Appling DMAIC methodology to assess and improve supply chain performance - in LCD industry as an example

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Abstract

Based on the interview about consults and customers, APS plays a vital role because of its blending with performance feedback, building integrated evaluation indices, and making the problem traceable. The role of APS is especially beneficial in supply chain, which has multi performance indices within. In this study, used thin film transistor – liquid crystal display (TFT-LCD) for Multi-Site Supply Chain Planning (MSSCP) as the targeted case and integrated Six Sigma as the feedback mechanism of decision to fulfill the planning of MSSCP. First, this research analyzed the network of MSSCP to identify the need and related problems in the field. The main point of this procedure is to change the supply chain network into measurable system diagram. Second, the study used the DMAIC of Six Sigma and blended with the concept of process incapability index (PCI) to build the evaluated model of planning system in MSSCP. The aim of this phase is to build the instant feedback. Finally, the study used the planning of MSSCP in TFT-LCD as a case, pointed out the factors result in poor performance and provided related strategy to improve them. The purpose of this study is to promote the level of planning in MSSCP and provide some suggestions for researchers and practitioners.

Keywords

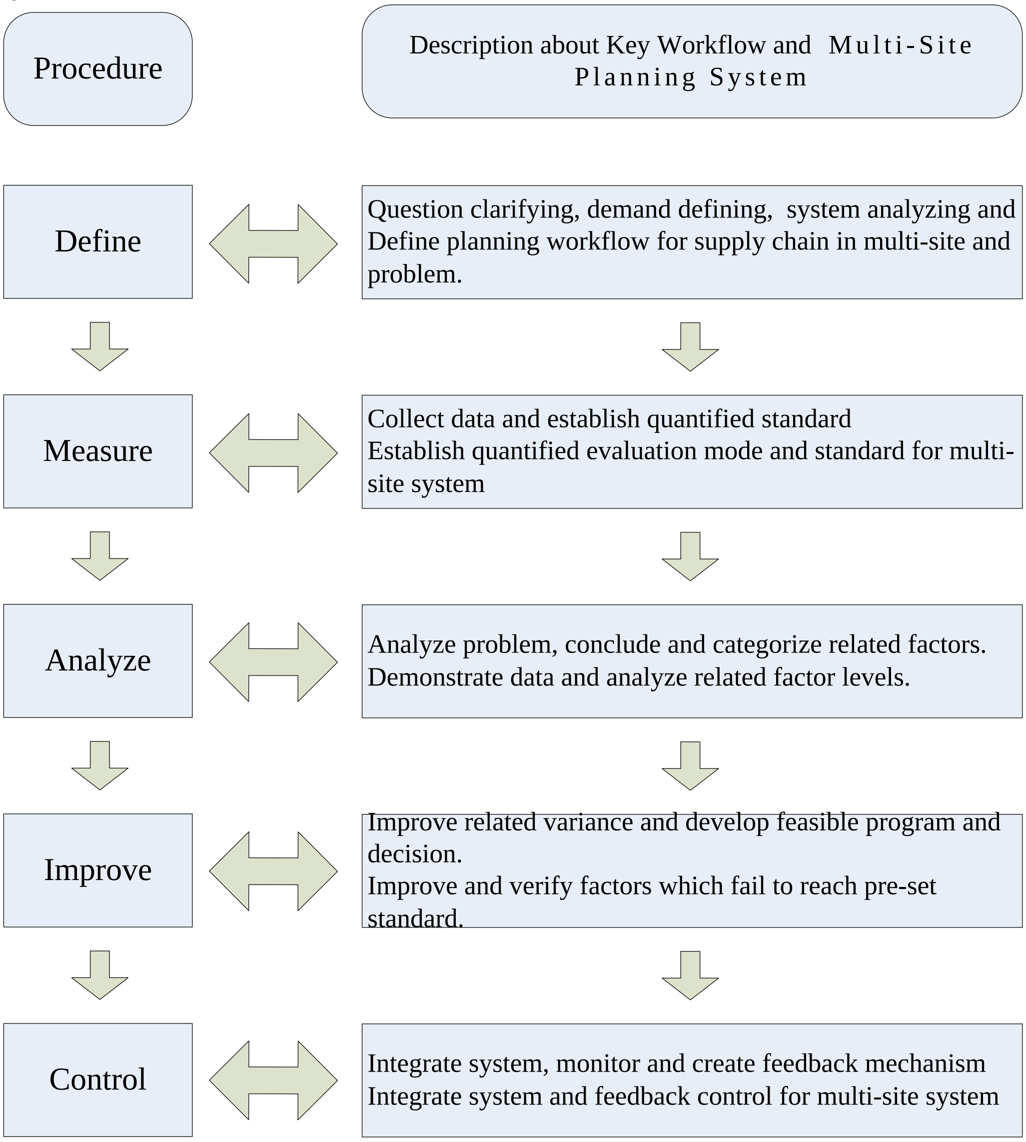
TFT-LCD's Multi-Site Supply Chain Planning, APS, Process incapability index, DMAIC methodology.

1. Introduction

Thin Film Transistor Liquid Crystal Display (TFT-LCD) industry is currently experiencing a high growth period. As noted by Hung (2006), total production value of TFT-LCD in 2004 has rated Taiwan as the world's biggest supplier. As industry scale increases, more and more manufactures, in order to pursuit a more efficient and flexible panel production, and shorten the time period taken for sea and land transportation, are considering the possibility of moving the former part of the production process elsewhere, to cope with new demands of diverse orders and outbound product. Moon et al.(2005) point out that in optimizing supply chain, it is necessary for the industry to take into account other related activities of the entire supply chain in addition to single-site consideration. While Esther (2007) suggests that the current problem can only be solved by integrating a systematic method, that is, the key solution lies in upgrading the efficiency of the entire supply chain by applying related instruments.

Gould (1998) proposes, on the other hand, that advance planning and scheduling (APS) is an important decision support system (DSS) in the supply chain management (SCM). McKay et al. (2003) mention that APS includes three functions: planning, scheduling and dispatching. Liker et al. (1999), in their study, place APS as a promoting system in the supply chain. Presently the multi-site supply chain planning (MSSCP) has become a very concerned issue for most manufacturers. Stadtler (2005) argues that supply chain planning (SCP) contains multiple goals, involving many conflicting factors, making supply chain planning a very complex process. In coping with such complex nature of supply chain, the industry has adopted the advanced planning and scheduling (APS) as an important application. Therefore, this study intends to map out a multi-site supply chain planning module, based on the unique features of the industry, as references for manufacturers in their medium- and long-term supply chain planning.

In summing up, the study, using order fulfillment rate as the basis for exploring performance evaluation, the pre-planning capability of advanced planning scheduling system and DMAIC steps of 6-sigma by Chen(2006), has defined, measured, analyzed and made improvement on the problems concerning multi-site planning scheduling. Finally the study sets up related system feedback and control plan, as shown in Figure1 , Integration Workflow of 6-Sigma Methodology On Multi-Site Planning System.



2. Define and Measurement Multi-Site Planning Performance

By applying the first step of 6-sigma, we first define the goal and problems in the system, based on customer demands. The purpose of multi-site supply chain planning is to achieve on-time delivery for various sites in planning orders. In the TFT-LCD multi-site supply chain, order fulfillment depends on the productivity conditions and transportation time between sites, as shown in Figure 2, Supply Chain Network of TFT-LCD Industry.

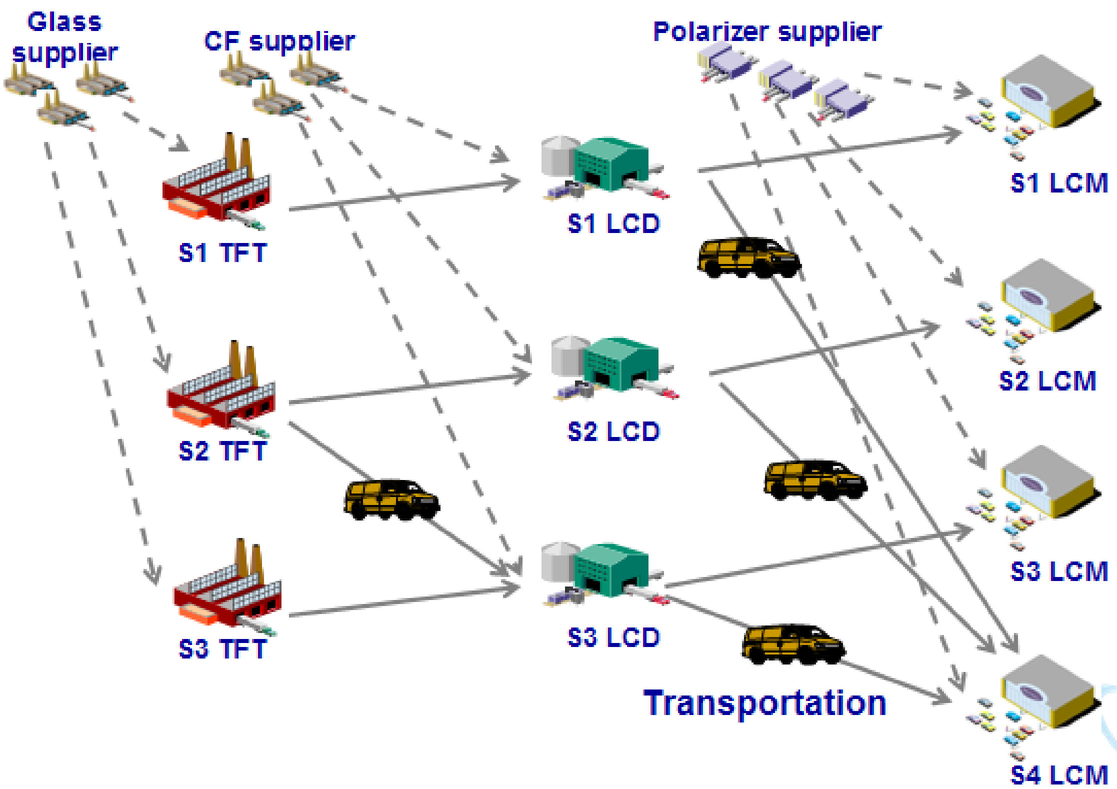


Figure 2. TFT-LCD Industry Supply Chain Network Chart

Viewing from the angle of workflow, the purpose of advanced scheduling system is to consider all related restrictions, and distribute demanded orders throughout various plant sites for production in an effective manner, to fulfill customer needs.

The preceding description indicates that the multi-order and multi-item plant site planning, facing complex supply chain, has to make overall consideration of all related factors: procedures, plant site productivity, materials, transportation, and so on. Thus the industry may gain a better understanding of the project boundary through multi-site system planning workflow, and effectively measure the standard of system planning.

As indicated in Figure3, Procedure of TFT-LCE Supply Chain Multi-Site Planning, each individual approach in the network is composed by manufacturing point, transportation point and the final customer warehouse. The circle represents manufacturing point, i.e., plant site in the production process, mainly consisting of three stages: TFT, LCD and LCM plants. Oval shape is the transportation point, representing transport operation from TFT plant to LCD plant, LCD plant to LCM plant, or LCM plant to customer's hub of warehouse. Transportation operation includes transportation mode: sea, land and air transportation etc. Circle represents semi-product or finished product in stock. Each node is indicated with an estimated time of treatment, as shown in Figure 5, order treatment time at TFT1 plant is 6 days, 3 days at LCD1 plant, transportation time from LCD1 plant to LCM1 plant is 2 days and the last assembly time taken at LCM1 plant is 2 days. Therefore the estimated time for the entire approach to complete is 13 days.

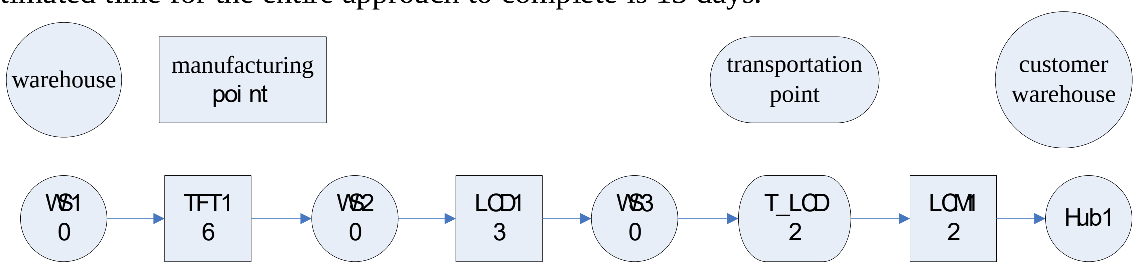


Figure 3. Procedure of TFT-LCE Supply Chain Multi-Site Planning

The above shows that an estimated time is noted at each node, with a purpose to track back the delivery date. In practice, the injecting point of order may be tracked back by the scheduled delivery date, since the introduction of orders usually won't happen at the same time point. In simulating the process, the system also tracks the initial time point of the order according back to the scheduled delivery date. The injecting date of order may be calculated by the aggregated treatment time of each node indicating order delivery date as follows:

Where,

o : Represents order;

p : Represents node, where time t is produced when o passes through;

r : Represents approach consisting of all p nodes that order o has passed through;

w : Represents the number of node on approach r;

T_{ro}^{R} : Represents the injecting time point (injecting date) of order o on approach r ;

T_{ro}^{D} : Represents the completion time point (delivery date) of order o on approach r ;

t_{rpo} : Represents treatment time (days) that order o takes at node p .

To avoid too earlier drafting of order during system planning, the injecting date D_{ro}^{R} is tracked back through delivery date D_{ro}^{D},. Obviously, the relation between injecting and delivery date of order o, and treatment time of each node may be expressed as follows:

$$T_{ro}^{D} = T_{ro}^{R} + \sum_{p=1}^{w} t_{rpo}$$

After identification of order injecting date D_{ro}^{R}, actual productivity and transportation mode of each order will be evaluated according to the starting date D_{ro}^{D}. The scheduled delivery date T_{ro}^{S} is then arranged by considered the actual restrictions such as productivity, materials, and transportation time of each node, as shown in the following description:

$$T_{ro}^{S} = T_{ro}^{R} + \sum_{p=1}^{w} t_{rpo}^{S}$$

T_{ro}^{S} : Represents the suggested completion time (completion date) of the scheduled order o on approach r ;

t_{rpo}^{S} : Represents the time (days) taken for the scheduled order o at node p ;

Apparently, $T_{ro}^{D} < T_{ro}^{S}$ indicates the selected approach r of order o failing to complete within the scheduled time span; while $T_{ro}^{D} > T_{ro}^{S}$ indicates the selected approach r of order o has completed within scheduled time. Time difference between scheduled time t_{rpo}^{s} and t_{rpo} at node p on approach r of order o is expressed as follows:

$$\delta_{rpo} = t_{rpo}^{s} - t_{rpo}$$

δ_{rpo}: Represents the time difference (minutes) between planned time t_{rpo}^{s} and scheduled time t_{rpo} .

Depending on the different purchased amount and type of order o, δ_{rpo} may varies at different node p and different approach r. To measure the system's planning capability, the study will further normalize the following planned results of each node:

$$U_{rpo} = \frac{G_{rpo}}{|\delta_{rpo}| + \varepsilon}$$

U_{rpo} is the normal value, G_{rpo} is the weighted value; when $\delta_{rpo} \geq 0$, $G_{rpo} = 1$, represents order fulfillment; when $\delta_{rpo} < 0$, $G_{rpo} = 0.5$, represents unfulfillment of order; constant ε functions to prevent $\delta_{rpo} = 0$ when $U_{rpo} \cong \infty$, therefore $\varepsilon = 1$.

It is obvious that $\delta_{rpo} = 0$ when $U_{rpo} = 1$, indicating consistence of scheduled and planned completion date of order, a desirable optimal condition. When $U_{rpo} < 1$, indicating inconsistence between scheduled and planned days taken to complete order. Thus a smaller U_{lpo} appears. Further exploration of influential factor is needed.

Table 1, Process Capability Index and Fulfillment Rate of Planning Approach is compiled by using 2~6 quality standards and index value corresponding to planned fulfillment rate.

Table1. Process Capability Index and Fulfillment Rate of Planning Approach

Quality Level	Index (C_{PLrp})	Rate of Planning Approach $\Phi(3C_{PLrp})$
6-Sigma	1.50	0.999996602
5-Sigma	1.17	0.999775947
4-Sigma	0.83	0.993612845
3-Sigma	0.50	0.933192799
2-Sigma	0.17	0.694974269

The study intends to further compile each long-, medium- and short-term planning cycles by using the transfer equation of fulfillment rate and process capability, as shown in Table 3, Planning Quality and Allowable Error of Days. For instance, the allowable error of ordinary long-term schedule is 7 days, when the resultant fulfillment rate is 75%, we may gain an error of 4.4 days if all orders are fulfilled, and an error of 2.2 days if all orders fail to be fulfilled, with the longest error of 7 days. Therefore, a long-term schedule is only acceptable when it reaches a 75% fulfillment rate.

Table 3. Planning Quality and Allowable Error of Days.

Planning Quality			2-Sigma					3-Sigma	4-Sigma	5-Sigma
Planning cycles				long-term schedule (month)			medium-term (week)			short-term (days)
P_r	0.51	0.6	0.7	0.75	0.8	0.85	0.9	0.93	0.99361	0.9997
C_{PLr}	0.01	0.08	0.17	0.22	0.28	0.35	0.43	0.49	0.83	1.14
Days for orders are fulfilled	119.7	11.8	5.7	4.4	3.6	2.9	2.3	2.0	1.2	0.9
Days for all orders fail to be fulfilled	59.8	5.9	2.9	2.2	1.8	1.4	1.2	1.0	0.6	0.4
Allowable Error of Days	179.5	17.8	8.6	6.6	5.3	4.3	3.5	3.0	1.8	1.3

By using a certain TFT-LCD plant as an example, we try to analyze all related data concerning its supply chain planning. Data analyzed includes 3475 orders, with 6-month planning cycle and 95 approach paths. All treated orders are arranged in order and the top 4 approaches of the largest planning volume are then used for productivity analysis. According to the above-mentioned plant types, including TFT, LCD and LCM, we then measure the planning quality by calculating the C_{PLrp} value of each plant site, We find in the above table the multi-site processes: R36, R44, R218 and R265, where the C_{PLr} of R36 equals to that of R44, with a fulfillment rate of 69%. R218 has a value of $C_{PLr} = 0.18$, with fulfillment of 70%, while R265 is $C_{PLr} = 0.16$, with a 68% fulfillment rate.as shown in Table 4, Planning Standard Index.

Table 4. Planning Standard Index.

Route r	CPLR	Fulfillment	TFT@L2 CPLRP-1	LCD2@L2C CPLRP-2	LCD3@L2C CPLRP-3	LCM2@FDT CPLRP-4	LCM2@WJ CPLRP-5
R36	0.17	0.695	0.35	0.45	0.73	-	0.65
R44	0.17	0.695	0.37	0.39	0.56	0.96	-
R218	0.18	0.705	0.38	0.43	0.87	0.48	-
R265	0.16	0.684	0.28	0.34	0.80	-	0.76

3. Improvement and Control on Multi-Site Planning

All influential factors induced from analysis stage are then classified into two levels according to influential characteristics, The first improvement level contains influential factors of multi-site approach, including sequence and selected method. Any change made on this level will affect the sequence of approach, planning of order etc. Therefore the planning standard of the entire approach is affected. In addition, manufacturing and transportation may be induced as approach influential factors, and further subdivided into classification as node influential factor.

There are mainly two node influential factors on the second improvement level: manufacturing and transportation nodes. Manufacturing is affected by productivity and material, which may be subdivided into restriction of plant productivity, distribution restriction of product grouping, and monthly production restriction of machine model. Transportation is affected by sea, land and air time schedules.

All approaches are filtered based on product outbound plant site, and arranged in order of consumable material group.

4. Conclusion

Using TFT-LCD industry as an example, this study provides an evaluation mode and workflow for the multi-site supply chain planning system. Major contributions of the study are described as follows:

(1) Building up a multi-site planning system: The complex multi-site supply chain network of TFT-LCD industry is transformed into a supply chain approach comprising of many individual single-site, which is then subdivided into several process section according to its industrial features to conduct analysis of planning standard. By using multi-site planning system under developing as an example, this mode conducts related system analysis and designing mode. Findings of this study may provide useful references for future system planners and industries as well.

(2) The measured planning standard reflects fulfillment rate of the planning system and as an index providing basis for system improvement. The other index C_{PLrp}, is used to measure the planning standard of the approach adopted by each plant site, and to identify major process section and plant site that affect the fulfillment rate of the approach. Findings of the study reveal that the productivity of plant site at the TFT section may affect the planning quality of the entire approach.

(3) Improvement for hierarchical planning factor: We propose countermeasures for each influential factor from the perspective of system design to modify the system. Finally, using APS to control identical planning data and compare efficiency. Resultant findings show an average 10% increase of all improved approaches with a shortened error of 10 days, making the planning standard of the system greatly increased.

(4) Starting from the perspective of multi-site supply chain planning, this study has integrated multi-site planning system with 6-sigma methodology, and established measuring index without unit to measure the planning standard of each approach and plant site and explore many issues existing in the currently adopted supply chain system. In practice, a supply chain is composed of many factors. Future studies are expected to take into consideration of output, order delivery and other factors, such as schedule and cost, to upgrade the performance of supply chain by constructing a more comprehensive supply chain decision-making system.

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