Cleared for Takeoff! Process Optimization for an In-Flight Catering Establishment

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***Abstract* — In-flight catering is of utmost importance to airlines and has constantly proved to be one of the most significant deciding factors for travelers. This paper, conducted in partnership with the Lebanese Beirut Airport Catering Company, is driven by the evident importance of the in-flight catering industry and its relative complexity compared to other operational systems. Another key driver comes from empirical research and on-site observations that indicated problems facing the company at the level of quality, finances, and efficiency. In this paper, the team showcases the benefits of applying Statistical Process Control in helping the company improve the safety and quality of its catered food through the introduction of control charts into the control of the meal production process. A recommendation is also presented for the meal traceability issues facing the company through an Access database and an Excel interface. In addition, an AutoRegressive Integrated Moving Average model is introduced that forecasted future demand as a prerequisite for the company's aggregate planning and economic order quantity models. The findings presented in this paper have provided the team with some promising results and a fitting springboard for optimization of the processes at the Lebanese Beirut Airport Catering Company.**

Keywords — Flight catering, Statistical Process Control, ARIMA forecast, Simulation, Lean manufacturing.

I. Introduction

The International Travel Catering Association (ITCA) states that airline catering is among the top three deciding factors for passengers booking and selecting airlines (Arabian Supply Chain, 2015). Quality and efficiency are of utmost importance to airline catering processes, and any improvements in these two are essential for decreasing costs and increasing profits. The Lebanese Beirut Airport Catering Company (LBACC), is an independent in-flight catering company, responsible for running the catering facilities at Rafic Hariri International Airport and providing catering to Middle East Airlines and other international airlines as well. In particular, LBACC has faced some significant economic losses due to the unjustified waste of produced meals. As seen in Table 1, 3,818 wasted meals were recorded for January 2019, which amounted to a total loss of around $18,000. These wastes are mainly attributed to discrepancies between dispatched meals from LBACC and received meals on the MEA planes. Besides that, LBACC receives myriad complaints from travelers. Fig. 1 shows a reported 57 complaints related to the company's products, recorded in June 2019. These complaints were attributed to different areas of the facility, ranging from desserts, butcher shop, washing area and the food production area.

Table 1. Expected losses per year incurred by wasted meals for January 2019 for LBACC

Airplane Type	***Airbus 320***		***Airbus 330***	
Seat Type	***Economy***	***Business***	***Economy***	***Business***
Number of Flights / Year	704		256	
* Total Number of seats / Flight	107	33	205	57
Number of Meals / Year	75328	23232	52480	14592
Total Demand / Year	165632			
- Given Produced Meals / Year	169450			
Total Wasted Meals / Year	3818			
/ Total Number of Flights	704 + 256 = 960			
Expected Wasted Meals / Flight	4			
* Number of Flights / Year	704		256	
Expected Total Meals Wasted / Year	2800		1018	
* Ratio of Meal Type to Total	*107/140	*33/140	*205/262	*57/262
Expected Meals Wasted / Year	2140	660	797	221
* Cost / Meal	$4.47	$5.63	$4.47	$5.63
Expected Loss / Year	$9,566	$3,716	$3,563	$1,244
Total Expected Cost / Year	**$18,088**			

These findings, in addition to numerous on-site observations showing a clear lack of efficiency in both the meal production and the tray-setting operation, which is the area responsible for putting together all the specified requirements for a meal tray. This provided us with compelling evidence to conduct our project in collaboration with LBACC.

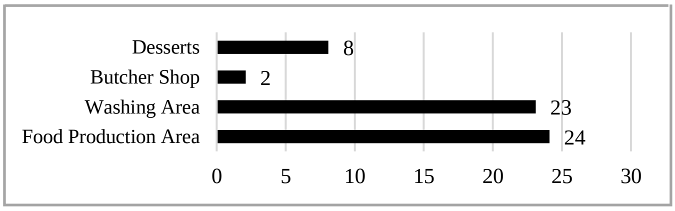

Fig. 1. Bar Graph showing category types of in-flight complaints for the month of June 2019 for LBACC

II. Objectives

The objectives of this project span three main areas, namely:

A. *Improving Food Quality Using Six-Sigma Methodology,* which was implemented through:

- Improving and stabilizing the meal preparation process
- Gathering Voice of the Customer (VOC) data
- Constructing and analyzing control charts for critical control points
- Working on an Excel/Access System for complaints

B. *Reducing production and storage costs,* by:

- Forecasting future demand
- Developing an optimal aggregate plan
- Recommending an optimal ordering policy, i.e. when and how much to order
- Solving the traceability issue of meals

C. *Improving the efficiency of the meal preparation process, by conducting the following:*

- Applying some facilities planning techniques to better visualize processes in the tray setting area
- Proposing Lean improvements to reduce food and non-food waste
- Simulating the meal preparation line before and after proposed improvements to compare between alternatives

It should be noted here that this paper will focus on the methods and results of completed progress, i.e. the quality-related objective and some aims for the costs-related objective, including forecasting and the traceability issue. An overview of incomplete objectives will be also given in section IV.

III. Background

In-flight catering supply chains are known to be one of the most complex operational systems (Bata et al., 2006). Revenues of flight companies are directly affected by any inconsistencies in its catered food, as this factor impacts customers significantly. Catered food, in this context, is seen as a product differentiator in the eyes of many customers (Bennett, 1994).

In this paper, we will focus on a comprehensive approach that includes several Industrial Engineering tools and techniques with the aim of achieving our higher-level objectives previously discussed in section II. The catering supply chain, and the industry in general, is a markedly difficult topic to deal with, in that it is both complex and time-sensitive (Sundarakani et. al, 2018). This view is reinforced by the fact that "airline catering is a neglected area of food research" and that "ways to improve catering quality […] needs to be studied" (Bennet, 1994; Sundarakani et. al, 2018). A survey of previous studies utilizing different industrial engineering tools both within and outside the catering industry are presented next.

A. *Simulation*

A simulation and an analysis of continuous production systems in the food production sector using ARENA were used to achieve an optimal production process (Matuszek & Jasik, 2008). The study showed that simulation results in times that are more or less equal to actual production times. The results also showed that simulation made it possible to quantify and analyze process alternatives with little cost.

B. *Minimizing wastes*

Sel et al. (2017) provide an example of a cafeteria catering in Turkey, where a stochastic model was developed to optimize production and reduce shortage and waste This is beneficial to our aim of developing an EOQ model to optimize ordering times and quantities. This model is specifically suitable due to the number of passengers being confirmed for in-flight catering establishments immediately before flight take-off, signifying that demand is not deterministic but non-stationary stochastic (Hasachoo & Masuchun, 2016).

C. *Quality Control*

A food safety framework currently used at LBACC, known as Hazard Analysis and Critical Control Point (HACCP), is seen as the most effective method for preventing foodborne illnesses in the food industry. However, an inherent weakness of HACCP is that it does not provide the user with advanced warning systems. To counter that, Statistical Process Control (SPC) "must become a vital part of the HACCP plan" (Hurst, 2013). SPC is a method of quality control which employs statistical methods to monitor and control processes But SPC must be introduced under an umbrella framework such as the DMAIC process, a five-phase driver for SPC, which has been shown to improve manufacturing processes on numerous occasions (Li et al., 2006; Sharma et al., 2016, etc.)

Taken together, it can be shown that an opportunity exists in the catering industry to make use of Industrial Engineering practices to improve the current processes at LBACC.

IV. Methods

A. *Improving Food Quality Using Six-Sigma Methodology*

Currently at LBACC, the quality team uses the HACCP methodology to enhance the safety of catered food, which is recognized by ISO 22000 as the most effective tool for preventing foodborne diseases (Hurst, 2013). However, and as previously stated, integrating Six Sigma and SPC into HACCP considerably strengthens and reinforces it. This integration was reinforced by employing the Define & Measure phases of the Define-Measure-Analyze-Improve-Control (DMAIC) approach.

a. *Define*

Defining requires setting a clear definition of the scope, objectives and procedures that must be performed to target our quality improvement objective. Table 2 showcases a project charter that was outlined with the help of the Quality Control and Food Hygiene manager at LBACC, Mr. Joseph Farhat.

Voice of Customer data, in the form of previously received customer complaints, were collected from LBACC to establish or confirm Critical-To-Quality (CTQ) characteristics and integrate them into HACCP on the two levels mentioned in the goal statement: food safety and food quality. Our Key Process Input Variables (KPIV's) were already set in place through HACCP, and more specifically, through the hazards. Hazards are biological, chemical or physical agents that are reasonably likely to cause illness or injury in the absence of their control. However, some complaints were not related to

Table 2. Project charter for the DMAIC process implemented on LBACC

Business Case The project supports higher-level aims of improving food quality and reducing appraisal costs.	***Opportunity Statement*** An opportunity exists to implement Statistical Process Control on the existing HACCP methodology by signaling out of control points and focusing on preventive measures.
Goal Statement Reduce customer complaints on two levels: food safety and food quality.	***Project Scope*** The project will focus on the production flow process that starts at the receival of the raw material till the meals are loaded in the aircraft.

fishbone diagrams in the Analysis phase of section V. After consultations with Mr. Joseph Farhat, the team decided upon two key high-level Key Process Output Variables (KPOV's): the number of customer complaints per month, and the number of reported incidents related to food safety per month.

b. Measure

In this phase, the six critical control points, seen in Table 3, and defined as stages in the production process that are critical to food safety, were investigated. Data measures for the critical control points were collected from LBACC's historical documentation records.

c. Analyze

In the Analyze phase, our work was divided into two main parts: Implementing control charts on the critical control points and using fishbone diagrams to analyze other KPIV's.

Two types of control charts were used in this phase. The first chart was an Individuals-Moving Range (X-MR) chart

Table 3. Critical control points classification by hazard and critical limits used by LBACC for food safety purposes

CCP Number and Production Stage	**Hazard**	**Critical Control Point**	**Critical Limits**
CCP1 Receiving	Growth and multiplication of harmful bacteria	Monitoring the temperature of chilled foods	Chilled food must be under 8°C
CCP2 Chilling	Growth and multiplication of harmful bacteria	Monitoring the temperature of refrigerators	Refrigerator temperature must be between 1°C and 5°C
CCP3 Cooking	Harmful bacteria staying alive	Monitoring cooking temperatures	Cooking temperature inside food must be above 75°C
CCP4 Blast Chilling	Growth and multiplication of harmful bacteria and dissociation of vesicles	Monitoring blast chilling temperatures	$T_0 > 63$°C and $T_f < 5$°C Within 4 hours
CCP5 Portioning	Growth and multiplication of harmful bacteria	Monitoring food temperature	Food temperature must be below 15°C
CCP6 Vegetable and Fruit Sanitization	Harmful bacteria staying alive	Monitoring peracetic acid concentration	Concentration of peracetic acid should be between 40ppm and 80ppm

used for the temperature recordings of CCP2, CCP4 and CCP5. This was especially beneficial to show patterns of variation of temperature and to provide warnings ahead of time, where, in this case, there were no subgroups. The second chart used was an Average-Range ($\bar{X}$-R) control chart used for CCP1 and CCP3. This was used for two cases: temperature recordings to compare between eleven suppliers for CCP1, and temperature recordings to analyze variations according to worker shifts for CCP3. In both cases, Phase I control charts are constructed and out of control points are removed. After removing all out of control points, Phase II control charts were reconstructed and could then be analyzed according to the Western Electric (WE) rules. WE rules are a set of decision rules used for control charts and developed by Western Electric company (Western Electric Co., 1956).

d. Improve

LBACC has been facing an issue of tracing meals outbound from its final storage area to the flights. This is causing considerable losses for the company (see Table 1 for losses in January 2019). As such, we developed an Excel interface and a corresponding Access database which would simultaneously solve this issue and provide LBACC with a platform to store and analyze incoming complaints. The Excel home screen interface has six buttons, five of which take the user to different data sheets in addition to an "Exit" button which closes the Excel sheet, as seen in Fig. 2. The data sheets are filled with all the needed information used by drop-down lists in the "Flights" and "Complaints" sheets. The Excel interface would be used by employees to fill out either quality-related complaints in the "Complaints" sheet or traceability issues in the "Flights" sheet. Whenever complaints are addressed, they are transferred to the "Complaints Access" sheet on Excel and then to the Access database

e. Control

It should be noted here that the DMAIC approach provides a framework for the quality department at LBACC to implement our recommendations. The upcoming weeks will provide us with an opportunity to iterate and re-iterate for continuous improvement to better fit with company needs and capabilities.

B. Reducing Production and Storage Costs

As for forecasting future demand, the team used previous demand data from 2018 and 2019. Taking into consideration both the seasonality and trend of the demand and MEA's fleet expansion, we produced a forecast using R language. In the

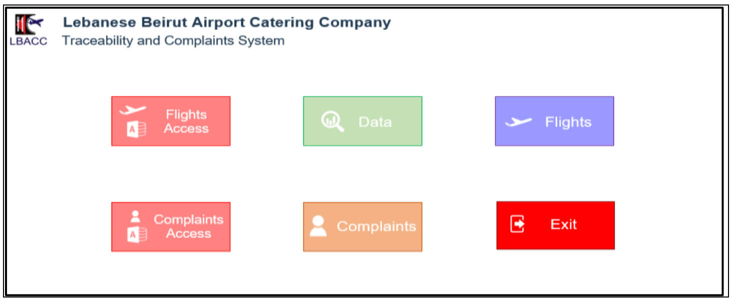

Fig. 2. Excel interface for the complaint traceability system for LBACC

code, we found the linear trend of the given data (Fig. 3) and de-trended the series by plotting the residuals, i.e. the differences between the actual data and linear regression line, to highlight the seasonality of the demand.

Next, we used the Auto Correlated Function (ACF) on the residuals to get the serial correlation in the demand data that varies over time. The serial correlation established was used to forecast future demand. The cumulative periodogram, a type of plot which identifies dominant cyclical time-series behaviors, was used to identify months attributed with the highest demands. Finally, we fitted the data into an ARIMA model and forecasted future demand. These have two main benefits: in addition to intrinsically providing management with some reliable measures for future demand, the demand data will also be used as input variables for our aim of developing a Linear Program (LP) model.

Complimenting the ARIMA forecast is a set of other tools and techniques which will be used to provide a comprehensive and coherent cost minimization strategy for LBACC. A Cost Breakdown Structure (CBS) will be developed to compare between costs linked to different meal options and give management a better idea of where the highest losses are incurred. Also, an EOQ model will be recommended as a framework that encapsulates different supplied products and aids in optimizing ordering policies of the company as to minimize inventory costs and eliminate shortages. Finally, an aggregate plan will be developed to optimize the number of workers given the forecasted demand.

C. *Improving the Efficiency of the Meal Preparation Process*

This objective will mainly focus on the tray setting area, i.e. the area where flight trays are prepared, packaged and stored before transportation to the flights. This area is especially disorganized, which calls for the introduction of Lean Manufacturing tools and Facility planning techniques. Subsequently, the tray setting process will be simulated before and after the improvements are made, including the addition of conveyor belts. This will aid in showcasing the benefits of implementing these changes to management.

V. Results

A. *Improving Quality Using Six-Sigma Methodology*

In the Analyze phase of the DMAIC process, control charts were constructed to look for out of control points to be analyzed according to WE rules. Only the X-MR chart is presented here for the sake of conciseness. In Fig. 4, a Phase

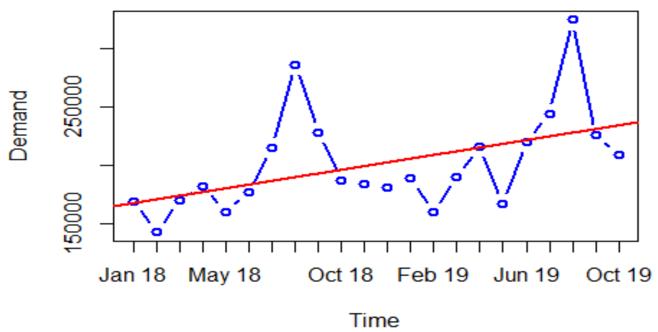

Fig. 3. Graph showing previous meal demand and corresponding linear trend for LBACC

I X-MR control chart for CCP2 (temperature recordings of a refrigerator) is shown, in which four points are seen to be out of control. The process capability (Cp) for phase I points shows a value of 0.50, which is less than 1.33, the recommended value for an existing process (Montgomery, 2013). As shown in Fig. 5, rule number 3, which states that four out of five consecutive points beyond the one-sigma limits signify an out of control point, is breached. It should be noted here that the phase 2 charts serve as an illustration for LBACC, but in practice, out of control points should be addressed if assignable causes exist and kept only if they are due to chance causes. Such assignable may include the refrigerator being left open for too long, refrigerator malfunctions, thermometer calibration errors, etc.

As part of the analysis phase, we also aimed to determine the cause and effect relationship between KPIV's and KPOV's during the entire food-making process at LBACC. As such, we acquired their production flow diagram and their complaints data to be able to pinpoint data effectively. The complaints were grouped into five main categories: dirty items, missing items, shortages, foreign bodies, and meal cooking. Fishbone diagrams were then constructed to narrow down the root cause for every complaint. By analyzing the data, we observed that the two most prominent independent problems were: employee training and ethics, and cleaning equipment and material. Recommendations to management were presented accordingly.

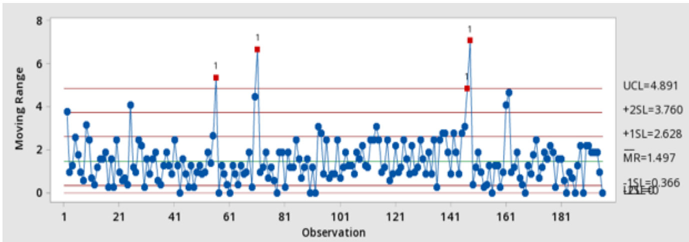

Fig. 4. Phase I X-MR chart for CCP2

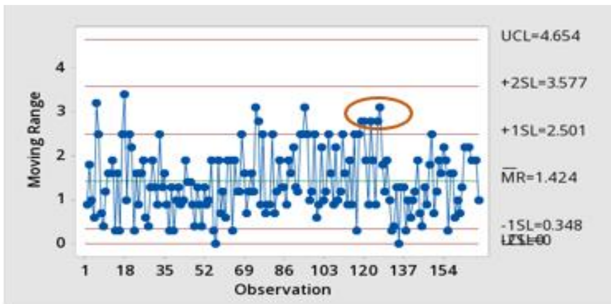

Fig. 5. Phase II X-MR chart for CCP2

complaintType	NumberofComplaints
Shortage	3
Missing Item	1
Meal Cooking	1
Foreign_Body_in_Meal	1
Dirty Item	1

Fig 6. Output statistics on Access for the number of complaint types received by LBACC

As for the Excel interface and Access database, complaints are stored and later used for statistics using queries, some of which we have already created. One example of these is outputting statistics for the number of complaint types as seen in Fig. 6. The same is viable for the traceability issues.

B. *Reducing Production and Storage Costs*

The resulting future demand plot, shown in red in Fig. 7, shows the future demand values in 2020. The plot manages to capture both the seasonality and the trend seen in 2018 and 2019 and forecasts monthly demand values in 2020 accordingly.

VI. Discussion

The work presented in this paper provides a comprehensive description of the methods and results for completed progress, in addition to an overview of soon-to-be completed progress.

The integration of SPC, and more specifically, the DMAIC process, into LBACC's existing framework of HACCP has provided management with a good illustration of how their Critical Control Points are performing. Quality control staff have already started implementing control charts on Minitab as an insight for out of control warning signals. However, this is done on a partial basis and only for some CCP's. An integrated control chart procedure does not yet exist for the meal production process.

To counter that, measurement data retrieved for the CCP's must be continuously updated using Excel or text files and processed into the Minitab charts using an automated Minitab macro (Scibilia, 2017). On the other hand, the usage of fishbone diagrams has proven to be a simple, yet structured method for identification of root causes. This has provided us with interesting insights for the categorization of customer complaints, in addition to the identification of the most common root causes. This DMAIC framework is expected to reap tangible benefits in terms of our higher-level objectives of improving quality and reducing customer complaints.

As for our forecasting results, the outlook is not as promising. With the October 17 uprising and the economic crisis in Lebanon, in addition to the COVID-19 outbreak around the world, demand for inbound and outbound flights from Beirut-Rafic Hariri International Airport has suffered. This is a clear example of the limitedness of forecasting in the face of "unexpected future events that can jeopardize

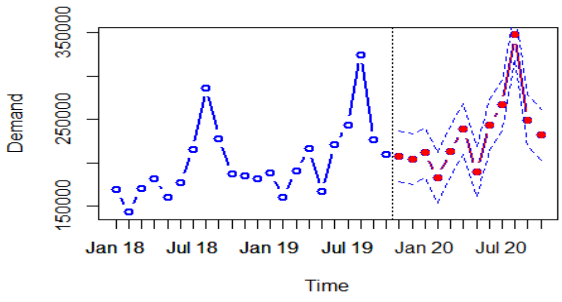

Fig. 7. Meal demand data for 2018 and 2019 and ARIMA forecast for 2020 for LBACC

forecasts", or what is known as "ontological explanations" for forecast inaccuracies (Næss et al., 2015). Nevertheless, ARIMA, which is "among the most widely used in the air passenger forecasting demand", and which is generally "found to offer accurate forecasts in the short and medium term", will still perform better than others as it is an auto regenerative model (Alhassan et al., 2017). An interesting aspect will be the examination of how the model will fare with the demand data for January and February 2020, which were still unavailable at the time of writing.

Overall, we hope that our three high-level objectives related to quality, costing and efficiency will provide LBACC with coherent and fitting results to utilize and build upon.

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