Schedule Nervousness in Production Operations of an Airline Catering Company: The Challenge of an Effective Demand Response Program

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Abstract—**Demand Response (DR), also known as electric load-shifting program, is a different way of shaping energy demand with the goal to reduce electricity costs for an organization. Extensive prior research studies have demonstrated the effectiveness of the action of DR through the use of operations research methodology e.g. efficient production scheduling. In the real world, schedulers typically issue an optimally planned operations schedule that takes into account the demands for manpower, machinery and even electricity profiles. However, due to the occurrence of schedule nervousness, the operations schedules are inevitably sub-optimally executed. In order to restore the optimal state, schedulers could alternatively issue a rescheduling plan and thereby it is imperative that planners identify the existence of the nervousness. This paper attempts to identify the schedule nervousness and its impact on the DR program at shop-floor scheduling in the production operations of an airline catering company. The study findings, which have proved the existence of scheduling nervousness in this industry and its impact over DR program, are expected to contribute to future research on the development of more efficient demand response plans as well as rescheduling plans by integrating the pattern of schedule nervousness found in this work.**

Keywords—schedule nervousness; production operations; demand response program; airline catering industry

I. INTRODUCTION

Currently, many researchers and practitioners are now interested in enhancing energy efficiency through the use of "Demand-side Management", which is defined as "*systematic utility and government activities designed to change the amount and/or timing of customer's use of electricity*" including energy efficiency and demand response [4]. Demand response is defined as "*changes in electric usages by demand side resources from their normal consumption pattern in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity uses at times of high wholesale market prices or when system reliability is jeopardized*" [6]. In Thailand, the Energy Regulatory Commission and Electricity Generating Authority of Thailand or EGAT launched a program called "Thailand Demand Response 2015" aimed to reduce 700 megawatts from participants across the country by the practical use of the demand response program especially during the peak periods each month, which were specified by EGAT.

Reference [12] stated that research interest in integrating operations scheduling together with energy is not something new. There are two main approaches for motivating manufacturers to reduce their energy consumption at peak periods, which are; *incentive based program*, the grid operators will directly pay compensation to customers for offering to control services over the energy consumption at peak periods. *Price based program*, the price of the electricity will fluctuate during the day, for example, time-of-use tariffs and critical peak pricing where the energy consumption during peak time will be charged with additional fees. There are many scheduling techniques that enable manufacturers to lower energy consumption at peak periods without any change in production volume. For example, *shifting load with scheduling*, a mathematical programming like mixed integer linear programming (MILP) can be used to solve the scheduling problem which comprises decisions such as what tasks to execute, where to process, in which order sequencing, etc. So, scheduling by shifting into less expensive periods is one of the potential solutions.

Extensive prior research studies have demonstrated the effectiveness of the action of DR through efficient production scheduling, as in [27] minimizing the total completion time and energy consumption in an operation with a single machine. A multi-objective genetic algorithm was proposed for generating the solution. Reference [5] applied the MILP for optimizing a production schedule by minimizing the make-span and energy (peak time and total energy consumption). Reference [2] proposed the *advanced planning and scheduling system* for reducing shop floor power peak. Reference [4] provided a sample in figure 1 on how manufacturers can shape their electricity consumption profile for energy cost reduction.

Reference [18] stated that although the scheduler may initiate the optimally planned operations (including the electricity load profile to avoid peak times), once new or unplanned jobs arrived, the operations schedules are inevitably sub-optimally executed. Schedulers need to issue a *rescheduling plan* in order to restore an optimal state*,* thus, *minimizing* energy consumption still depends on the *rescheduling plan*.

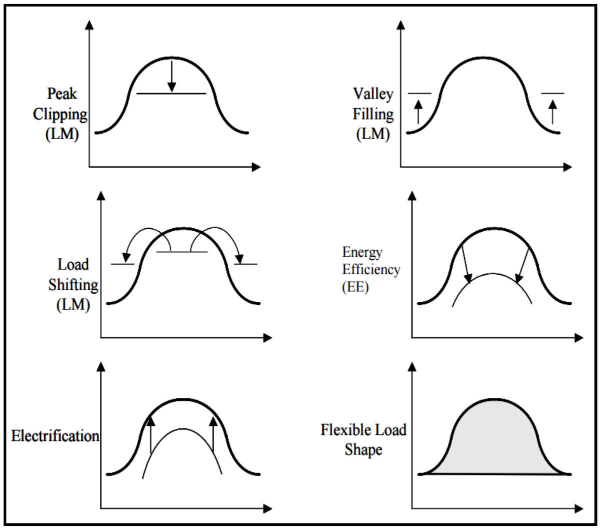


Fig. 1. Load Shapes
Source: Charles River Associates (2005) [4]

The Master Production Scheduling (MPS) is a very important tool in planning and controlling for the manufacturer. It links the Master Requirement Planning (MRP) system with the production planning, and details the planning and scheduling of raw materials and components. The arrival or occurrence of those unplanned jobs which cause changes in planned schedules will result in a change in MPS and might lead to a major change in Material Requirement Planning (MRP), which finally will affect the efficiency of the production operations; this situation is called *schedule nervousness.* [25]

Reference [23] report *"Schedule nervousness arises due to revisions in the original plan which in turn results in different replenishment decisions in successive planning cycles e.g. a previously planned order is revised following demand realization",* while [10] defined it as *"a frequent change to the production schedule";* some authors have also referred to it as schedule instability. [14][23]

Reference [3] stated that a revision in an original planned schedule could result in a disruption in the production and distribution system, while [8] found the impact of schedule nervousness will lead to changes in personal task scheduling problems, machine utilization problems, electricity usage and delivery problems. So, it's rational to say that schedule nervousness proved to be one of the key factors that affected the effectiveness of both operations scheduling and demand response programs.

A numbers of authors have confirmed the effectiveness of using various operation scheduling techniques for reducing schedule nervousness (see references [11][7][19]). But before we can go that far, we first need to prove whether schedule nervousness does really exist or not. Hence, proving its existence by quantifying schedule nervousness is a must, and to the best of our knowledge, this is the first paper that attempts to analyze the impact of schedule nervousness on production operations of the airline catering industry by using the actual production data. One of the closest papers to this topic was presented as in [10], but the schedule nervousness in her paper was gathered through the perceived score from airline catering staff in Hong Kong.

The operational system of an airline catering company is much more complex than people thought, says Singapore Airport Terminal Services (SATS), an in-house catering company of Singapore Airlines based at Singapore's Changi airport, which is now capable of producing up to 80,000 meals daily, while LSG sky chef at Qingdao, in northeast China could produce in-flight up to 100,000 in-flight meals per day. In addition to food and beverages, airline caterers are still responsible for preparing and assembling non-food products e.g. towels, newspapers and amenity kits etc. One of the biggest challenges for every caterer is the unavailability of information on the exact numbers of meals until just minutes prior to departure time [9]. The production is based on planned MPS that was prepared only by using forecasted meal numbers. So, the planned schedule (including the electric load-shifting program) is exposing the schedule nervousness.

The objective of this research is to identify whether the schedule nervousness does really exist in the production operations of airline caterers or not. The revision in planned schedule will be quantified into schedule instability by the use of actual production data. The impact over production operations and electric load-shifting will be also observed. The contribution of this research can be of benefit to both researchers and practitioners. *For the researcher*, the level of schedule nervousness found in this work can be used for a future integration into the objective function for minimizing the energy consumption especially for peak periods under the demand response program and for minimizing schedule nervousness in production operations. *For practitioners*, since the nervousness quantified in this work stemmed from the actual production data, it enables them to observe the trend of nervousness occurring in the planned operation, which in turn allows them to include this fact within their future scheduling in order to produce more effective plans

II. PROBLEM FORMULATION

This research used the case study of an airline catering company located in Bangkok, Thailand. The company services its customers with food and non-food items for both domestic and international flights. The operations process can be briefly summarized in figure 2.

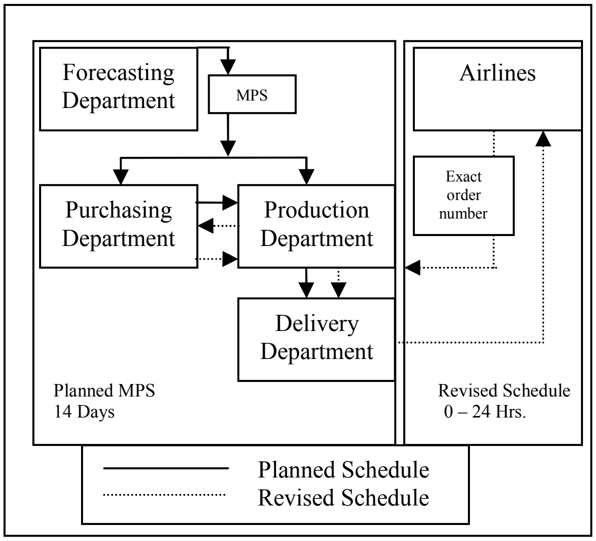


Fig. 2. Operations Process

On the left-hand side of figure 2, the forecasting department issued a master production scheduling (MPS) two weeks in advance of delivery time (departure flight time); the length of planning horizon is 7 days. One copy is distributed to the purchasing department for the purchase of input needed within the plan in each MPS. Another copy is sent to the production department for optimal planning in the use of manpower, machines, job scheduling and electric load-shifting plans for the demand response program. Usually, the production started 12-24 hours before the departure time. Currently, the company is only still in the planning period of its electric load-shifting program before soon fully implementing the demand response program; planning the task schedule with concern for electricity consumption, jobs with higher electricity consumption e.g. roasting and baking were planned with the aim to reduce these activities during the peak.

As mentioned earlier, the exact number of meals will be only known just prior to departure time. The airline usually places their exact meal order within 24 hours of departure, but sometimes could only give 4-5 hours notice, that’s why the operation scheduling cannot be executed based on the actual order, and hence, the production is very exposed to schedule nervousness. Thus, we would like to prove the existence of schedule nervousness in the airline catering industry and observe whether the job sequencing can be executed as planned. If so, we can then conclude that schedule nervousness causes production operations and the electric load-shifting program to become less efficient

Reference [17] indicate there are several formulas to quantify schedule nervousness in the production operations, but the most used was that proposed by Sridharan et al [21], who were among the first developers of a formula for measuring instability. The formula and its notation are shown in (1)

$$I = \left\{ \sum_{i=1}^{n} \sum_{k>1} \sum_{t=Mk}^{Mk+N-1} \left| Q_{ti}^{k} - Q_{ti}^{k-1} \right| \right\} / S \tag{1}$$

A similar formula was used by several others (see references [29][25][26]) and later summarized by [13] as a measurement of instability in terms of the number of units rescheduled as a percentage of total number of units in all planning cycles where i = index, n = total number of items in MRP structure, t = time period, k = planning cycle, Q_{ti}^{k} = scheduled order quantity for items i in period t during planning cycle k, Q_{ti}^{k-1} = scheduled order quantity for items i in period t during planning cycle $k-1$, M_k = beginning period of planning cycle k, N = planning horizon length and S = total number of orders in all planning cycles

Later, Pujawan [14] criticized that the changes to an order with larger quantity would imply more nervousness than the smaller order. Also the different types of change could distribute a different degree of instability. So he proposed a new model by weighting each change with the corresponding order quantity and type of changes. Hence, the instability in this research will be quantified by his approach. A similar formula was also used in [10]. The formula and notation are as below;

i = types of change;
j = period in planning horizon;
t = planning cycle;
k = order;
h = length of planning horizon;
w_i = weight of type i change;
$Q^t_{(i,t,j)}$ = the quantity of order k which in the previous planning cycle was scheduled to be produced in period j but experiencing type i change when observed in planning cycle t
$I(t,j)$ = aggregate instability observed in planning cycle t from all orders where in the previous cycle they were scheduled in period j
$I(t)$ = total instability observed in planning cycle t

The total instability in planning cycle t where all orders were scheduled in period j can be calculated as follows [14]

$$I(t,j) = \sum_{i} \sum_{k} w_i q^t(i,k,j) \tag{2}$$

There are three types of change (i) found in the production operations of this case study; 1= increase in order quantity, 2= decrease in order quantity and 3= change in production start time. The values of w in this work were calculated followed the original approach of Pujawan [14] by obtaining data from the production managers through the use of pair-wise comparison for three types of changes. The results from the pair-wise comparison are then converted into weight by using the analytical hierarchy process (AHP); the final weights are; w_1= 0.60, w_2 = 0.21 and w_3 = 0.19. A higher order quantity than the planned schedule resulted in the highest weight because of the requirement in the production standard that says cooked meals must be rapidly cooled in temperature right after being cooked, and rapidly cooled again after being portioned in the serving container before loading onto the aircraft. These steps required at least 5-8 hours to reduce the temperature of the food to the desired level. So, a higher quantity than planned schedule causes higher nervousness than a lower quantity planned schedule.

The data used in this research was collected from the production in January 2015, a planned MPS with 7-day length of horizon was monitored and compared with the actual production. The change in planned schedule, revision of the actual production schedule will be quantified into instability by using the above formula.

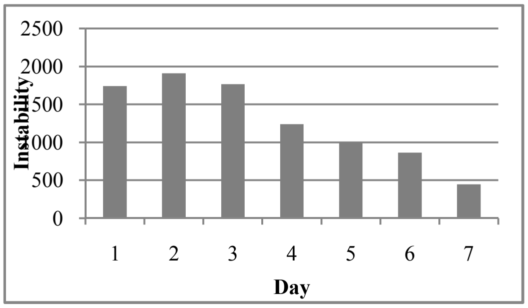


Fig. 3. Instability Observed

III. RESULTS

The total actual production of 2,565 orders with a total of 37,245 kilograms of input was analyzed. According to the findings in table 1 and figure 3, a total of 741 changes occurred within the length of planned schedule. The major cause of change was from a forecasting error and followed by the customers, inventory error and production defects respectively. Combining the findings in table 1 with the corresponding weight for each types of change (*i*), the schedule nervousness in the production operations of airline caterers found in this work is shown in Figure 3

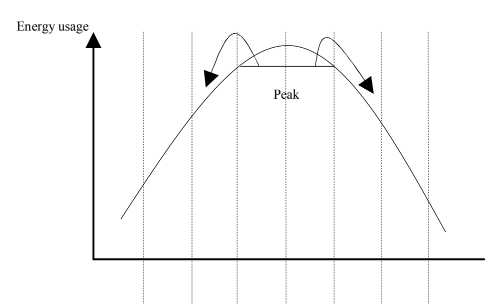
TABLE 1 : Causes of changed observed in planning horizon

	Causes of changed observed in planning horizon (Days)								
Cause of Changes	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**	**%**
Forecast Error	56	78	67	50	63	44	36	394	53.17
Customers	32	42	33	33	30	7	31	208	28.07
Inventory Error	12	10	13	22	14	23	17	111	14.98
Defect	7	2	3	5	2	4	5	28	3.78
Total Change	107	132	116	110	109	78	89	741	100.00
Total Order	357	375	359	373	345	379	377	2,565	
Total KG of input	4,695	5,733	5,182	5,003	6,080	5,337	5,215	37,245	

The instability observed was high during the first 3 days and peaked at day 2, before diminishing until the last day of MPS. To explain further, the MPS (on job schedule, manpower, machines and electricity load profile) was planned based on a forecasting report that was issued 7-14 days before the production date. The input for production was also purchased based on the same forecasting report. Once the real confirmed order was received within 12-24 hours of flight time, the production requirement required rapidly chilling of the meals right after they were cooked and further chilling after they were portioned on the serving trays, which required at least 5-8 hours. When confirmed orders received were different from the planned schedule, the revision on the original planned schedule during the first three days of MPS was mostly due to intervening in the planned schedule by adding or removing to the actual order, and hence caused the highest nervousness since the job sequence was messed up; it took 1-2 days before the rescheduling plan which was revised to handle the changes that occurred to become effective, hence that's why the instability in figure 3 began to diminish after day 3

How does it affect the production operations and demand response program?

Once the real-confirmed order was received, the impact of nervousness on the production operations and demand response program over the job sequencing in shop-floor operations were observed. Figure 4, represents how a manager schedules his job sequencing, and it should be noted that the job sequences "Original Schedule" were from a real production plan, whereas an evaluation of energy usage for each job is only based on a manager's experience, and so we have roughly turned an inexact watt usage into a graph based on Charles River Associates [4] and represented in "Planned Schedule" in order to more easily see the impact



Period Number	1	2	3	4	5	6	7	8
Original Schedule (Before)	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*
Planned Schedule	*A*	*D*	*C*	*B*	*G*	*F*	*E*	*H*
Actual Job Observed	*A*		*D*	*C*		*B*	*G*	*F*

Fig. 4. Impact of nervousness on shop-floor scheduling

Job *A*, 50 kilograms of roast neck of pork was planned to be cooked at time period 1 of day 1 (normally followed by Job *B*, but under the idea to avoid peak period, job *D* was brought forward),; the pork was trimmed and prepared a night before by the preliminary department, manpower was scheduled a week earlier, the required machine, blast chiller and chilled storage room were reserved corresponding to the load shifting schedule (Planned Schedule).

Once the real-confirmed order was received in the early morning, whereby 50 kilograms was increased to 70 kilograms, an intervention was required to be made with the preliminary department for immediately supply of an extra 20 kilograms of roast neck of pork. Workers from another job were requested to lend a hand, an intervention had to be made in the oven schedule to roast the extra 20 kilograms, and finally, use of the blast chiller was needed along with requesting use of the chilled storage room to store this additional order. All of which resulted in the sub-optimal performance of machine schedule, e.g. oven had to operate below its potential capacity to produce this additional order.

The above situation was caused just through one change in one product item, however there were a total of 107 changes on day-1, Schedule nervousness violated the planned schedule by interfering with both the job and machine sequencing. Thus, it is rational to suggest that as long as nervousness exists and scheduler keeps being ignored, the planned demand response program as well as planned MPS will inevitably not be optimally executed

IV. DISCUSSION AND CONCLUSION

Possible improvements and future research direction

The major contribution of this research is the confirmation of an existence of schedule nervousness in production operations of airline caterers. The shape of the instability graph in this paper shares the same direction with the findings of several others in different industries (see Reference [14][16]). The instability of the planning horizon (observed from the changed in job sequencing at shop-floor execution), which is usually high during the beginning, proved that the use of “frozen period" could reduce the impact of nervousness (see references [1][20] [26]).

Safety stock is also one of the solutions that is already proven by several authors as an effective method to reduce the nervousness (see references [22][25][29][15]).

Since the nature of the airline catering industry is quite different from other manufacturing industries, the limitation of the exact amount of meals only being known a few minutes prior to departure time means that any disruption in production or delivery system will result in a flight delay, something that is one of the most sensitive situations for any airline. Identifying frozen period in the schedule by trying to integrate this unique nature of airline catering industry is one of the recommended future research directions. The study of optimizing safety stock and instability level by seeing as a service level constraint in the MILP is also a potential research question.

For a demand response program, since this paper has already proved the existence of schedule nervousness in the airline catering industry as well as made some observations over its impact to the shop-floor schedule, integrating the instability found in this work into an objective function and/or a service level constraint when scheduling for an optimal electric load-shifting program is a most interesting recommendation for both academicians and practitioners.

Conclusion

This is the first study that proves the impact of schedule nervousness over the production operations and demand response program by the use of actual production data from the case study of an airline catering company in Thailand. The findings led to the conclusion that an optimally planned production scheduling as well as electric load-shifting program could not be optimally executed as planned once nervousness occurred; the revision of the planned schedule created an intervention in job sequencing in shop-floor operations that resulted in reduced efficiency of operations and electricity consumption. Integrating the nervousness found in this work into the future planning on MPS and also for electric load-shifting program is recommended for a future research direction

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