Application of Discrete Event Simulation for Production Line Performance Evaluation

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Abstract—Simulation, in particular discrete event simulation, has still not gained industries wide acceptance as decision support tool for performance evaluation. This study intends to provide the example of the application of discrete event simulation in evaluating performance of a production line. The data was collected from an electronic manufacturing company’s production line and the simulation model is built using ProModel simulation software. After validating the model and running the simulation, the result is obtained. The finding shows that the workers in the production line is underutilized and the bottleneck is detected at the inspection machine which has cause a higher manufacturing lead time. We suggest that these problems can be overcome by merging several tasks together to reduce the number of workers and increasing the capacity of the inspection machine. This study shows an another example of the benefits of simulation knowledge to manufacturing organization and its application in industry should be encouraged.

Keywords—simulation technique; discrete event simulation; production line performance

I. INTRODUCTION

Simulation is defined as the process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding the behavior of the system or of evaluating various strategies (within the limits imposed by a criterion or set of criteria) for the operation of a system[1].

It is a vital problem-solving methodology for the solution of many real-world problems in a diverse set of industries. Reference [2] listed three typical application areas of simulation: (i) explorative studies of existing systems to improve them, (ii) studies of existing systems with some changes made to them, similar to the first purpose but used to validate a specific alternative, e.g. a proposed investment, and (iii) design and validation of new systems.

By these three applications, simulation provides analysis, description and evaluation capabilities of systems, and if successfully applied can support collaborative work across organizational boundaries and thereby improve information and communication. In addition, simulation can be used for training and education purposes. By these means, simulation can significantly improve system knowledge, shorten development lead time and support decision making throughout an organization.

One area where simulation is finding increased application is in manufacturing and service system design and improvement. Its unique ability to accurately predict the performance of complex systems makes it ideally suited for systems planning [7].

Meanwhile, performance measurement (PM) is the key to improving productivity, and is a prerequisite to diagnosing, trouble-shooting and improving the manufacturing system. Reference [13] defines five major reasons for companies to measure performance:

• improved control, since feedback is essential for any system;
• clear responsibilities and objectives, because good performance measures clarify who is responsible for specific results or problems;
• strategic alignment of objectives, because performance measures have proved to be a good means of communicating a company’s strategy throughout the organisation;
• understanding business processes, since measuring data requires an understanding of the manufacturing process; and
• determining process capability, because understanding a process also means knowing its capacity.

Appropriate performance measures can ensure that managers adopt a long-term perspective and allocate the company’s resources to the most effective improvement activities. Thus, performance measurement (PM) is an absolutely essential operational element in order to lead the organization towards improvement, guide progress and direct the efforts towards planned objectives.

The most commonly estimated performance measures by simulation include throughput, time in system for parts, time
parts spend in queues, queue sizes, timeliness of deliveries and utilization of equipment or personnel [2] [13].

II. LITERATURE REVIEW

The literatures below provide some examples of simulation application in various industries in order to study the system performance.

Reference [4] study seeks to reduce service time at a busy fast food restaurant named Tim Hortons on campus, University of Michigan. ProModel simulation software is adopted to improve its efficiency by modeled and evaluated several service scenarios based on customer system time, as well as answering the specific questions addressed. The main performance metric is evaluate the average system time per customer in term of total time a customer spend in the system, from entry at arrival queue, to exit. The purpose of this study is to simulate different scenarios and determine the efficiency of the service system to customers. There are a selection of soups and sandwiches at food preparation area and another two cash register counter beside it. For this study, the system is modeled by (1) adding one server either to soups server or to sandwiches server at food preparation area, (2) two separate arrival queues (a combination of cash register counter and either one food serve); (3) add a runner between food preparation area and cash register counter and others. After running the ten models, it is possible to adding a third cash register counter which appears to be the scenarios the reduce customer waiting time the most. Adding a runner has a potential to reduce the time spent in the system. However, adding a second arrival queue does not appear to be improvement to the system. In addition, the study has recommended that to operate with five workers and adopt (1) scenario as they decrease average system time the most.

Reference [8] studied a variety of lean tools to assess and address the problem of overcrowding of the Emergency Departments (EDs), leading to the medical personnel overload, and the excessive waiting time to receive proper care in Canadian hospitals. The outcomes help authors to understand the long waiting time in process system and overwhelming delays. In addition, simulation model software ProModel was used to transmit this information in a visual form and the comparative analysis is performed. In summary of this study, simulation of the overall process that made virtual changes more predictable.

Reference [12] study intended to develop decision making on expanding capacity and plant layout in Plastic Packaging Company by using simulation model. In order to expand production capacity, maximize space utilization, and forecast space requirement for future stage, several alternatives are evaluated. Simulation model is used to run various scenarios to see the effects. In this way, the optimum layout for new plant can be identified with the constraint of factory size. The authors implementation success was attributed to appropriate steps being undertaken as follow: (1) Input level - the model place the machine location according to the physical layout and each product process flow is created. Product specific data required processing each product type, customise the simulation experiment by changing certain requirement in the model to Schedule each product items for production to follow. These are the input data required before undergo the process of Model building by using ProModel software package - (2) implementing level. (3) output level - validate and verify the evidence was gathered from simulation results and ensure that the simulation running result model is represented the real production system. In conclusion, the physical layout is decided according to the criterion of space available for WIP and easy flow of material.

Reference [3] study adopted a simulation model - ProModel to find an adequacy number of cashiers and baggers in Colombian supermarkets to reduce the customer waiting time. This purpose of this study is to create a general framework for Colombian supermarkets in order to face the decision of minimum number of cashier and baggers required given in service level. The models is design and put in a simulation environment to prove the effect of the main factors defined and their second level interactions based on seven supermarket’s real data. Five factors were chosen to be simulated: (1) day-of-the-month scenario (regular working days, Saturdays, Holidays and biweekly payment day), (2) supermarket size – referring it the real state floor surface and the number of cashier available, (3) item register time at checkout unit, (4) number of cashiers and baggers and, (5) Ways of payment (cash, credit card, debit card, check or voucher). The sample was collected include all kind of day-of-the-month scenarios. For each supermarket size, number of arrivals, number of registered item and ways of payment proportions per hour will collect during those days. In the findings, develop a flexible schedule of shift to cover the demand during the afternoon, way-of-payment time best-fitting distribution is discovered for each scenario, and a combination of cashier and bagger is founded out to meet an average waiting and system time for each scenario. However, it seem like not powerful enough for service promises which was to serve 98% of the customers in less than 7 minutes due to the variability of maximum times.

Reference [11] study proposed a solution using Radio Frequency Identification (RFID) - IC (Integrated Circuit) tags to reduce customer waiting time in a retail store and also become the backed up line if the cash counters waiting time became longer. Other than that, the customer flow, particularly the customer waiting time at checkout unit in retail store is examined to reduce the sale transaction time with the assistance of Point Of Sale (POS) system. POS software is usually recognized to correspond to merchandizing, in-store
merchandizing and operation. According to the author, the POS data are accumulated customers daily sales every day and installed at the front desk. When a customer purchases an item, the scanner was used to scan the barcode and interpret into the POS system one by one. While for the IC tags the customer only put a basket of all item on stand of RFID, then the total amount for items is displayed on the screen. Hence time to read bar codes of all items can be eliminated. Through a series of simulation experiment, customer waiting time are identified by leading the customer to shortest register line, adopting IC tags and changing allocation of items on the shelves. The location of congestion inside the retail shop is identified by 3D Arena simulation software. In conclusion, the proposed procedure was applied to an actual real life at a convenience store on the campus of Nagoya University. By the way, the advanced in technology, IC tags allow to improve in transaction at the cash counter in a retail store.

Reference [6] study developed a simulation model to predict delay and produce a logical and rational management of check-in and security checkpoint inside the airport terminal. The passenger flow from the terminal airport, from entrance to boarding was analysed in the South Italian reality (Capodichino - Naples International Airport). All passengers behave differently at the airport, and the experience is certain key factor in the performance of their actions, difficult to predict a priority and delays occur. Therefore, the development of a simulation model help to infer and predict, take into account the available capacity and the fact that the volume of passengers depends on day time and the week day, the different passenger behaviour. This model enables to optimize in a logical and rational management all check-in desks and security control inside the terminal. The authors used Rockwell Arena [2, 3, 4, and 5] and obtained the results of queue average values, and waiting time as well as related to minimum and maximum peak in relation to the amount of resources left open in the model. The critical results show the combination of check-in desks and security control checkpoints able to minimise the cost. This solution allows a right trade-off between costs and offered service levels.

Reference [9] adopted a case study to seek an improvement of the General Surgery patients' treatment duration at general surgery clinic at the well-known, training and research hospital. The purpose of this study is to reduce the waiting time and eliminate the bottlenecks by speeding up the process by using what-if analysis. The simulation model of existing system was demonstrated and developed via ProModel software program. There are 4 scenarios have been established to determine the critical factor which effect patient's waiting durations: (1) the capacity of the operating room, (2) the number of bed, (3) the working hour for operating room and, (4) test duration such as biochemical, radiology and advanced test. The extensive of data collection was completed in six months and ten times repetitively. In the findings, the improvement on capacity was provided by adding an operating room, increases the bed capacity and working hour for operating room and, removed unnecessary test duration if possible. All outcomes of study showed that the improvement in efficiency is acquired without any financial burden for the hospital budget by enhancing the processes in General Surgery clinic via using simulation modeling.

Reference [10] study seek to determine whether the introduction of self-service technology in a service delivery process could reduce actual waiting times and improve service levels. A simulation model of a hotel check-in process was developed after observing the front desk of a 300-room hotel located in Pennsylvania which serves a mix of business and leisure of guests. The waiting time system to be studied extended from the arrival of the customer to the check-in desk to the departure of the customer to her/his room. However, the decision of either check-in by a service employee at service desk or using additional self-service kiosk will based on the desired service option of customer according to the resource available, customer arrivals and employee processing times, customer behavior and its scenarios. A simulation model was applied and formulated using the ARENA, simulation software. Two performances were measures to compare the simulated and actual systems: (1) average number of customers arriving and maximum customers waiting in line. In the result, the number of self-service kiosk and the number of service employees on waiting times and service and service levels shows a significant interaction statistically. For example, adding a self-service kiosk to the current setup significantly reduced total customer waiting time, resulting in a service level of 99.3%. The finding shows that replacing a service employee by a self-service kiosk with a faster processing time to reduce the labor costs. However, there are several issues that need to be considering when the implementation was a reduction of labor costs. (1) the performance depends on the utilization of the system when the demand may be relative high. (2) pay close attention to the processing time of the Self-service kiosk based on the skill and experience of customers using the self-service kiosk.
simulation software is adopted. The findings show the simulation has been done to anticipate the waiting time problems of the port which is time consuming to the users. The clear project progress and result measurements were being put in place, for example, (1) operating 3 to 5 docks with high capacity of vehicles, (2) there are only 2 hours of maximum waiting time either in port of Merak or port of Bakauheni, (3) the replacement of big carrier ship to small ship to maintain the capacity of shipping during big wave condition and, (4) the additional numbers of ships is recommended in order to reduce the waiting time.

III. PROBLEM DEFINITION

This study is done at an electronic company located at Batu Pahat, Johor, Malaysia, which among others producing printed circuit boards. There are seven main processes in printed circuit boards (PCBs) production line: manual insert, flux sprayer, deeping, touch up, internal circuit test, inspection, and packing. At manual insert, six workers are hired to insert electronic components to the PCBs manually. Next process is flux sprayer to spray soldering flux to PCBs before the electronics components are soldered at deeping machine. After that the PCBs go to touch up process for manually repair if there is any defect during auto soldering. Next the PCBs will undergo internal circuit test (ICT) to ensure that the circuit functions properly. Then the PCBs go to final inspection before they are packed and shipped to customers.

The problem appears when this electronic product manufacturer always cannot meet their targeted output and they do not use any tool to help them to evaluate their existing production line performance.

IV. METHODOLOGY

Simulation approach used in this study is the application of discrete event simulation using ProModel software. In ProModel, a model consists of elements such as entities (the items being processed), locations (the places where processing occurs), resources (agent used to process and move entities), and paths (aisles and pathways along which entities and resources traverse). PCBs’ production line of the studied company is modeled. Input data include inter arrival times of entities entering the production line, arrival quantity, arrival frequency, processing time of each location, capacity of each location, moving time from one location to another, etc. The data are gathered using time study techniques. Processing time data keyed in into Stat::fit software for distribution fitting. Then the simulation model is verified to eliminate syntactic and typographic error, and validated to ensure that the simulation model is an accurate representation of the real system.

V. RESULT

Performance statistics are gathered during the simulation and automatically summarized for analysis. The metrics are workers and machines utilization, queue size (average and maximum content), locations’ states (e.g., % empty, % occupied, % in operation, % idle, % waiting & blocked, etc.), total output, average time in system, and etc. For this study, three performance measures are taken into main consideration: workers utilization, queue size (bottleneck), and total output. Figure 2 and figure 3 show the result of simulation for existing PCBs production line. From the results, it is concluded that workers utilization is low and the bottleneck occurs at the internal circuit test location. These two lead to the problem of production line cannot meet their target (For 11 working hours, targeted output is 1700 pieces of PCBs, actual output is 1530 pieces PCBs).

VI. ALTERNATIVE EXPERIMENTS
To improve the performance of the existing production line, two alternative solutions are proposed.

First alternative is to add another internal circuit test machine and one worker at touch up process. This alternative will increase on average the utilization of workers about 39%, eliminate the bottleneck, and increase total output about 40%.

Second alternative is to reduce the number of manual insert workers from 6 to 3 and add another internal circuit test machine and one touch up worker. This alternative will increase on average the utilization of workers about 179%, eliminate bottleneck, and increase total output about 39%.

VII. CONCLUSION

This study shows another example of discrete event simulation to assess existing production line performance and evaluate alternatives to improve existing performance. Rather than leave design decisions to chance, simulation provides a way to validate whether or not the best decisions are being made. Simulation avoids the expensive, time-consuming, and disruptive of traditional trial-and-error techniques. So, the application of simulation in industries should be encouraged.

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REFERENCE


