53	52.8	52.8	NO
RAW MATERIAL-00152	Coil	41.3	8	23	8	0.7	220	52.8	11.5	11.5	NO
RAW MATERIAL-00152	Coil	0.1	9	6	13	0.7	220	11.5	11.4	11.4	NO
RAW MATERIAL-00152	Coil	0.45	9	8	4	0.7	220	11.4	11.0	10.95	NO
RAW MATERIAL-00152	Coil	215	9	27	21	0.7	220	10.95	16.0	-204.05	YES
RAW MATERIAL-00152	Coil	0.2	9	28	21	0.7	220	15.95	15.8	15.75	NO
RAW MATERIAL-00152	Coil	0.05	10	3	13	0.7	220	15.75	15.7	15.7	NO

First of all, we calculate inventory at the beginning of each period for each SKU according to their determined *s* and valid *Q* values. Then we find inventory at the end of period – initial state by subtracting planned-consumed difference from inventory at the beginning of period. If this amount is less than the determined reorder point, the inventory of this raw material is replenished by the amount equal to the multiples of its standard package size to provide the inventory at the end of period – final state be greater than its reorder point. Besides, if inventory at the end of period – initial state is less than zero, the production halts. The periods at which production halts are filtered and the number of production orders that are halted due to the shortages is calculated like shown in Table 5.10.

In Table 5.10, the production halts due to the shortage of 18.8 kg of raw material-00054 at the Common FSA at the 15th hour of 12.11.2012. This raw material is used at the Common FSA more than its planned amount for 19 batches. By sorting the planned-consumed differences from largest to smallest, we conclude that only the first batch at which 50.05 kg of raw material-00054 is used more than its planned amount, i.e., greater than periodic shortage amount – 18.8 kg, is halted.

Table 5.10 Shortage per batch

Raw Material Code	FSA	month	day	hour	BATCH NO	Planned-Consumed Difference, kg per **batch**	Planned-Consumed Difference, kg per **period**	Cumulative Difference per batch	State
RAW MATERIAL-00054	Common	11	12	15	BATCH-86866	50.05	18.79	50.05	OK
RAW MATERIAL-00054	Common	11	12	15	BATCH-74871	50.00	18.79	100.05	NOTOK
RAW MATERIAL-00054	Common	11	12	15	BATCH-91207	50.00	18.79	150.05	NOTOK
RAW MATERIAL-00054	Common	11	12	15	BATCH-47715	43.20	18.79	193.25	NOTOK
RAW MATERIAL-00054	Common	11	12	15	BATCH-47844	39.00	18.79	232.25	NOTOK
RAW MATERIAL-00054	Common	11	12	15	BATCH-48943	35.00	18.79	267.25	NOTOK
RAW MATERIAL-00054	Common	11	12	15	BATCH-70709	20.20	18.79	287.45	NOTOK
RAW MATERIAL-00054	Common	11	12	15	BATCH-67800	15.00	18.79	302.45	NOTOK
RAW MATERIAL-00054	Common	11	12	15	BATCH-85413	4.20	18.79	306.65	NOTOK
RAW MATERIAL-00054	Common	11	12	15	BATCH-94123	2.55	18.79	309.20	NOTOK
RAW MATERIAL-00054	Common	11	12	15	BATCH-69830	0.75	18.79	309.95	NOTOK
RAW MATERIAL-00054	Common	11	12	15	BATCH-62687	0.45	18.79	310.40	NOTOK
RAW MATERIAL-00054	Common	11	12	15	BATCH-86890	0.40	18.79	310.80	NOTOK
RAW MATERIAL-00054	Common	11	12	15	BATCH-76048	0.25	18.79	311.05	NOTOK
RAW MATERIAL-00054	Common	11	12	15	BATCH-61745	0.10	18.79	311.15	NOTOK
RAW MATERIAL-00054	Common	11	12	15	BATCH-79776	0.05	18.79	311.20	NOTOK
RAW MATERIAL-00054	Common	11	12	15	BATCH-83577	0.05	18.79	311.25	NOTOK
RAW MATERIAL-00054	Common	11	12	15	BATCH-92519	0.05	18.79	311.30	NOTOK
RAW MATERIAL-00054	Common	11	12	15	BATCH-69879	0.05	18.79	311.35	NOTOK

To sum up, by adopting the proposed method, the number of halts decreases from 9,506 to 466, i.e., by 95% and the overall halt ratio decreases from 19.3% to 0.9%.

Storing the right items at FSAs decreases the number of halts as usual, but also increases the inventory at FSAs. We will give priority to the A status FSIs for the storage for preventing the capacity violations. According to the simulation made using spreadsheets, we also calculate the average inventories at each FSA. The results are demonstrated at Table 5.11.

Table 5.11 Average Inventory for each FSA

FSA	Average inventory, kg	Capacity, kg
Wood	62,322	57,000
Coil	26,862	12,000
Dispersion	12,067	36,000
Common	71,249	66,000
Waterbased	11,272	18,000
Total	**183,772**	**189,000**

As mentioned before, chapter 4 and chapter 5 are interrelated. After developing inventory policies for FSIs, periodic transportation amounts will be affected but yearly transportation amounts will not be affected too much. To observe the effect of the developed inventory policies, the inventory of each FSI at any FSA will start at inventory levels equal to their standard package sizes. In chapter 4, it is observed that “1+3 period method” works well (by not taking the standard package sizes of unweighed raw materials and FSIs). Here, we check whether “1+3 period method” works still well or not after the developed inventory policies and implicitly the change in the periodic consumptions. According to this analysis, similar to the result of the previous case, there is a need for the emergency milk run vehicle in only one period and the utilization of the regular milk run vehicle is 26.5%.

CHAPTER 6

CONCLUSIONS

In this thesis, logistics activities within a paint company are in focus. Emergency transportations are common-place due to lack of some direct materials (FSIs) being used in the production. In order to ensure a smooth production, these materials need to be transported from the central warehouse to the production areas. Due to the waiting times during the emergency transportation, the production times of the products increase. We would like to minimize the order-to-delivery cycle time in order to increase the customer satisfaction ratio. For achieving these objectives, the number of halts during production has to be minimized. To coordinate these transportation activities, we propose to change the internal logistics activities via a milk run system and inventory policies for the direct materials. Ultimately, we recommend the introduction of a production logistics department.

The recommended department will be the internal supplier of the production department, while it will also be the internal customer of the warehousing department.

The duties of the proposed production logistics department are:

1) To identify FSIs.

Firstly, floor stock usages of the raw materials at each FSA will be analyzed beyond the picking list quantities, i.e., excess usages. Then for the verification, the items will be checked whether they are at one of the FSAs during cycle countings or not. If they are, these items will be identified as FSIs.

Contrary to the general opinion, material shortages are predictable. Thus, identification of FSIs and keeping them ready at FSAs are very crucial issues for handling with the halts during production due to lack of raw materials.

2) To set inventory policies for FSIs.

An (*s,Q*) inventory policy will be adapted for FSIs according to the periodic review setting. Here, *s*, the reorder point, is calculated by taking the last year's excess usages into consideration. *Q* is the standard package size of each FSI that is determined by the purchasing department indirectly (the purchasing department selects the suppliers and comes to an agreement with them on the standard package sizes).

3) To ensure timely information flow to the warehousing department.

As mentioned before, this department will be the internal customer with respect to the warehousing department according to the VMI concept. Hence, the production logistics departmet will give orders for the required amounts of each raw material (FSIs and non-FSIs) in the picking lists and for the FSIs whose inventory levels are less than or equal to their determined *s* values. This information flow will be ensured before the beginning of each period (hour). According to this information, the warehousing department will bring the orders (from which raw material to which FSA at what quantity) given by the production logistics department to each FSA.

4) To define barcode system for real time data to all departments.

Currently, the barcode system is only used at the shop floor and the warehouses, i.e., it is not used at the FSAs. However, it needs to be used at the FSAs. Thus, the warehousing department will use barcode system when he submits the raw material to each FSA and the production operator will use barcode system when he takes the raw materials from FSAs for the purpose of using them at the shop floor. By this way, we will have chance to track the inventory levels of each SKU electronically and e-signals can be provided.

5) To report the excess materials to be removed from FSAs.

Collection of waste and excess materials is beyond the scope of our thesis. However, due to the capacity constraint of each FSA, some raw materials need to removed from FSAs by taking the forecasts of each raw material into consideration (the ones that will not be used in the near future). Furthermore, as FSAs are very expensive areas for the storage, excess inventory should be kept at the central raw material warehouse rather than FSAs.

6)To coordinate the information and material (control sample) flows among the color laboratory, quality control laboratory and the production.

This issue is also beyond the scope of our thesis. According to the case study of 2012, waiting due to the material shortages and due to the lack of information between laboratories and production are the biggest waste of the company. In this thesis, we propose a system to handle with the halts due to the material shortages. In the current system, the production operator performs the necessary processes as written in the manufacturing card. Then, he delivers a sample to one of the laboratories. The operator in the laboratory checks whether the production batch matches to the specification set by the R&D department or not and gives a decision about the batch. Usually, the production operator is not informed about the decision of the laboratories. Hence, the production batch waits for a long time in the equipment uselessly. To handle with such inappropriateness, logistics activities concerning laboratories can be studied as a future study.

7) To monitor the system and make necessary adjustments.

As mentioned before, the inventory levels of each SKU will be tracked via the barcode system. Whenever the inventory level of one of the FSIs drops to its determined reorder point, one standard package size of this SKU is also included in the next hour's milk run together with the raw materials that are in the picking lists.

8) To sustain the system via keeping FSIs and order policies up to date.

Due to the change in the product mix sold during a year, FSIs and reorder points for each FSI may change. For this reason, the analysis related with the determination of FSIs and the order policies needs to be repeated at each year.

9) To set performance measures and measure the performance of the system.

The internal customers score the internal suppliers. As the warehousing department will be the internal customer of the production logistics department, the proposed deparment will score the warehousing department according to the determined performance measures. Furthermore, as the proposed department will be internal supplier of the production department according to the VMI concept, the production department will score the production logistics department.

Via the introduction of the new department, the production and the warehousing departments do not need to perform additional tasks that are not in their original job definitions. Production people must only deal with production. Transportation of the raw materials to and from FSAs is not their job. Besides, preparing the orders related with the unplanned consumptions is very time-consuming for the warehousing department. The production logistics department will be the subdivision of the planning department not the production and the warehousing department. Because setting order policies that is one of the vital parts of the new system is the planning department's job.

The proposed milk run system is planned to have one fixed route as it is preferred by the management due to its operational simplicity. For this reason, we do not need to deal with any routing issues.

Within this thesis, we propose inventory policies for the direct materials that are consumed by the production department. Here, the management prefers a fixed cycle time of one hour again due to its operational simplicity. Hence, we restrict our attention to periodic review inventory models.

In the scope of this study, only the direct materials that are used by the production department are dealt with. Possible future studies can focus on indirect materials such as filters and pins. Furthermore, rather than only looking into production logistics activies, all the logistics activities concerning departments such as color and quality control laboratories can be studied. In addition to the coordination of the material flows, information flows between each department such as the delivery of the decision information for a production batch by the quality control department to the production department can be the subject of as future studies. As mentioned before, collection of waste and leftovers is also beyond the scope of our thesis. But this subject can also be studied in the future.

In this thesis, the same service level is applied for each FSI, but by taking the business impact of FSIs into consideration, different service levels may be applied to them in the future studies.

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