Dynamic Buffer Management for Raw Material Supply in the Footwear Industry

John Reyes and Kevin Alvarez
Universidad Técnica de Ambato (Faculty of Systems Engineering, Electronics and Industrial), Ambato, Ecuador
Email: johnpreyes@uta.edu.ec, kevin-alvarez@hotmail.es

Rosa Vasquez
Pesticide Action Network, Penang, Malaysia
Email: omega2412@gmail.com

***Abstract*—In this paper, the application of inventory buffers is proposed as a management tool for the supply of raw material in the footwear industry. This allows to increase competitiveness and a significant decrease in investment in materials stored in the warehouses. This technique based on the holistic view will achieve the global optimum of the system giving importance to factors that prevent success of companies. In this sense, it is identified that the market demand is the system´s constraint for the development of the master production schedule. Considering this, it is necessary to concentrate all the materials in the central warehouse to establish an optimum inventory levels or buffers. Using a technique of colors materials ordering program is regularly reviewed through dynamic buffer management. As a result, the model improves the way how inventory of materials in the footwear industries is managed for resupply. Giving a priority to the materials low in stock. This generates 18,7 % of annual saving in inventory costs.**

***Index Terms*—raw materials consumption, lead time, buffer, bill of materials, supply chain, priority**

I. Introduction

Historically, Industrial Engineering has tried to understand the behavior of production systems and large number of models for this purpose has been created. However, the majority does not consider the relationships between systems; it is not perceived the system as a whole, which is formed of subsystems and with many relations among themselves, resulting in the search for optimal local, which does not necessarily produce the global optimum of the system.

Traditional models, such as Material Requirements Planning (MRP) are purely deterministic; these do not contemplate the existence of random and try to impose operational rules for the system. This scheme makes each unit to operate separately, generating each direct its operations to achieve goals that are not fully aligned with the objective of the organization [1]. In contrast to this, the proposal made by Eliyahu Goldratt [2] with respect to the scheduling of production and capacity utilization have gotten that many executives think differently about how to use resources . The Theory of Constraints (TOC) is an approach to address decisions towards achieving the goal of an organization; in other words, make money, now and in the future [2]. Thus, the concepts of the TOC present a framework to identify constraints and improve performance of companies [3]. In this context the management of inventories has been becoming one of the major challenges facing managers with regard to the planning and the control, especially in manufacturing companies [4].

In the field of footwear is necessary a process of continuous improvement using dynamic inventory management tools, because the survival of these companies is based on quality, competitiveness, time and inventory rotation. Thus, in recent years it has been generating restructuring processes caused by globalization of the economy [5] which has increased international competition due to the mass production of Asian countries. The offer (exporters) is concentrated in the Southeast Asian economies, led by China and highlighting the growth of other emerging countries such as Vietnam and Indonesia [6].

Although, that companies are increasingly competing, yet some of them persist in obsolete management tools that do not allow them to achieve their goal; the main challenge is to have the right material, in sufficient quantity and at the right time, but the evidence shows that this challenge is not surpassed by several companies in which there are references to high inventory levels, while inventory for others it is depleted which prevents supply immediate demand.

An inadequate management and valuation of inventories may contribute to the failure of business and on the contrary, a good valuation, management and control contribute to business success [7]. Today competitive environment makes it essential that companies pay attention to inventory management, so as to reduce operating costs and increase throughput of companies, ensuring customer satisfaction by providing better service levels [8].

The Theory of Constraints makes a transversal transformation in the organization, harmonizes and gives synergies that transcend over collective economic expectations, hence it has been fairly applied globally by

Manuscript received December 3, 2014; revised April 27, 2015.

doi: 10.12720/jiii.4.1.1-8

companies [9], however in Ecuador his research has been timid what motivates this issue for the benefits it can bring to the industry under study.

Therefore, the aim of this paper is to apply the guidelines of the approach of the Theory of Constraints on supplies of raw material, using the dynamic buffer management because according to TOC, it is not about to eliminate stock completely, but the inventory must to have a target level [10]. Careful observation of the buffers is applied to solve the inevitable fluctuations of the plant and the market, since to understand how to properly manage inventory buffers improves the competitive position of companies [11].

It is applied in a company pilot of the footwear industry Ecuadorian; however the exposed procedure can be applied in other industries or companies with similar problems, with appropriate adjustments.

II. State of the Art

A. *Theory of Constraints*

The fundamental concept of the theory of constraints is that all planning on generating a product or service is basically a series of processes linked. Each process has a specific capacity of production, and in almost all cases there is a process that limits or restricts the performance of the entire operation [12].

A constraint is anything that limits a system to achieve higher performance in meeting its goal [13]. In an organization, the goal is to make money, now and in the future [2]. To satisfy the interests of shareholders the company must "make money, now and in the future", to satisfy the interests of employees the company must "maintain a safe environment and satisfying for staff, now and in the future" [2] and to satisfy the interests of their market the company must "give satisfaction to the market now and in the future" [2].

Many companies confuse the ways and the necessary conditions for the goal. Quality, customer service, sales, market share, are ways to achieve the goal but none of them is the goal itself [14].

This analysis is manifested in increased business performance which is achieved thanks to sales, not just production. Also the prime way to reduce costs is to produce only those products determined by sales in a timely fashion, to restrain excessive manufacturing and to eliminate all waste in manufacturing methods [15].

B. *The Sistem: Drum – Buffer – Rope*

There are only a few resources capacity constraint (CCR) in all factories. The DBR method recognizes that restriction dictates the rate of production of the entire plant. Therefore, the main resource capacity constraint is the drum whose rhythm drives the whole plant. A buffer stock facing each CCR is also needed; this buffer protects the throughput of the plant against any disturbance. To ensure that the stock does not exceed the level allowed by the buffer should limit the rate at which material is released into the plant, should tie a rope from the CCR until the first operation [11].

III. Company Analysis

A. *Supply Chain*

A supply chain is formed by all those parties directly or indirectly involved in satisfying a request from a client [16]. In this context, the solution of the TOC thinking results in a significant increase in sales, release of working capital, increased inventory turnover and higher profit margins. The key elements of the solution are [17]:

- Inventory = Buffers.
- Aggregation of inventory to the central warehouse.
- Connection = Real consumption.
- Priorities of the buffers.
- Challenge policies of lots.
- Variable buffers = Dynamic buffer management.

The development of the buffers begins with an analysis of the company's supply chain in the Fig. 1, emphasizing the process of raw material supply. The company has two warehouses for storage of raw material, suppliers deliver materials to wineries and there is also a connection between them because the first also supplies material to the second.

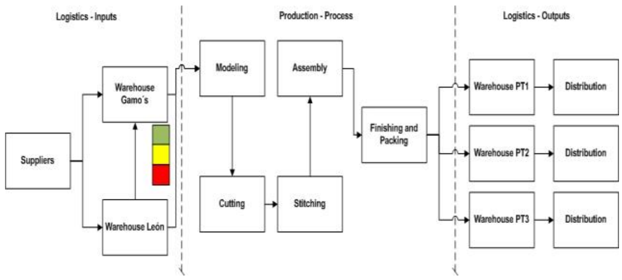

Figure 1. Pilot company's supply chain in the footwear industry.

B. *Drum*

The drum essentially represents the master production schedule of Table I, which focuses around the rate of return that defines the constraint [12] that is the market demand and the challenge is to increase it at the same level of capacity of a resource.

TABLE I. Master Production Schedule

MODEL	WEEKS / PAIR					
	1	2	3	4	5	6
BMP N	245	602	210	853	519	341
BENMPA N	75	439	290	442	301	167
TXPA C	0	0	96	109	330	32
BENMPA C	0	0	0	14	103	0
BMJ NL	57	0	0	0	59	0
DPH N	0	88	50	44	69	97
DPH B	0	0	0	75	28	22
HTS3PA C	55	27	24	0	103	0
PTXPA C	0	0	0	0	16	0

In that sense, the sales history of the last three years is taken to forecast demand. The forecast allows obtaining the master production schedule (MPS) that must be objective and consistent with the current situation of the company. It represents the most detailed level of planning that lists the products that will be produced, when to be manufactured and the quantity [18]. In relation to this, Table I show the first 6 weeks of the MPS for the 10 bestselling models in the past three years. It is emphasized that the analysis is done on a planning horizon of 52 weeks.

IV. Buffer – Target Inventory Level

Considering the importance of preventing that a constraint is "hungry" for stock-out, it is established before a buffer "time"; in other words, inventory can be expressed as the expected time for this is required in the plant (raw material inventory) or is sold (inventory of finished product), for example it says "there are 6 weeks of inventory" [19].

The buffer is the target inventory level calculated on the basis of recent historical demand, which ensures no shortage and to find the appropriate size of the initial target level the following 5 parameters must be considered:

- The average rate of product sales or consumption.
- The variability of sales or consumption. We need to know how much demand we might have to fulfill.
- The average replenishment time.
- The variability of replenishment time, how reliable is our source of supply? We need to be reasonable certain that our replenishment will arrive before we have a stock-out and miss sales.
- The service level to customers we want to achieve.

Identified the five parameters is used (1):

$$Bu = A + (Sigma * \sigma) \qquad (1)$$

where *Bu* represents the buffer, *A* is the average rate of product sales in the replenishment lead time, *Sigma* is a measure of the intrinsic variability of a process [20] depending on the level of service desired and σ is the standard deviation of demand during the replenishment lead time.

A. Bill of Material

The technical data of the production relative to the structure of the product include the bill of material (BOM) that shows the entire composition of the product and from it the need in quantity is developed [21]. Table II shows part of the BOM for the model BMP N; it is worth mentioning that data from all the models of the company is required to obtain raw material consumption.

B. Forecast Consumption of Raw Material

A database is created with the BOM of all models and consumption of all raw materials (Table III) is obtained. The consumption for a model is obtained by multiplying the amount of MPS by the consumption of the specific bill of materials; as an example for the model BMP N, the consumption of Thread Enkador in week 1 is given by multiplying 245 pairs obtained from the MPS in Table I by 9 meters obtained from the BOM in Table II; resulting that consumption in the first week is 2205 meters of Thread Enkador only for that model.

C. Recent Consumption of Raw Material

The TOC solution proposes that whenever there is a consumption of the store to the market that consumption is reported immediately, so it is calculated the consumption of raw material of the three months prior to the start of the study in order to calculate the initial buffer. Table IV is calculated based on the recent MPS and bills of material by model.

TABLE II. Bill of Materials for Model BMP

Description	Code	Consumption	Unit
Thread Enkador	54401	9	MT
Hook Double Eye	5201	4	UN
Eyelet Of137	8801	24	UN
Rivet	34501	16	UN
Label Flag	232901	1	PR
Label Number	280001	2	UN
Sponge 2 cm	229701	4,2	DM
Latex 10 mm	1201	7	DM
Glue	180101	0,003	LT
Woven Heel	191801	30	DM
Woven for “*capellada*”	191801	9	DM
Leather Napa	185901	18	DM

TABLE III. Forecast Consumption of Raw Material

Description	Unit	WEEKLY CONSUMPTION					
		1	2	3	4	5	6
Latex	DM	1715	4214	1519	6139	3710	2387
Insole Dupalm	DM	566	2541	1734	2449	2872	1192
Sole Q493 Viking	PR	0	0	7	9	4	0
Hook Double Eye	UN	980	2408	868	3448	2092	1364
Hook One Eye	UN	440	1672	136	304	408	496
Eyelet Of137	UN	5880	14448	5152	21216	12920	9384
Thread Enkador	MT	4431	9993	9378	10817	10140	5522
Sole M.G.	PR	75	447	326	456	457	167

TABLE IV. Recent Consumption of Raw Material

Description	Unit	RECENT WEEKLY CONSUMPTION					
		1	2	3	4	5	6
Latex	DM	6244	3234	4361	2240	1750	350
Insole Dupalm	DM	1360	2361	1332	2047	1001	2235
Sole Q493 Viking	PR	252	14	23	0	0	0
Hook Double Eye	UN	3568	1848	2492	1280	1000	200
Hook One Eye	UN	472	0	0	336	1048	344
Eyelet Of137	UN	19392	10976	14768	9760	6000	2720
Thread Enkador	MT	9525	7012	7331	6532	3856	3322
Sole M.G.	PR	280	426	150	300	150	460

TABLE V. Central Warehouse Stock

Description	Unit	Stock
Latex	DM	1500
Insole Dupalm	DM	86800
Sole Q493 Viking	PR	3616
Hook Double Eye	UN	47500
Hook One Eye	UN	52500
Eyelet Of137	UN	350000
Thread Enkador	MT	70001
Sole M.G.	PR	1995

D. Raw Material Inventory

One of the key elements of the TOC solution is the aggregation of the inventory to the central warehouse, in the case of study there are two warehouses of raw material as shown in Fig. 1, all materials will be consolidated in a single warehouse and the initial inventory is obtained in the Table V which is taken into account also the raw material in transit.

E. Initial Target Level

An example calculation is presented for the sole MG as the unavailability of soles in the warehouse results in considerable losses of money. In the calculation of the Table VI is used (1) to determine the initial target level.

TABLE VI. CALCULATION OF INITIAL BUFFER FOR THE SOLE M.G.

Code		**Material**	
167501		Sole M.G.	
Lead Time		**12 weeks**	
#	**Recent Consumption**	**#**	**Recent Consumption**
1	426	7	140
2	150	8	285
3	300	9	320
4	150	10	185
5	460	11	192
6	450	**12**	420
Average		289	
Sigma		3	
Standard Deviation		125	
Buffer		666	

In Table VI the lead time of the material is identified, followed obtained from Table IV as much data as indicating the lead time, so that the average and standard deviation were calculated. Sigma finely set with a value of 3 as it provides 99.73% confidence level, this value allows for a broad service level to customers direct from the warehouse of raw material, which is production. It is considered 3 as the optimum value that allows to have the right amount expected that the client requires [22].

V. DINAMYC BUFFER MANAGEMENT

The theory of constraints is a process of continuous improvement, based on systems thinking, which helps companies increase their profits with a simple and practical approach [23]. In this context the buffers management [24] is performed over time to maintain strict control of the expected consumption and the inherent variability of the system.

< 0%	BLUE	TOO MUCH STOCK
0% - 33%	GREEN	
33% - 66%	YELLOW	
66% - 100%	RED	
> 100%	BLACK	MISS SALE

Figure 2. Buffer zones and penetration rates.

A. Buffer Zones

The TOC buffers are divided into three main zones and two additional zones for further analysis. Fig. 2 shows all zones and penetration rates. The black zone is the most dangerous indicates miss sale, the following is the red zone or emergency. The middle zone or yellow zone indicates prevention, the following is the green zone or sufficient inventory and the upper zone is blue indicates too much stock.

B. Eliyahu Goldratt's Target Level Management Rules

- When a penetration into the red zone occurs monitor how deep the penetration is. If the penetration is too deep or it persist for too long then the target level should be increased.
- If the stock rises excessively or it has remained in the blue zone for a whole replenishment time period then the target level should be decreased.
- Every time you increase the target level wait for a replenishment cycle before starting to check again.
- Every time you decrease the target level wait for the inventory to get down below the new green level and only then start to check again for the conditions to decrease the target level further [19].

C. Buffer Management

Table VII shows buffer management for the Sole M.G., the first thing that is done is collect the following data for week 1: lead time and initial buffer of Table VI, free stock of Table V, the raw material in transit and forecasted consumption of raw material of Table III.

The calculation is made in Table VII, is governed by the following equations:

Equation (2) calculates the stock that the warehouse has to subtract consumption on that date.

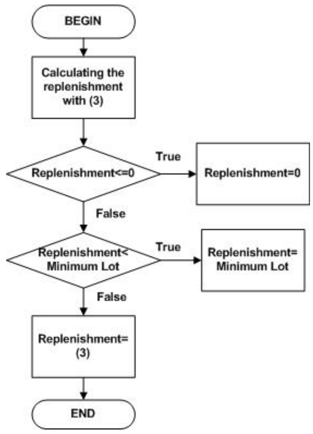

Figure 3. Flowchart for calculating replenishment.

$$SW = SF + RMT - C \tag{2}$$

Equation (3) takes a more complex analysis since the outcome is decided whether, would be replenished or not? The first thing obtained is the value with (3) and followed this is decided as shown in Fig. 3.

$$RE = Bu - SW \tag{3}$$

Equation (4) calculates the stock that the warehouse has without subtracting consumption on that date.

$$ST = SF + RMT \tag{4}$$

The values of the equations have their representation in Table VII as well: *SW* is the stock in warehouse, *SF* is the free stock, *RMT* is the raw material in transit, *C* is the expected consumption, *RE* is the replenishment, *Bu* is the buffer and *ST* is the stock with raw material in transit.

TABLE VII. DYNAMIC BUFFER MANAGEMENT FOR THE SOLE M.G.

Week	Bu	SF	RMT	SW	C	RE	ST	%Cons. CT	Prior. CT
1	666	1995	0	1920	75	0	1995	-188%	Blue
2	666	1920	0	1473	447	0	1920	-121%	Blue
3	666	1473	0	1147	326	0	1473	-72%	Blue
4	666	1147	0	691	456	0	1147	-4%	Blue
5	666	691	0	234	457	432	691	65%	Yellow
6	666	234	432	499	167	300	666	25%	Green
7	666	499	300	584	215	300	799	12%	Green
8	666	584	300	558	326	300	884	16%	Green
9	666	558	300	763	95	0	858	-15%	Blue
10	666	763	0	361	402	305	763	46%	Yellow
11	1339	361	977	755	584	1256	1339	44%	Yellow
12	1339	755	1256	1732	279	0	2011	-29%	Blue
13	1339	1732	0	1475	257	0	1732	-10%	Blue
14	1339	1475	0	1195	280	300	1475	11%	Green
15	1339	1195	300	1141	354	300	1495	15%	Green
16	1339	1141	300	477	964	862	1441	64%	Yellow
17	1339	477	862	1339	0	0	1339	0%	Green
18	1339	1339	0	782	557	557	1339	42%	Yellow
19	1339	782	557	962	377	377	1339	28%	Green
20	1339	962	377	960	379	379	1339	28%	Green
21	1339	960	379	1197	142	300	1339	11%	Green
22	1339	1197	300	752	745	587	1497	44%	Yellow
23	1339	752	587	1168	171	300	1339	13%	Green
24	1339	1168	300	1190	278	300	1468	11%	Green
25	1339	1190	300	1365	125	0	1490	-2%	Blue
26	1339	1365	0	1041	324	300	1365	22%	Green
27	1339	1041	300	928	413	411	1341	31%	Green
28	1339	928	411	1016	323	323	1339	24%	Green
29	1339	1016	323	1238	101	300	1339	8%	Green
30	1339	1238	300	927	611	412	1538	31%	Green
31	1339	927	412	591	748	748	1339	56%	Yellow
32	1339	591	748	973	366	366	1339	27%	Green
33	1339	973	366	1315	24	300	1339	2%	Green
34	1339	1315	300	1316	299	300	1615	2%	Green
35	1339	1316	300	1522	94	0	1616	-14%	Blue
36	1339	1522	0	1500	22	0	1522	-12%	Blue
37	1339	1500	0	994	506	345	1500	26%	Green
38	1339	994	345	915	424	424	1339	32%	Green
39	1339	915	424	1082	257	300	1339	19%	Green

The percentage of consumption is calculated using (5), this value allows knowing the zone in which the raw material inventory is and dynamic analysis of the buffer is decided based on this result.

$$BuCT = \frac{Bu - (SF + RMT - C)}{Bu} \tag{5}$$

where *BuCT* represents the status of the buffer and *Bu* is the buffer size of (1).

The priority (Prior CT), that is, the inventory zone is decided with respect to Fig. 2.

With all the information move on to analysis from week 1 for the Sole M.G., the buffer is changed in week 11 and in this case, since there it is maintained because no alarm zones is presented, however, there materials where the buffer management is more often.

The dynamic buffer management seen more intuitively in Fig. 4 where the buffer is divided into the three primary zones: green, yellow and red, the stock in warehouse (SW) of (2) also is graphic which allows observing zones in which penetrates the inventory over time.

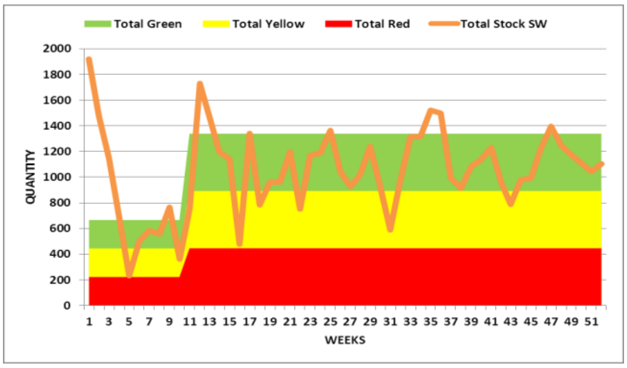

Figure 4. Dynamic buffer management for the Sole M.G.

In Fig. 4 it can be seen that there is an excessive amount of inventory in the first weeks, so during that time the material is only consumed to level the buffer, from there the buffer management is realized you are tracking and maintains the inventory most of the time in the green zone or optimal level.

D. Materials Supply Program

Provide materials to raw material warehouse without any planning makes the inventory starts to grow uncontrollably, in other words, the system is losing money and is moving away from its optimal [25], therefore should tie a rope from demand to the supply of raw material. The rope dictates how much inventory is allowed in total which ensures that the stock does not grow beyond the level dictated by the buffer.

TABLE VIII. ORDER PROGRAM FOR THE SOLE M.G.

Week	Order Date	Arrival	Order
5	03-mar-14	26-may-14	432
6	10-mar-14	02-jun-14	300
7	17-mar-14	09-jun-14	300
8	24-mar-14	16-jun-14	300
10	07-apr-14	30-jun-14	305
11	14-apr-14	07-jul-14	1256
14	05-may-14	28-jul-14	300
15	12-may-14	04-aug-14	300
16	19-may-14	11-aug-14	861
18	02-jun-14	25-aug-14	557
19	09-jun-14	01-sep-14	377
20	16-jun-14	08-sep-14	379
21	23-jun-14	15-sep-14	300
22	30-jun-14	22-sep-14	587
23	07-jul-14	29-sep-14	300
24	14-jul-14	06-oct-14	300
26	28-jul-14	20-oct-14	300

In the company, the rope refers to any system of communication that, monitoring the constraint, indicates the precise moment that the materials must be replenished so that compliance with the master production schedule [26]. Table VIII is the order program for the Sole M.G., the order date (*FO*) is governed by the lead time (*LT*) and the week that is required for production (*FP*) as indicated (6).

$$OD = PD - ((LT+1))*7 \tag{6}$$

VI. RESULTS

A. Percentages Priority Zones

In Fig. 5 consolidates all materials, priorities in each week and the percentage of each zone is calculated.

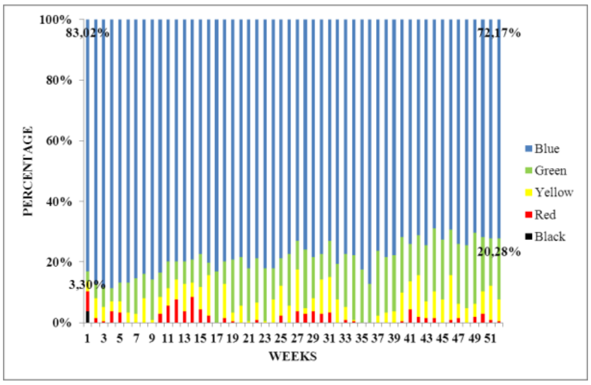

Figure 5. Percentages priority zones.

It is noted in the Fig. 5 that the black zone is completely removed, the red zone is reduced to 0.47 %, the yellow and green areas have an increasing tendency and on the contrary the blue zone decreases over time. Table IX shows the percentages of improvement in a range of 13 weeks, which allows taking the actions required for monitoring and dynamic buffer management as "changing the way in which approach things usually, we make sure not to fall into inertia" [27].

TABLE IX. IMPROVEMENT PERCENTAGES FOR EACH ZONE.

Weeks Range	Black	Red	Yellow	Green	Blue
1-13	⇩ 3,77%	⇩ 2,83%	⇧ 5,66%	⇧ 4,25%	⇩ 3,30%
13-26	⇩ 0,00%	⇩ 3,77%	⇩ 3,30%	⇧ 9,43%	⇩ 2,36%
26-39	⇩ 0,00%	⇩ 0,00%	⇩ 1,89%	⇧ 1,42%	⇧ -0,47%
39-52	⇩ 0,00%	⇧ -0,47%	⇧ 3,30%	⇧ 1,89%	⇩ 5,66%
Total					
1-52	⇩ **3,77%**	⇩ **6,13%**	⇧ **3,77%**	⇧ **16,98%**	⇩ **10,85%**

B. Money in Stock

The result more representative of the dynamic buffer management is given for the money in inventory by making weekly monitoring of this indicator; inventory is multiplied by the unit cost of the material to obtain the total cost. It is noted in the Fig. 6 a decreasing trend because it seeks to have the target inventory level adequate to meet market demand.

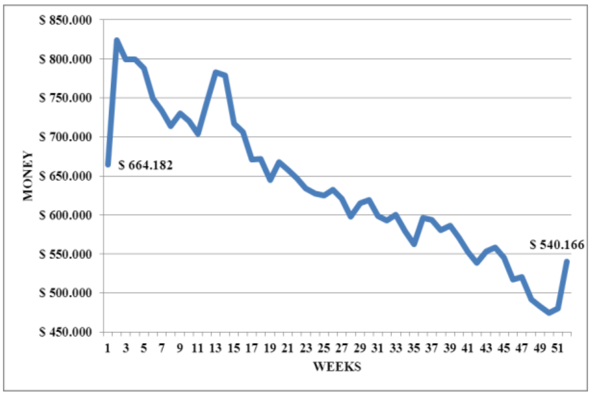

Figure 6. Money trend in stock.

C. Saving Money

The money that the company saves to implement dynamic buffer management is quite considerable (Table X), what demonstrates the efficiency that has the methodology with regard to others, it represents a competitive advantage for the company which can improve delivery times, supply correctly the raw material to the warehouse, have a methodology that allows dynamic operations and cope the variability of manufacturing systems. The percent efficiency is calculated using (7).

TABLE X. SAVING MONEY.

Comparison of Money in Inventory	
Week 1	$ 664.182,01
Week 52	$ 540.165,55
Saving	**$ 124.016,47**

$$Efficiency = \frac{540.165,55}{664.182,01} = 81,3\% \qquad (7)$$

The theory of constraints is a thought in which no place is given to inertia, continuous improvement in the company should be constant and begins by making the leap of faith to new forms of administration, such as dynamic buffer management and the applications of this approach that resulting in a company "Ever Flourishing" [28].

VII. Conclusion

In this paper, a model is proposed to manage the inventory through dynamic buffer management that provides sufficient information for the supply of materials and shows the priority color of each reference, thereby avoiding reaching the blue zone or too much stock and the black zone or miss sale. A target inventory level is ensured and has a management model, dynamic in time allows keeping a tight control of the money invested. The model generates 18,7 % of annual saving in inventory cost and the results show that the model suggested by this paper ensures a successful inventory status for the footwear industries because restocking in the process of raw material supply is based on recent and current demand. The proposed methodology provides a reference for optimal and efficient management of raw material, using theory of constraints.

Acknowledgment

The authors would like to thanks to Universidad Técnica de Ambato for financing the project "Anthropometric and methods for the design of jobs in manufacturing footwear small and medium industry Evaluation of Tungurahua, Ecuador" (Resolution 2345-CU-P-2013).

References

[1] W. Marín and E. V. Gutiérrez, "Development and implementation of a theory of constraints model to synchronize the supply chain operations with production constraints," *EIA. Esc. Ing. Antioq*, vol. 10, no. 19, pp. 67-77, June 2013.

[2] E. Goldratt, *It`s Not Luck*, 1st ed., Great Barrington: North River Press, 1994.

[3] R. Sivasubramanian, V. Selladurai, and N. Rajamramasamy, "The effect of the drum-buffer-rope (DBR) approach on the performance of a synchronous manufacturing system (SMS)," *Production Planning & Control: The Management of Operations*, vol. 11, no. 8, pp. 820-824, November 2010.

[4] M. D'Avinoa, V. De Simonea, and M. Schiraldi, "Revised MRP for reducing inventory level and smoothing order releases: A case in manufacturing industry," *Production Planning & Control: The Management of Operations*, vol. 25, no. 10, pp. 814-820, 2014.

[5] M. E. Morales, S. Sanabria, and M. Arias, "Knowledge accumulation, innovation and competitiveness in enterprise agglomerations," *Revista Dimensión Empresarial*, vol. 18, no. 2, pp. 19-53, December 2010.

[6] R. García and A. Maldonado, "Competitiveness of colombian leather shoes: perspective revealed comparative advantage," *Dimens. Empres*, vol. 11, no. 1, pp. 77-91, 2013.

[7] M. Duque, J. Osorio, and D. Agudelo, "Inventories in manufacturing enterprises, the treatment and assessment: A view from cost accounting," *Contaduría Universidad de Antioquia*, no. 56, pp. 61-79, 2010.

[8] D. Arango, W. Adarme, and J. Zapata, "Collaborative inventory in supply chain optimization," *Dyna Rev. Fac. Nac. Minas*, vol. 80, no. 181, pp. 71-80, 2013.

[9] V. Sinuco, "In search of the ideal project. An orientation for projects exploration and formulation," *Rev. Esc. Adm. Neg.*, no. 74, pp. 138-149, 2013.

[10] M. Naora, E. Bernardesb, and A. Coman, "Theory of constraints: Is it a theory and a good one?" *International Journal of Production Research*, vol. 51, no. 2, pp. 83-90, 2013.

[11] E. Goldratty and J. Cox, *The Goal: A Process of Ongoing Improvement*, 4 ed., Great Barrington: North River Press, 2014.

[12] S. N. Chapman, *Fundamentals of Production Planning and Control*, 1st ed. Upper Saddle River, United States: Prentice Hall, 2006.

[13] V. Ortíz and A. Caicedo, "Optimal production plan in a soft drink bottling plant," *Revista Ingeniería Industrial*, vol. 11, no. 1, pp. 69-82, 2012.

[14] E. Goldratt, *The Haystack Syndrome*, 1st ed., Great Barrington: North River Press, 1990.

[15] P. Pangsri, "A decision framework to select alternative based on lean manufacturing concepts in design processes," *Journal of Industrial and Intelligent Information*, vol. 2, no. 1, pp. 1-5, March 2014.

[16] E. Cruz, "Supply chain social responsibility," *Revista Gestión & Región*, no. 13, pp. 89-106, June 2012.

[17] R. Poler, J. Mula, and M. Dias, "Inventory theory," in *Operations Research Problems*, London: Springer, 2014, pp. 141-169.

[18] M. Groover, *Fundamentals of Modern Manufacturing: Materials, Processes, and Systems*, 5 ed., United States: John Wiley & Sons, 2012.

[19] E. Schragenheim and R. Burkhar. Drum Buffer Rope and Buffer Management in a Make-to-Stock Environment. Inherent Simplicity. [Online]. Date of consultation: March 22, 2014. Available: http://www.inherentsimplicity.com/index.php?option=com_content&view=article&id=34&Itemid=36&lang=es

[20] D. A. Pacheco, "Theory of Constraints and Six Sigma: Investigating differences and similarities for continuous improvement," *Independent Journal of Management & Production*, vol. 5, no. 2, pp. 331-343, May 2014.

[21] P. Gopalakrishnan and A. Haleem, *Handbook of Materials Management*, 2 ed., Noida, India: PHI Learning Pvt. Ltd., 2015.

[22] J. Arango, J. Giraldo, and O. Castrillón, "Inventory and buy management from Holt-Winters forecasting and service level discrimination by ABC classification," *Scientia and Technica*, vol. 18, no. 4, pp. 743-747, December 2013.

[23] E. Goldratt, *The Choice*, Revised ed., Great Barrington: North River Press, 2010.

[24] R. Stratton and R. Burkhard, "The supply chain solutions of TOC," in *Proc. TOCICO International Conference: 11th Annual Worldwide Gathering of TOC Professionals*, Bad Nauheim, Germany, 2013.

[25] M. Birrell, *Forget the Urgent! A Business Dialog based on the Best Seller the Goal*, 1st ed., Santiago, Chile: Henry Camp, 2012.

[26] L. Huang S. Moore, and P. McCarty, "Managing for business sustainability in China: A case study of Shoetown Footwear Co., Ltd," *International Journal of Innovation and Sustainable Development*, vol. 8, no. 2, pp. 125-145, 2014.

[27] J. Harrison, "Interview with marshall goldsmith," *Strategic Direction*, vol. 28, no. 4, pp. 33-35, 2012.

[28] E. Goldratt. Ever Flourishing. Goldratt Consulting. [Online]. Date of consultation: June 18, 2014. Available: http://www.la.goldrattconsulting.com/index.php/vision-viable

John Reyes is M.Sc. of Industrial Engineering of the University of Santiago of Chile. He is now Lecturer and Coordinator of Operational Research and Development Unit at the Faculty of Systems Engineering, Electronics and Industrial in the Universidad Técnica de Ambato (UTA), Ecuador. His research interests include operations research, management and inventory control, management and production processes.

Kevin Álvarez was born in the city of Ambato, Tungurahua, Ecuador in 1992. Mr. Álvarez received his bachelor degree in Industrial Engineering at Universidad Técnica de Ambato in 2014. Currently, he plans to take a master degree curse. His research interests include supply chain, management production and quality control. At the Faculty of Industrial Engineering, Technical University of Ambato he was the best graduate.

Rosa Vasquez is Ph.D., Environmental Science, Ohio State University. Rosa assisted with translation and gave technical advice for the preparation and correction of this paper. Rosa is from Ecuador and bilingual in English and Spanish.