Journal of Software Engineering

ISSN 1819-4311

Academic Journals Inc.

www.academicjournals.com

Journal of Software Engineering 10 (1): 89-98, 2016
ISSN 1819-4311 / DOI: 10.3923/jse.2016.89.98

Research on Product Production Process Optimization Based on Value Stream Theory

[1]Li Qin, [2]Peng Lixia, [1]Liu Haidong and [1]Zhang Qi
[1]School of Mechanical Engineering, Panzhihua University, PanZhiHua Sichuan, 617000, China
[2]Department of Automation Engineering, Xi'an International University, Xian, Shanxi, 710077, China

Corresponding Author: Li Qin, School of Mechanical Engineering, Panzhihua University, PanZhiHua Sichuan, 617000, China

ABSTRACT

Value flow technology is used to study problems including poor balance in production line and excessive work-in-process inventory during the production process of plasma display panels. Firstly, the work measurement technology is used to find relevant data for calculation and draw status picture of product value flow. In addition, the unreasonable places and waste phenomenon of products in the production process are found. Then, for these problems, industrial engineering and lean thinking is used to optimize product production process from various aspects. Moreover, the future value flow chart is drawn. The results have shown that comparing with the functional IE, after using the Value flow technology to optimize the product manufacturing process of the plasma display panels, numerous non-value-added activities in the production process are removed to increase balance rate of production line, shorten delivery cycle and further decrease production cost.

Key words: Value stream mapping, lean production, production process, improvement

INTRODUCTION

The enterprise production operation process is the key parts for the enterprise to create value and gain profit. So, the production operation process management plays an important role in enterprise management. Product manufacturing process optimization can further reduce the production cost and improve production efficiency, etc., which also can bring great performance (Lu and Luo, 2008). In current studies, the fundamental industrial engineering method (Gu and Du, 2013; Zhang, 2012), the six sigma method (Cheng, 2011), the TRIZ theory (Xu *et al*., 2013), the TOPSIS method (Xu *et al*., 2013), the lean production (Ang *et al*., 2011) and so forth are used to optimize the product manufacturing process.

The lean production is a production management method originated from Toyota Motor Corp. It has already carried out in Japan for more than half a century. American did deep analysis on the lean production and summarized its management thought, characteristics and connotation at the end of 1980 s. Lean production has been widely promoted and applied in the western countries and has obtained great achievement in many enterprises. However, it was applied in China in later phase, mainly in the automobile industry. Compared with the mass production, the lean production has the following advantages: the human resource is reduced, the development cycle of the new products is shortened, the work-in-process inventory during the production is reduced, the inventory of the finished products is reduced, the product quality is improved, the space occupied by the factory is reduced, etc. During the production, it is common to see great wastage. The Value

Stream Mapping technology in the lean production is the basis and key point of implementing the lean system and eliminating the process waste. This study introduces the lean production into the television manufacturers and identifies the waste through applying the Value Stream Mapping technology, puts forward several improvement measures and achieves the goal of reducing the cost, shortening the production cycle and improving the quality through eliminating the non value-added activities.

The Value Stream Mapping (VSM) is a visualization tool for describing the logistics and information stream and a powerful tool for distinguishing and reducing the waste during the production. At present, VSM technology is widely applied in many domains and has achieved good application effect, such as automobile production (Zhang *et al*., 2012; Yang and Xu, 2008; Li and Xu, 2008; Miao *et al*., 2009), refrigerator (Cao *et al*., 2010), air conditioner (Yang and Zhang, 2009), communications (Hao, 2010), electronics (Sobczyk and Koch, 2008; Jin and Li, 2009), etc. This study applies VSM technology into the television production, as there are no cases that about applying such technology into the television production industry from the current research. Besides, at present, the output capacity and export volume of our domestic color TV rank the first in the world. The domestic demands increase year by year. The status of the domestic televisions in the market competition has been promoted gradually and it basically can dominate the Chinese market. However, the domestic television manufacturing enterprises basically follow the way of large-scale production. Their competition with the foreign products mainly depends on the cost advantage with cheap labor force. Meanwhile, many problems of this enterprise cannot be exposed.

After the investigation on several domestic large television manufacturing enterprises, it turns out that there are also some problems in the product manufacturing process of the plasma display panels after the product manufacturing process being optimized by using the fundamental industrial engineering method, such as long distance of materials transferring, too much work-in-process inventory, long lead time, etc.

Therefore, this study has proposed to apply VSM technology to optimize the product manufacturing process of the plasma display panels to solve the problem that existed in the product manufacturing process of the plasma display panels, which is key to improve the enterprise competitiveness in such enterprises.

MATERIALS AND METHODS

Current status of product manufacturing process: A consumer electronics manufacturer is specialized in researching, developing, producing, marketing and serving of some industries, such as plasma display panel television, liquid crystal display television, air conditioner, refrigerator, etc. The production of the plasma display panel television and the liquid crystal display television has many things in common. Many problems occur during the production of both televisions. For instance, the workers on the production line are not evenly distributed, which leads to the waste of time, the logistics distance between some processes is too long, the work-in-process inventory and semi-finished products are accumulated severely, etc. This study takes the production of plasma display panel TV as the research object. It is feasible to refer to it for the improvement of the liquid crystal display television production.

The production process of the plasma display panel television is mainly composed of eight parts, i.e., complete machine assembly, label sticking, initial debugging, complete machine aging, function debugging, factory settings, bar code scanning, packaging, etc. Each part is composed of several

Table 1: Production process status

Operation No.	Operation names	Operation time (sec)	No. of operators	Operation No.	Operation names	Operation time (sec)	No. of operators
1	Screen online	9	3	14	Initial debugging	30	1
2	Install PCB	35	2	15	Complete machine aging (doing aging test on 200 sets)	7200	1
3	Combine the fame and the screen	31	3	16	VGA function debugging	11	1
4	Fasten the frame and screen	15	2	17	TV function debugging	9	1
5	Install mound layer	25	2	18	AV/S function debugging	8	1
6	Install the power filter	36	1	19	USB network function debugging	13	1
7	Install the loudspeaker	35	1	20	Factory settings (operate three sets simultaneously)	99	3
8	Insert the belt connecting line	31	1	21	Check appearance	32	2
9	Standardize the wiring	5	1	22	Scan bar code (operate three sets simultaneously)	70	3
10	Fasten the rear cover	35	4	23	Put the complete machine on the packing line	20	2
11	Stick the model label	32	1	24	Get the pendant, fasten the screws	30	2
12	Fasten the pendant	34	3	25	Pack the complete machine (pack two sets simultaneously)	90	6
13	Make the complete machine upright	17	2	26	Finished product offline	15	2

Table 2: Production station status

Station No.	Station names	Operation No.	Time (sec)	No. of operators	Station No.	Station names	Operation No.	Time (sec)	No. of operators
A1	Assemble the complete machine	1-10	36	20	A5	Function debugging	16-19	41	4
A2	Stick the label	11-12	34	4	A6	Factory settings	20-21	33	5
A3	Initial debugging	13-14	30	3	A7	Scan bar code	22	23	3
A4	Do aging test on the complete machine	15	36	1	A8	Packing	23-26	45	12

stations and procedures. The operation of each station is completed by one or more workers. From the online of the product to the offline of the product, there are 26 procedures and 52 operators in total. The second counter chronometry is adopted for the operation time of each procedure. Implement measurement on line for many times and then get the mean value, which is shown in Table 1.

According to the sequence of the production process and the working time, it is feasible to achieve the production takt time and the number of operators of each production station, which is shown in Table 2.

Current status chart and problem analysis of VSM

Current status chart of VSM: The average monthly order quantity of the company is 17,600 sets. Work for 22 days every month and adopt 1 shift. The daily effective working time is 8 h. The takt time is (Wang and Zhang, 2011):

$$C = \frac{F_e}{N} = 36 \text{ s}$$

In the above formula, F_e refers to the effective working time (second) every month, N refers to the demand quantity (set) from the customer every month.

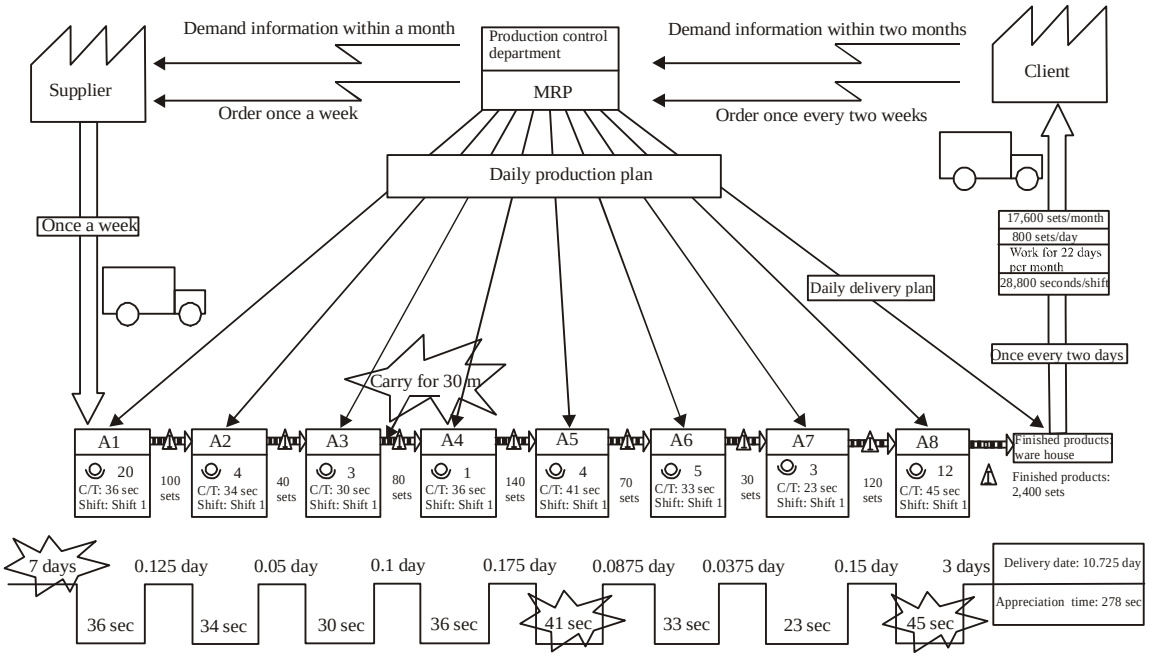

Fig. 1: Current status chart of VSM

According to the production data information of each station after field measurement, apply the specific symbol of VSM and formulate the current status chart (Fig. 1) of the product production based on the sequence of the operation elements. A1, A2, A3,....., A8 refer to the stations, the specific names of each station are shown in Table 2.

Problem analysis: Apply Seven Wastes of Lean Production, use PIWTQMP questionnaire, analyze the production process of the products and identify the following problems:

Over production: From VSM, there is high work-in-process inventory between the complete machine assembly and label sticking. The production of the complete machine assembly belongs to the overproduction. As the complete machine assembly is a relatively independent production line, affected by the traditional idea of mass production. It is believed that the more and faster the production achieves, lower the production cost will get. The actual over production gives rise too much waste. It not only generates much inventory capital, but also is required to save and carry many components. Therefore, it requires many storage space and carriers, which will lead to severer waste. The most obvious characteristic of the lean value stream is to avoid over production.

Over abundant warehouse inventory: The frequency of the supplier's accepting the order is once a week. Low frequency of the raw material delivery gives rise to over abundant warehouse inventory. From the current status chart of VSM, it can be seen that the raw material can be stored for seven days. In addition, the inventory phenomenon of the finished products is relatively serious. The inventory reaches 2,400 sets. The inventory time reaches 3 days. The delivery period is once per two days. Namely, the warehouse of the finished products has left about 1 day of safety inventory all along.

Too much work-in-process inventory: From the current status chart of VSM, there are about 30-40 sets of work-in-process inventory of each station with the storage time from 0.0375-0.175 day (i.e. 2.25-10.5 h). Too much work-in-process inventory will give rise to the stagnation and waiting of the production line. In other words, it will waste lots of production time and lead to difficulty in controlling the production process and lots of waste of raw material. Besides, it is quite easy to produce defective products and thus, causes the increasing of the production cost.

Long transferring distance: As the production of the plasma display panel television is completed in three adjacent workshops (i.e., assembly, aging and debugging) and the connection of each workshop is not in proper place, it gives rise to a great waste of labor force. After the initial debugging, it has 30 m away from the station of the complete machine aging, which presents the irrational workshop layout and improper production arrangement.

Weak balance of production line: The first step for achieving the continuous flow of the assembly line is to balance the production line, which requires rationally arranging the operators and effectively balancing the work load and finally realizes the smooth flow of the assembly line.

The formula for the balance rate of the production line (Lan *et al*., 2006):

$$\text{Balance rate of the production line} = \frac{\text{Working hour summation}}{\text{Longest working time}} \times \text{Number of stations} = \frac{278}{(8\times 45)} = 77.22\%$$

It indicates that, the balance rate of the current production line is relatively weak and 22.78% of the time was wasted due to the imbalance of the production line.

Improvement proposal design

Improve the production process: Apply "5W1H" questioning technique (Yi and Guo, 2014) to question the purpose, method, time, location, personnel and cause and identify the existing problems in the current production process; aiming at the actual problems, apply four major principles of "ECRS" (Yi and Guo, 2014) and put forward corresponding improvement measures for the production process.

Combine the processes:

- In Table 1, the operation time of Operation No. 4 and 5 (fastening the screen and frame and installing mound layer) is relatively short, 15 and 25 s, respectively. Both are less than the takt time (36 s) of the whole machine assembly station, which leads to the waiting time of the personnel. Combine both processes, which are completed by two persons. After process combination, it reduces the ending action of the previous process and the preparation action of the next process. Besides, the operation time is measured as 36 sec. It not only solves the waiting problem of the operators, but also reduces 2 operators and thus the production cost is reduced
- In Table 1, as for Operation No. 8 and 9 (insert the belt connecting line and standardize the wiring), although the total operation time of both is not more than the takt time, the current way is to separate both processes which will be completed by two operators respectively, as the assembled television is rectangular and the length is longer than the width of the production line. Besides, the television is put on the cushion based on the length direction. However,

"standardize wiring" requires rotating the television screen for 90^0, which only can be done on the specific position, where the tray fixture of the production line can rise, fall and rotate. After rotating the television screen for 90° and standardizing the wiring, rotate it back and come to the next process. However, only one place of the production line can be rotated, so it does not be combined with the process of inserting the belt connecting line. In addition, it takes only 5 sec for standardizing the wiring, which is far less than the takt time of the production line. The operator in this process needs to wait for long time, which wastes lots of time. Combine two processes and move the operation of inserting the belt connecting line to the place of standardizing the wiring. After the process of inserting the belt connecting line is finished, it is feasible to directly carry out the process of standardizing the wiring, which can reduces the labor of an operator

- Improvement of the function debugging station. At present, four different kinds of function debugging are completed by four different operators. The debugging time for each kind is relatively short, about 10 sec. Now, merge four functions and assign two operators to finish them. After field measurement, the total time is reduced by 7 sec, i.e., four kinds of debugging after combination take 34 sec in total, which is within the takt time of the production line

Shorten the transferring distance: As the production should be completed in three different workshops, after the assembly workshop completes Operation 1-4, the products should be moved to the aging workshop for aging test. Although both workshops are close to each other, there are 5 assembly lines in the assembly workshop (parallel with each other and distributed uniformly). Besides, each assembly line has the same function, with 10 m interval between each line. The plasma display panel television is assembled on the assembly line that is 30 m far away from the complete machine aging workshop. From the actual production situation of the company, five assembly lines can meet the customer's demands without being operated simultaneously. Therefore, that arranging the assembly of such television on that assembly line near the aging workshop can save the transferring distance of 20 m.

Rearrange the process:

- Scan bar code. Its takt time is 23 sec. This process is done by 3 operators to operate 3 televisions, taking about 70 sec in total. Therefore, the original takt time is 70÷3 = 23 sec and now it only needs 2 operators instead of 3 operators to work on 2 sets and then the achieved takt time is 70÷2 = 35 sec. It not only reduces the labor force, but also balances the production line
- Packing station. Its takt time is determined by the operation time according to the process of complete machine package. There are totally 6 operators in this process, which are divided into two groups (3 operators per group). They pack two televisions simultaneously. Two operators pack the televisions and one operator fetches the foam and installation instruction, which totally takes 90 sec. In other words, it takes 45 sec to pack a television. From the site, the worker for putting the instruction spends little time (9 sec), but wastes lots of time for waiting. To balance the production line, it is necessary to assign an additional worker in the process of complete machine package and divide this process into three groups. Two workers do the packing and one worker fetches the foam and installation instruction for three cartons at the same time, which also takes 90 sec to complete the packaging of 3 televisions, with the takt time of 30 sec

Establish safety inventory and buffer inventory: When the customer's order mode and takt time are changed or an accident breaks off the process flow, the buffer inventory can be used for meeting the customer's demands for the finished products. The safety inventory and buffer inventory constitute sufficient extra inventory, which can reduce uncertain risk. In addition, in this way, such inventory still can meet the customer's demands and the enterprise does not need to formulate temporary overtime work plan urgently.

According to the actual situation, establish the inventory of 0.5 day. Namely, 400 sets of finished products are used for the safety inventory and buffer inventory.

Establish a finished product supermarket: The finished product supermarket is a system adopted for the delivery section in VSM, which is used for store some quantity of finished products. After they are delivered, it is necessary to make supplement (Wang, 2012). Under the situation that the continuous flow cannot be established, it is necessary to use the finished product supermarket. After calculation, establish a finished product supermarket that can meet the inventory demands of 0.5 day and make corresponding mark in the future VSM.

Determine the control method for the former process: To better preserve the production mobility, it is necessary to establish the channel of First In First Out (FIFO) among each station. The buffer inventory required by each FIFO channel is calculated according to the actual situation after improvement.

Design kanban system: As the products produced by the enterprise are not diversified, the current system operation is relatively suitable according to the pace of material application. In VSM, formulate the following Kanban:

- Kanban about material application: Used for telling the material processor to apply for the quantity of the finished products to be delivered from the finished product warehouse
- Kanban about production: Used for telling the operator of each production unit about the quantity of the products that can supplement for the ones taken out from the supermarket

Improve the raw material delivery method: At present, some raw material (e.g., filter, loudspeaker, etc.) adopted for the products are outsourced. The lead time of the purchased parts takes about one week. Therefore, the inventory of the corresponding raw material should be kept above the level of one week, which not only occupies lots of working capital of the enterprise, but also increase the lead time of the products. To solve such problem, the purchase department has negotiated with the suppliers and the suppliers agree to send material once every five days, so that the inventory of the raw material has been shorted to 5 from 7 days.

RESULTS AND DISCUSSION

According to the above improvement design, adopt second chronograph measurement for each process to solve the mean value for many times and formulate the future VSM of the product, which is shown in Fig. 2. After improvement, apply the same formula to calculate the balance rate of the production line:

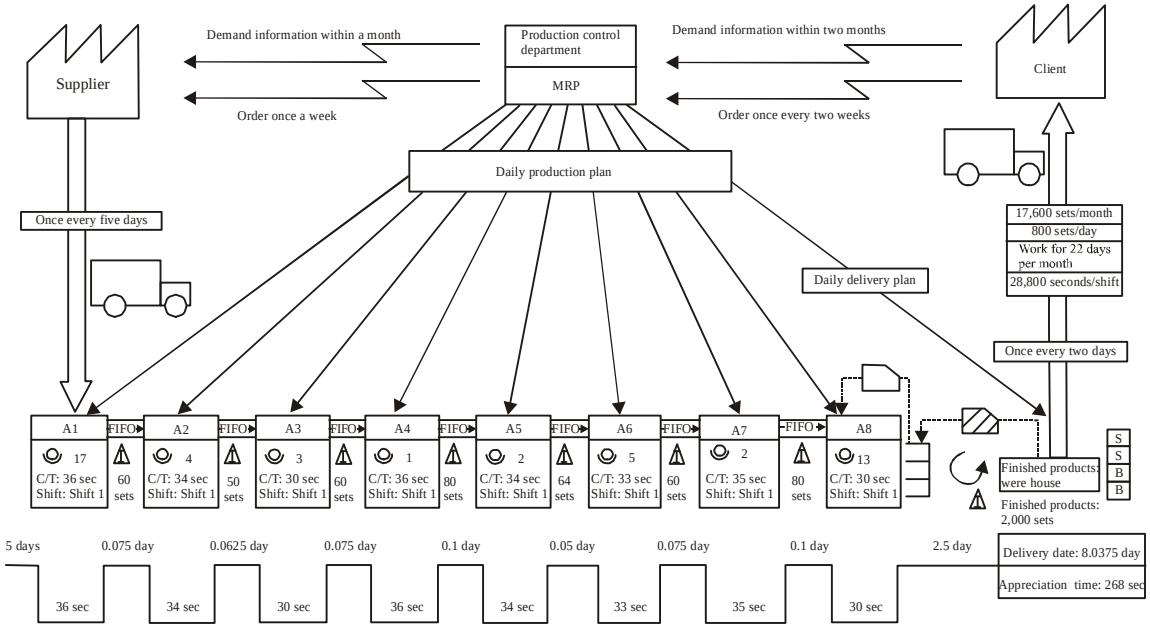

Fig. 2: Future VSM of the product

Table 3: Comparison on effect before and after improvement

Items	Lead time (day)	No. of operator (person)	Transferring distance	Work-in-process inventory (set)	Balance rate of production line (%)
Functional IE optimization results	10.725	52	88	580	77.22
Optimization results after using value flow	8.0375	47	58	430	93.06
Improvement effect	Reduced by 25.06%	Reduced by 9.6%	Reduced by 34.09%	Reduced by 25.86%	Increased by 15.84%

$$\text{Balance rate of the production line} = \frac{\text{Working hour summation of each process}}{\text{Longest working time} \times \text{No. of stations}} = 268/(8\times 36) = 93.06\%$$

The data comparison after and before improvement is shown in Table 3 and the following effect is achieved:

- Reduce the number of the operators and reduce the cost. To reasonably arrange the operators effectively improves the negative phenomena, such as a waste of waiting time of the workers in the production field, a waste of labor force, etc. The number of the operators is reduced to 47 now from 52 before the improvement, which reduces the labor cost
- Improve the balance rate of the production line. Through improvement of the production line, adjust the load of each station on the production line, which greatly increases the balance rate of the production lime from 77.22% before the improvement to 93.06% now and reduces the waste resulting from the imbalance of the station. Basically, it realizes a stream production
- Shorten the lead time of the product. After the improvement, the lead time is shortened to 8.0375 days from 10.725 before the improvement, which effectively reduces the time of the work-in-process inventory, as well as inventory cost
- Reduces the work-in-process inventory. Through the improvement, the work-in-process inventory is reduced 430 sets from 580 sets, which means a reduction of 25.86%

CONCLUSION

This study applies the VSM technology; merges, rearranges and simplifies the production process of the products, scientifically arrange and adjust the personnel, process and other related aspects after identifying the problems during the production; designs the quantity of the safety inventory and buffer inventory, finished product supermarket, Kanban system, etc.

The results have shown that comparing with the functional IE, after using the Value flow technology to optimize the product manufacturing process of the plasma display panels, numerous non-value-added activities in the production process are removed, in the process, the lead time, the number of operators, the transferring distance, the work-in-process inventory, the balance rate of production Line are improved. Finally, it has achieved the goal of eliminating all wastes and enhancing the productivity and enterprise competitiveness.

REFERENCES

Ang, Y.J., SH.Q. Guo and R.M. Huang, 2011. Improvement of process based upon lean production. Mech. Elect. Eng. Mag., 28: 1461-1464.

Cao, G.A., W.J. Wan and X. Zhang, 2010. Analysis and improvement of the value stream in fridge production. J. Hefei Univ. Technol. (Nat. Sci.), 33: 1471-1475.

Cheng, X.F., 2011. Study on the application of the six sigma in the modern power enterprise management. China Elect. Power Edu., 12: 78-82.

Gu, P.P. and M. Du, 2013. Application research of fundamental IE on assembly line balance. Logis. Manage., 36: 100-129.

Hao, J.M., 2010. An approach of improving business availability of communications network based on value stream mapping. J. Ind. Eng. Eng. Manage., 4: 66-70.

Jin, Z.H. and J. Li, 2009. To analyse and to improve for the production line of computer radiator based on the value flowing. Value Eng., 28: 80-82.

Lan, X.J., Y. Chen and H.T. Tang, 2006. Balancing and continuous improvement of SMT production line. Ind. Eng. Manage., 11: 109-111.

Li, J. and M.Q. Xu, 2008. Analysis and improvement of a slippery track production line based on the value flowized. Ind. Eng. Manage., 13: 122-126.

Lu, L.X. and Q.G. Luo, 2008. Enterprise production operation process reform. Guangxi Qual. Supervis. Guide Period., 11: 66-76.

Miao, Z.H., K.L. Xu and Z.H.F. Li, 2009. Production line redesign by using value flow diagram: A case study. Ind. Eng. J., 12: 115-119.

Sobczyk, T. and T. Koch, 2008. A method for measuring operational and financial performance of a production value stream. Int. Fed. Inform. Process., 257: 151-163.

Wang, J.G., 2012. Research on production line improvement of WD615Oil bottom based on the value stream map analyzing method. Master's Thesis, Shandong University, Jinan.

Wang, L.L. and F.R. Zhang, 2011. Production Plan and Control. China Machine Press, Beijing, China, pp: 114-116.

Xu, H., Y.Y. Li and Z.L. Ma, 2013. Study on production process optimization Based on TRIZ theory and TOPSIS method China's high-tech enterprises. TRIZ J., 28: 19-22.

Yang, L. and X.P. Zhang, 2009. Research on the application and effect of the value stream management in an air conditioner manufacturer. Ind. Eng. Manage., 14: 90-96.

Yang, Y.X. and K.L. Xu, 2008. Analysis and improvement of production line based on the value stream mapping. Mach. Tool Hydraulics, 36: 40-42.

Yi, S.H.P. and F. Guo, 2014. Fundament of Industrial Engineering. China Machine Press, Beijing, China, pp: 39-41.

Zhang, X.L., 2012. Business optimization research to work flow based on process analysis method. Ind. Eng. Manage., 17: 40-45.

Zhang, Y., S.S. Jin, D.Z.H. Feng and D.P. Yang, 2012. Analysis and improvement of gear production line based on value stream diagram. Group Technol. Prod. Moderniz., 29: 7-12.