Integrated Capacity Planning Tool Implementation in an OSAT Company using the Six Sigma DMAIC Framework

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Abstract: Capacity planning is an essential factor in addressing manufacturing challenges. An Outsourced Semiconductor for Assembly and Test (OSAT) Company must have a capacity planning process that shows the availability of the current resources like labor and equipment to meet the current and future demand. This project involved the study of an OSAT company in the Philippines and their capacity planning processes. Despite the company's use of computer-based systems for capacity planning, such as CAPTOOL and Microsoft Excel, data quality issues still persist, including problems with data timeliness, reliability, redundancies, and report inconsistencies. These problems are brought about by tedious data processing activities and data operation silos. Hence, an in-house capacity planning simulation tool called IPLAN was designed and developed for the OSAT company, integrating with the existing enterprise resource planning (ERP) system and utilizing current source data, in order to address the aforementioned issues. Along with the iterative Software Development Lifecycle (SDLC), the Six-Sigma Define-Measure-Analyze-Improve-Control (DMAIC) methodology was used to review the processes, understand the problems, and generate ideas to improve the existing capacity planning process, and further enhance support for decision-making activities. IPLAN significantly shortened the duration for data extraction, data uploading, and report generation. The positive result of testing the system's functions and a high user satisfaction rating indicates IPLAN as an effective tool for capacity planning. Moreover, the results also imply that the DMAIC framework, partnered with constant communication with project stakeholders throughout the system implementation process, is an effective approach in defining problems, measuring the performance, analyzing areas for improvements in the existing system, and accordingly determining solutions and controls that are tailor-fitted to the needs of the OSAT company.

Key Words: capacity planning; information technology; systems development; manufacturing; business process improvement

1. INTRODUCTION

Semiconductor manufacturing companies have important capital investment decisions for acquiring new types of machine tools for their facilities (Catay et al., 2002). Capacity planning determines an organization's necessary resources to sustain a given demand over a planning horizon (Chen et al., 2009). Capacity planning and investment is a challenging task in the semiconductor manufacturing industry. These companies supply integrated circuit devices to many end-products such as computers, communications, and electronics, which have dynamic market demands. In order to achieve competitive advantage, such companies need to place high investments on machines that could provide optimal utilization (Biwer et al. 2018) and state-of-art wafer fabrication equipment (Ellis et al. 2017). Furthermore, it is also vital to perform continuous improvement on processes for customer demand forecasting, and planning for capacity, demand, and resources.

Capacity planning is an essential factor in addressing the operations' challenges regarding supply, possible machine breakdowns, fluctuating yield factors, lead times, and quality concerns. In any manufacturing company, the capacity configuration and allocation need significant decisions to become crucial to the semiconductor industry because of the high cost and long lead-time for equipment procurement and clean-room construction. (Karabuk et al. 2003). A research conducted in China found problems encountered in capacity planning that include complex processes, changes in technology and products, and high investment cost on equipment (Geng et al. 2009). A strategic capacity planning is essential to improve business performance that will determine the timing of acquiring machines (Geng et al. 2009). Researchers also recommended taking an integrated approach to capacity planning, which links to other planning processes. The challenges in the production environment empower the use of digital transformation that includes process automation through an application that will help with the advanced planning and scheduling (Vieira et al. 2019).

The Outsourced Semiconductor for Assembly and Test (OSAT) company involved in this study operates its business in some countries all over Southeast Asia, Europe, and the United States of America as the main headquarters. The company offers more than 1,000 different package formats and sizes produced by other manufacturing plants. There is a high impact on the organization if there is uncertain demand and supply that could lead to increased costs and lead times (Biwer et al. 2018). The semiconductor industry needs to cope with the variability, which depends on customer demand.

One of the OSAT Company's missions is to create innovative solutions for semiconductor and microelectronics companies using advanced technology. Innovation also involves reviewing the relevant processes and finding ways to simplify them. The company promotes process automation and continuous improvement to provide quality output to the customer that will meet or exceed customer expectations. However, the existing capacity planning process has plenty of sub-processes to perform that contribute to the capacity engineers' working hours to generate capacity reports. The capacity engineers will extract data from an ERP application, then upload the data to the existing application called CAPTOOL program developed using Microsoft Access in 2009. Data processing will only begin once data uploading is completed. Various Microsoft Excel files are created or maintained individually by Capacity Engineers, including demand forecast reports, machine allocation, capacity reports, and monitoring the number of units per hour (UPH) produced by a certain machine.

This study's objective is to review the existing capacity planning process and implement a tool to enhance collecting and managing data that will help in data analysis to support an efficient fulfillment of competing demands. Six Sigma DMAIC framework has been used widely for manufacturing and business processes. The DMAIC Methodology was executed together with the management support is a powerful tool that can reduce processes, eliminate waste and improve customer satisfaction (Gangidi, 2018). The Six Sigma DMAIC framework was applied to evaluate the existing capacity planning process.
Simultaneously, the Software Development Life Cycle methodology served as a reference for the development of the application.

Six-Sigma DMAIC methodology was developed by Motorola in 1986 to measure overall business improvement. The Intersil semiconductor manufacturing company developed a comprehensive roadmap for their capacity and cycle time improvements using Six-Sigma - DMAIC methodology (Barney, 2002). The phases in the DMAIC methodology are as follows: (1) Define, which determines the customer requirements; (2) Measure, wherein the data collection takes place; (3) Analyze, which involves root cause analysis; (4) Improve, gives insights or providing corrective and preventive actions; and (5) Control, wherein the maintaining the sustaining control over the process.

2. METHODOLOGY

2.1 Define

The first step of the Define phase is the validation of business opportunity started by capturing the voice of the customer (VOC) using surveys, interviews, focus group discussions, and observations. The customer identified as an internal customer represented by the Corporate IE that belongs to the management team. The customer mentioned the pain points encountered with the current process. An interview was also conducted to the Corporate IE staff and local IE user. They mentioned that some manufacturing sites used a different way to do capacity planning, including varying tools, methods, and formats for data preparation, extraction, and processing. During the discussion, the group decided to form a project team that will focus on the requirements and implementation of the project. The project team consists of IT professionals, Stakeholders (decisionmakers), and Capacity Engineers (end-users) who have extensive experience in the semiconductor manufacturing industry. A project charter was created that includes business case, project scope, and its objectives. The stakeholder is also the requestor classified as internal customer.

Modeling of the As-Is process of the capacity planning using CAPTOOL of the OSAT company was also performed. A business process model and notation (BPMN) diagram was used to visualize the process from checking the forecast data to the creation of the new proposed allocation report. Additionally, a Supplier, Input, Process, Outputs, and Customers (SIPOC) diagram was produced to show the relevant elements of the existing capacity planning process of an OSAT company, per the As-Is process. The highlevel SIPOC diagram was presented to the Stakeholder representing the supplier of the information and the recipient of the processed output.

2.2 Measure

The second phase involves numerical studies and data analysis. On this phase, a functional flowchart was created to show how the customer demand data is processed on each group before the final commit report provided to the customer. The current state performance of data processing is quantified to form a baseline for the process improvement.

2.3 Analyze

The third phase involves the evaluation of problems in the capacity planning process. The problems were modeled using the Ishikawa or Fishbone diagram in order to easily identify possible causes and sub-causes of problems.

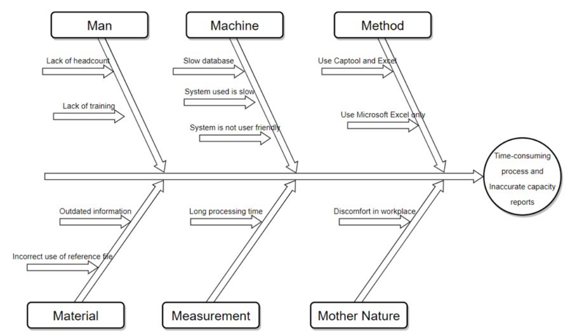

Fig. 1. Ishikawa Diagram

2.4 Improve

In this phase, the objective is to develop and implement the solutions to fix and prevent problems. The technical team did brainstorming and used 5 Whys as the tool to build a solution using latest technology. The 5 Whys used based on the Ishikawa diagram are the following: (1) Why is there lack of training? (2) Why is the application slow? (3) Why do the approaches used by capacity engineers vary? (4) Why are the data/materials used incorrect/outdated? (5) Why does it take time to process the reports?

Based on the improvement points, corresponding user requirements were identified. The user requirements were transformed into a functional or technical specification document that also corresponds to the inputs from Analyze phase. The functional specification document was used as the developer's reference in program coding and system design.

2.5 Control

This is the stage wherein the solution is being monitored or maintained. The proposed application should be accessible via web browser at any given time. This ensures that information such as forecast demand data, machine inventory and capacity reports are highly available to the end-user. The proposed application for tracking program changes and change requests is ServiceNow. ServiceNow is a ticketing system used in the OSAT company to handle any enhancements required in an application. The application enhancements tickets are being reviewed by the Technical Manager and Change Management Board to ensure the quality of the application to be deployed and possible impact to the other applications as well. The proposed control process also implements the change management process that includes the following steps: request for change; impact analysis; approve//deny; implement change; and review/reporting.

3. RESULTS AND DISCUSSION

Based on the current capacity planning process of an OSAT company, data collection and processing are challenging and laborious tasks which are also crucial part of the process. It takes an average of one (1) week to generate and submit capacity reports. The multiple files and formats that are created or maintained individually by capacity engineers pose problems on the timeliness of information as source files used might also be outdated. The data processing slack is caused by the CAPTOOL application, taking long hours depending on the data volume and instances of system crashes if CAPTOOL's capacity is exceeded. Some capacity engineers said that system navigation is complicated as well brought about by the excessive number of fields to fill-up and command buttons to trigger. Consequently, other capacity engineers opted to use Microsoft Excel for data processing because it easy to use. Unfortunately, capacity reports like demand and machine allocation plans have been doubted since these were manually created. This process only applies to a specific manufacturing plant of the OSAT company. In another manufacturing plant, some capacity engineers depend on the forecast demand data provided by another group. They do not use the existing CAPTOOL application, but instead manage their capacity reports using solely Microsoft Excel.

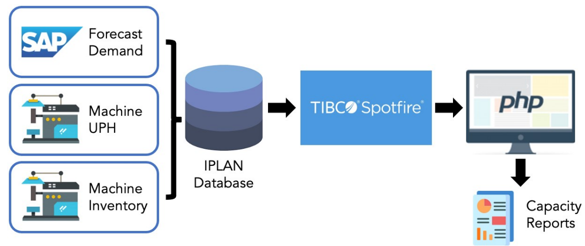

Fig. 2. IPLAN System Design

Figure 2 shows the design of the proposed IPLAN system, which was presented to the internal customer to align with the project objective. The technical experts studied the requirements based on the results derived from the Six-Sigma DMAIC approach from the Define, Measure and Analyze phases and the functional/technical requirements. The team had recommended integrating the proposed application to the source of information as an innovative solution in order to eliminate the need for capacity engineers to manually perform data extraction and data uploading. Due to the complexity of capacity computation, the technical team also decided to do in-house development to suit the specific business requirement. A centralized database will handle forecast, machine inventory, and UPH value. Another developer used Tibco Spotfire for processing and computation of capacity reports in IPLAN application because of its capability to process and analyze many data from the ERP application.

The technical team used an iterative Software Development Life Cycle (SDLC) methodology as a reference for the development of the application. It is the standard methodology used by the Information Technology Department of the OSAT Company in developing programs. Iterations allow for versions of the developed system to be evaluated by end-users, with the revisions and another set of functions/features to be integrated in the next version, until the system is completed. Furthermore, the architecture design of IPLAN comprises four layers: Data, Application, Web, and Client tier. The Data-tier represents the input data from the Application tier, such as APACHE, SAP (ERP Application), and Employee Central (Boomi Server). The Web tier displays the data processed through the IPLAN web application with Spotfire data analytics that the user will access in the Client tier.

System integration testing was done to find programming errors, understand how the system functions, and better estimate what the full implementation will require. The technical team created and used a testing environment to perform some necessary process steps with users and training. The technical team administered the test scripts with a user present. The superusers (capacity engineers) tested the program with the use of test scripts. The technical team did validation on the manually extracted file versus to the system generated one. The team achieved positive test results and handed over the program to the end-user for further testing. The end-user performed another set of testing to ensure that demand forecast data sent to the IPLAN application is accurate and finally achieved positive test results.

Aside from the comparative study performed on the old and new applications and the end-user feedback through an interview, the researcher also conducted a survey to get the satisfaction rate. A set of questions related to data collection and processing were written on the survey form that the correspondents need to choose an answer whether CAPTOOL, iPLAN or Neutral, meaning either of the system is selected. The percentage result is classified into three levels of satisfaction rate: low, medium and high. The new application acquired a high satisfaction rate based on the computed survey results (see Table 1).

Table 1. User Satisfaction Survey Results

OPTION	CAPTOOL	NEUTRAL	IPLAN	TOTAL
Answer Score	1	2	3	
Number of Answers	1	2	3	6
Value (Score x Answers)	1	4	9	14

4. CONCLUSIONS

According to the capacity engineers, their overall data processing has been improved in the new application compared to their experienced in old program that took three to four days. The overall capacity planning process that took 7 days was reduced to 2 days. The generation of capacity reports in CAPTOOL program that took hours became minutes in the new application that emphasize the system performance. The project team members and end-users deemed that system functions were sufficient. The availability of machine inventory and forecast demand data were displayed since records have been consolidated into a single database and an application that is accessible anytime through web browser. A centralized capacity planning information and the use of standard formula across all manufacturing plants have also been implemented.

Given the positive test results and feedback from the Capacity engineers, the requestor which is also the stakeholder from the Corporate IE management group has decided to implement iPLAN application to the other manufacturing plants outside the Philippines of the said OSAT company. This intends to eliminate the manual collecting and consolidation of capacity reports from each manufacturing plant across Southeast Asia and Europe regions. The promptness of receiving the capacity reports from different manufacturing plants has been a tedious task for the Corporate IE Management team due to numerous follow-ups that are burdensome to the management team. Hence, the iPLAN application is essential to the OSAT company in order to centralize the capacity planning process. The readiness of information in the iPLAN application also enables the management team to execute faster actions and make better decisions particularly on acquisition of manufacturing equipment, which cost millions of dollars. iPLAN can be enhanced to optimize the company's data and get a holistic view of the current situation of the OSAT company.

This project has demonstrated that the tools of DMAIC methodology were proven efficient in defining the problems and creating the solution to improve the process of capacity planning of the OSAT company like the case of Intersil Semiconductor, where they used DMAIC methodology that significantly improved their process (Foster & Maguire, n.d.). Though some applications are now available in the market, like D-SIMCON application used by RBOSCH Semiconductor Company, they need customization to align with their complex requirement (Mosinski & Bosch, 2017). This project opted to use in-house development, so it will specifically fit with the business requirement of the OSAT company and integrated to an ERP application to provide accurate forecast data. This project provides a guideline on processes that can be improved using the Six Sigma DMAIC framework, which is also a recognized discipline for continuous process improvement commonly found in manufacturing companies. This project had motivated the proponents to resolve the issues on decentralized processes, outdated information, and time-consuming report preparation. Furthermore, the process review on capacity planning helped the OSAT Company eliminate redundant tasks and provide a tool for the standard procedure of capacity planning. It is an advantage that the technical team working on this project have common understanding about the business requirement and have the same working experience.

It is recommended that a future study on the computation for the number of units a specific machine can produce. A study on demand and production planning would also help as a holistic approach to make strategic capacity planning decisions. The prospective study may contribute to the improvement of the application. This project is a feasible solution as Industry 4.0 technologies become more prevalent. The participation of the end-users in the system integration testing is essential to determine the success. Ultimately, it is essential to get corporate support in any project implementation. The management team of the OSAT company has fully supported this project that drives the desire for users to adapt and accept the change.

5. ACKNOWLEDGMENTS

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