Managing Aircraft Ground Handling Delays in Vietnam Airlines by using Supply Chain Strategy

Doan Hong Le*1, Perfecto G. Aquino, Jr2, Nguyen Le Phuong3
1,2Duy Tan University, Danang City, Vietnam
3International University – Vietnam National University HCMC

Abstract- **Punctuality is one of the key performance indicators in the airline industry and an important service differentiator especially for valuable high-yield customers based on the supply chain strategy. In addition, improved on-time performance can help achieve significant cost savings. Airlines report delay costs from 0.6 to up to as much as 2.9% of their operating revenues. Vietnam Airlines (VNA) stated that they want to convey passengers or freight from one point to another with maximum safety, efficiency and on time performance. However, within 12.34% of delayed flights in 2011due to aircraft ground handling (annual report's TOC), VNA operation is not very effective in aircraft ground handling. The project is about aircraft ground handling process in VNA. Supply chain strategy can be used in airlines to improve its fluency.**

Keywords- *Delay, Supply chain strategy, Aircraft Ground Handling, Punctuality, management*

1. Introduction

Supply chain management has become a key factor for major manufacturers in the industry. The new strategies introduced by the aircraft manufacturers have increased the complexity of the supply process, design and production from the aviation industry. This paper highlights a series of factors regarding the aircraft programs supply chain management. VNA was established by the Vietnam government in 1956. It was officially established as the national flag carrier of Vietnam in 1993. Currently, VNA operates flights to 35 international destinations in Asia, Australia, Europe and the Middle East, and to 18 domestic destinations in Vietnam. With a modern fleet of aircraft (including 6 Airbus A320s, 30 Airbus A321s, 9 A330s, and 10 Boeing 777s, 14 ATRs 72 and 2 Fokker 80s), VNA provides service with traditional Vietnamese hospitality ensuring passengers have the best possible introduction to the wonderful and vibrant country of Vietnam. Having recently redesigned their business class cabin, VNA is now able to provide luxury travel to compete with many of the larger international airlines. Serving European destinations such as Paris and Frankfurt as well as cities in America and all over Asia, and through partnerships with airlines such as Qantas, Cathay Pacific, and Korean Airlines, VNA is making the country of Vietnam a more accessible destination whether for a short break or a longer period of travel. This is an opportune time for aerospace supply chain stakeholders to brace for an anticipated expansion in their sector.

According to TOC which represents for VNA at TSN airport, in 2011, there were 4,477 delayed and cancelled flights upon 64,012 flights operated by VNA (approximately 18.05% of total flights). Many causes of delays are outside the responsibility of the VNA such as weather, airport authorities and air traffic control. However, some delays are controllable for example, ground handling, aircraft maintenance and flight or cabin crew rotation. On top of the negative impact on customer satisfaction, delays are expensive. Direct and indirect delay costs typically range from 0.6% to 2.0% of revenue, depending on the size and type of operation. Thus, punctuality should rank high on top-management's agenda and to be a leadership challenge throughout the organization from strategy and planning all the way to frontline operations.

2. Research Problems

By supply chain strategy the flights are on time, it is good for passengers and also helps the airlines' bottom lines. These strategies have led to the complexity of aircraft design, processes, and aerospace supply chain management. The passenger's choice of airlines may be affected by the on-time arrival experience of passengers. The passengers may show stronger reaction (switch to other airlines) when they realize utility losses

International Journal of Supply Chain Management
IJSCM, ISSN: 2050-7399 (Online), 2051-3771 (Print)

(service level below their expectation) than when they experience utility gains (service level above their expectation).More importantly, punctual airlines appear to be more profitable [1-7]. According to AEA (the Association of European Airlines) a top-10 carrier performing carries $100 to $400 million in annual delay costs and for each percentage point improvement in punctuality there is a potential profit improvement of $4 to $16 million, depending on the size of the airlines. In 2011, there were 3,978 delayed flights upon 64,012 flights operated by VNA (approximately 12.34% of total flights) due to aircraft ground handling (annual report's TOC).

VNA always focuses on Direct Operating Cost (DOC), because DOC include ground handling costs, depreciation, interest, insurance, fuel costs, crew costs, maintenance costs, landing fees and navigation fees. For airlines, flights delay mean increase turnaround time and DOC as well. In VNA, the major source of flight delays at TSN airport is aircraft ground handling, usually caused by several mistakes made or wrong activities. This research, therefore, is focused on ground handling services analyzes to prevent the flight delays.

3. Research objectives

The objectives of this research paper are to:

1. To identify factors that cause delay in aircraft ground handling.
2. To evaluate effect of wrong activities in aircraft ground handling.
3. To develop a model for integrating all aircraft ground handling malfunction.
4. To control flight delay and reduce Direct Operating Cost in flights.

4. Literature Review

4.1. Definition of Aircraft Ground Handling and supply chain strategy

After aircraft is parked and chocks are put, turnaround process begins. The turnaround of an aircraft comprises the sequence of ground operations required to service the aircraft between two flights, from the time the chocks (rubber blocks to prevent aircraft from moving) are put in front of the wheels after it lands, to the time the chocks are removed and the aircraft is ready to leave. There are a number of key tasks carried out during and aircraft turnaround such as: loading and unloading passengers and baggage, safety and security checks, catering replenishment, cleaning and the completion of essential post and pre-flight administration. It should be noted that the servicing arrangements and turnaround tasks vary for different aircraft and different operators. The turnaround processes are typically shared between several organizations and it is essential that they work together effectively to deliver the optimal turnaround. This is further complicated when the aircraft is being handled at a remote airport by third party ground handling organizations.

4.2. Aircraft Ground Handling in VNA at TSN Airport

Ground handling help to address service requirements of an airliner between the time it arrives at a terminal gate and the time it departs on its next flight. Speed, efficiency, and accuracy are very important in ground handling services in order to minimize the turnaround time. Aircraft ground handling includes services on the ramp such as: guiding the aircraft into and out of the parking position, air-bridge positioning/removal ,towing with pushback tractors, lavatory drainage, water cartage, air conditioning, air starts units, luggage handling, gate checked luggage, air cargo handling, catering trucks ,refueling tanker truck, ground power, passenger stairs and wheelchair lifts. These services belonged to VNA members such as: TIAGS, VAECO, VN/CX, FCD 919, Flight Attendant and VINAPCO. TOC is able to verify what flight is at what gate through SAC, the time the plane arrived and the time the plane is scheduled to depart via OCC. Hence, TOC forward this flight information to each VNA member by SITATEX and monitor the progress of each flight.

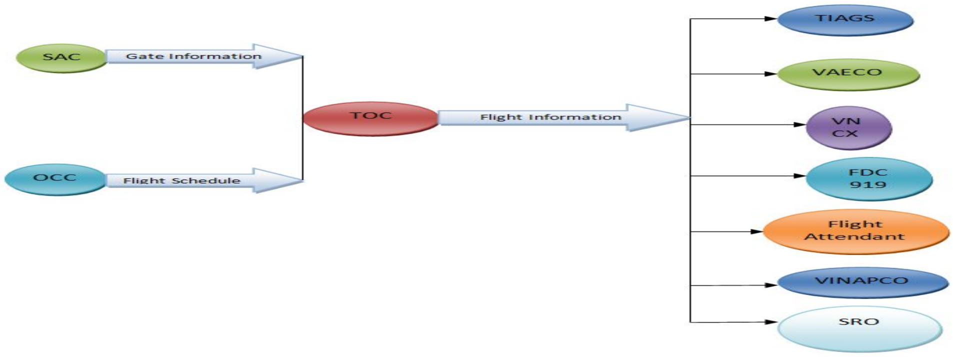


Figure1. Aircraft ground handling operation in VNA

VNA Operations said that it costs them too much money for every minute that a flight is delayed. It is important to note that, for an airline, the "value" of delay is not just its effect on an individual airframe but its effect on the operating schedule. Passengers do not go out to the airport to fly on a specific airplane. They go to catch the one o'clock flight to Da Nang which is promised in the airline's published schedule.

4.3. Modeling of turnaround process using petri nets

When aircraft turnaround is finished and aircraft is ready to leave according to schedule, aircraft pilot contacts ATC and waits for the clearance to begin push-back procedure. Figure 2 below illustrates the conceptual model of the system.

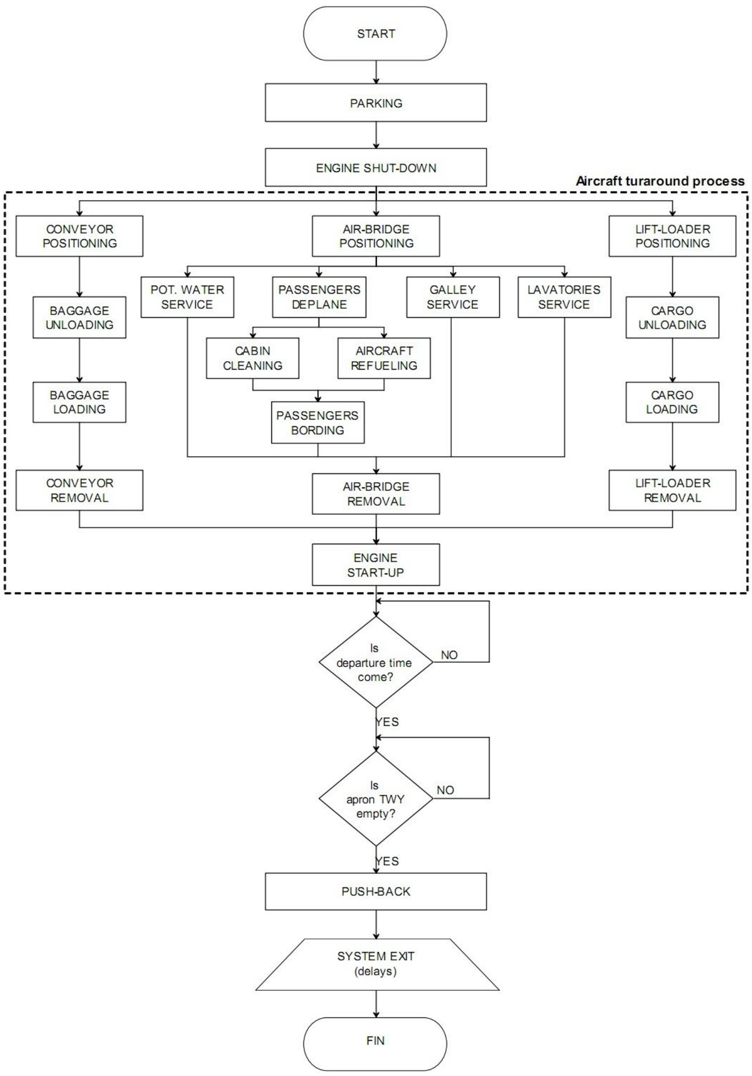


Figure2. Conceptual model of the aircraft ground handling system

According to [8], it is found that one of the things in making the logistics at an airport complex is the large number of actors involved, as well as the many activities that are sensitive to time. One very time-sensitive process, where almost all of the actors are involved, is the turn-around process, which makes it a key process for airport logistics. With some adjustments, it will be possible to use the optimization algorithm developed for scheduling de-icing trucks, even for the other activities in turnaround process. There were many different models of the aircraft turnaround process that have been developed in order to investigate its sensitivity to changes of available resources, aircraft arrival delays, different gate assignment strategies. The specific class of Petri Nets used is the Hierarchical Stochastic Colored Timed Petri Nets (CPN). Petri Nets are a graphical and mathematical modeling tool for the supply chain strategy.

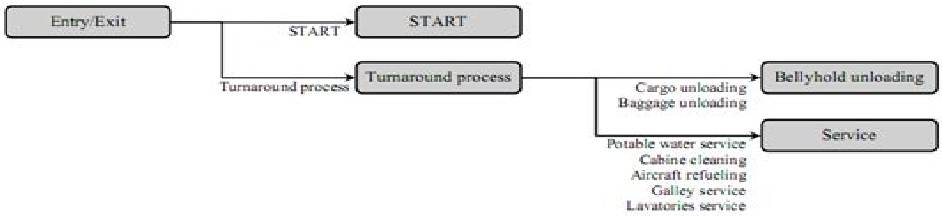


Figure3. Hierarchical graph of CPN model f turnaround process

The highest hierarchical level called Entry/Exit which models: aircraft arrival (ENTER), parking, entering turnaround process queue, push back and departure (EXIT). The two subnet of hierarchy level 2, START is used for data input (schedule arrival time, aircraft type, and schedule departure time); Turnaround process, models all activities of aircraft turnaround process and it is connected with two hierarchies level 3 subnets: Service and Bellyhold unloading, which models ground service and cargo/baggage handling activities. Experiments differ in terms of gate-assignment strategy. The first experiment gates were dedicated to aircraft according to gate assignment plan, while in the second were automatically assigned during aircraft arrival. Scenario 2 assumes lack or failure of ground handling equipment. Scenario 3 assumes aircraft arrival time as a random variable with uniform distribution (schedule time +/- 5 minutes). Scenario 4 assumes variable passenger deplaning and boarding time such as late transfer passengers.Through analysis it has been clear that gate-assignment strategy where gates are dedicated to aircrafts according to gate assignment plan leads to additional delays when operations are perturbed. Departure delay as well as turnaround process is always smaller when using automatic assignment strategy than using strict gate assignment strategy [9-12]. This is of great importance, especially at hub airports where most of the passengers are transfer passengers whose inbound flights delays will cause delays of outbound flights. Moreover, the change of gate assignment close to aircraft arrival will usually result in a longer turnaround (need to transfer outbound baggage, cargo and passengers ...).

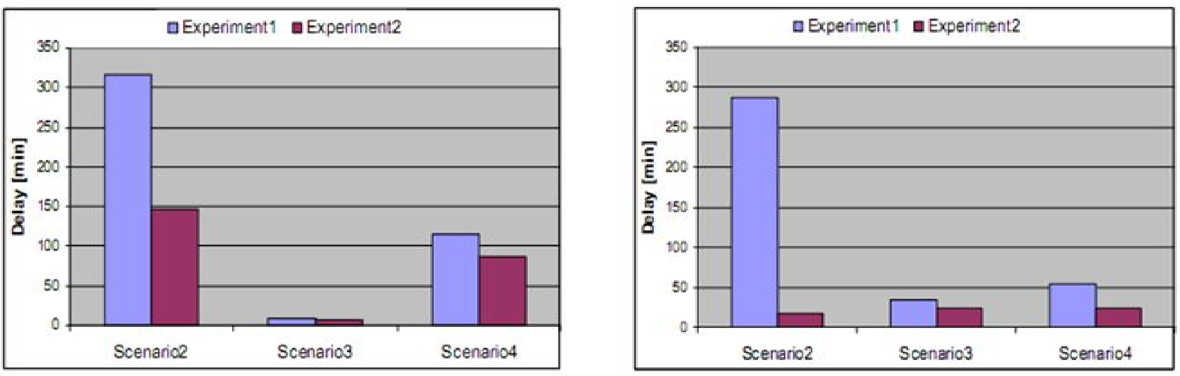


Figure4. Comparison of experiment 1 and experiment 2 simulation results

5. Research design

Applying quantitative method will be more suitable in order to fulfill the purpose of this research, since this study is researching how control delay in aircraft ground handling, due to the fact that data analysis procedure (such as graph or statistics) are difficult to measure in a qualitative way. This study identifies the factors caused delay in VNA flights especially in ground handling services, how those factors link together and the effect of each factor in overall process. Then set up a model based on the fault tree analysis method for modeling malfunctions of aircraft ground handling and find out the final effect if every component is this model is controlled.

5.1. Data Collection

In this paper, secondary data were collected for supply chain strategy. The secondary data used have been critically evaluated and collected from company reports, books, scientific articles in order to obtain, collect, statistic and analyze all relevant data of each ground delay case that caused by the Vietnam Airline's company members during the last three years to find out the more frequent points and set up a model for controlling those points based on above information. Last but not least, due to the advantage of internet source such as the researcher can access easily and quickly about various types of information; it is used to help researcher achieving practical understanding more of aircraft services.

6. Findings and Discussions

6.1. Defects analysis

The study chooses defects that occur frequently based on figure 6. These defects are 'late cockpit crew', 'late cabin crew', 'late refueling tanker positioning' and 'moving aircraft from hangar to parking late'. After analyzing these defects and found out the solutions to minimize these defects by using knowledge, brainstorm with expert, books and internet source, these defects will be tested by simulating to make sure those solutions can apply and work. In aircraft ground handling operation of VNA at TSN airport, the cockpit crew must arrive at the aircraft at least an hour before departure (one hour and a half for VIP flights). Then they will review the information of the flight including the weather, the number of passengers on board; works out the flight plan; files it with air traffic control and meets with the rest of the crew and make sure all of the instruments and controls are working properly. Hence, the more time cockpit crew incur and arrived late to the aircraft, the more delay time flights are recorded. Mean shows that the time for this defect takes almost one hour. Standard deviation indicates that the data points tend to be spread out over a large range of values. If this defect occurs, the time for cockpit crew come late to aircraft could be very large. Thus, flight could be delayed more than one or two hours and it is not good for the passengers and detrimental to the airline because passengers have to wait longer for their flight and VNA lost much money for DOC in one hour or two hours [13-15].

6.2. Multiple linear regressions

The supply chain strategy organize the whole process from the first stage to last one. For each data of T (late cockpit crew), T (flight delay) is resulted in Table 4 because the cockpit crew activity belongs to critical path and any delay of this activity directly impacts the turnaround time. Hence, researcher uses multiple linear regression to model the relationship between T (late cockpit crew) and T (flight delay) by using data in Table4.

Predictor	Coefficients	Standard Error	T stat	P-value
T(late cockpit crew)	13.9028	0.8186	16.98	0
T(flight delay)	1.39156	0.02809	49.54	0

S = 13.4836 R-Sq = 70.2% R-Sq(adj) = 70.2%

Analysis of variance

Source	DF	SS	MS	F	P
Regression	1	446190	446190	2454,2	0
Residual Error	1042	189443	182		
Total	1043	635633			

The regression equation is:

T (late cockpit crew) = 13.9 + 1.39*T (flight delay)

Reliability simulation and test mode

For mean = 50.5822 and standard deviation = 23.8206

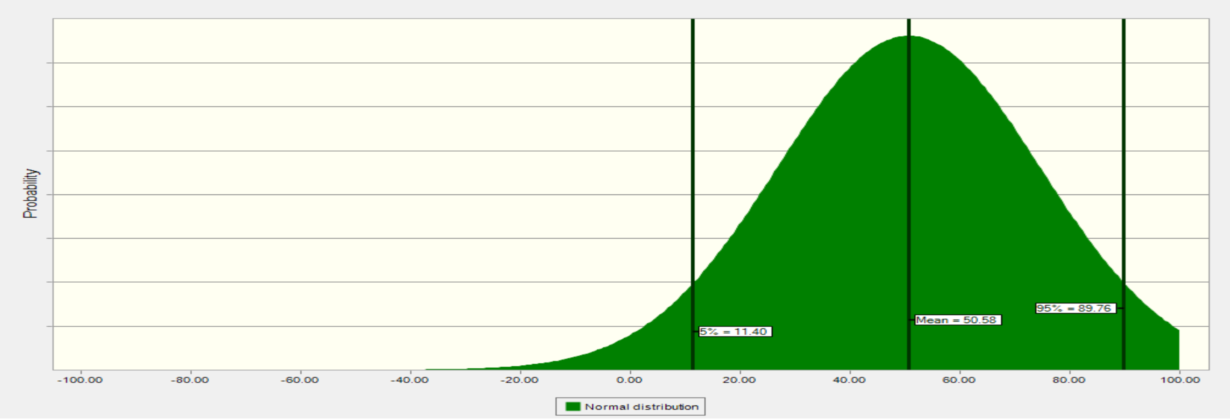


Figure5. Normal distribution for 'late cock pit crew' defects before applying solutions

A set of 150 random numbers of T (late cockpit crew) as well as 150 errors of this defect are created. By using above equation of multiple linear regressions

T (flight delay) = {T (late cockpit crew) – 13.9} / 1.39

The researchers compute the T (flight delay) and count error based on T (flight delay) again (positive = delay and negative = punctuality). Table5 shows that, there are 142 errors after simulating and the result are accepted [16,17].

Table1. 'Late cockpit crew' defectswith mean = 50.58 and standard deviation = 23.82

T(late cockpit crew)	T(flight delay)	Error = 150	Trial values	50.58;23.82	T(flight delay)	Error = 142
110	50	1	1	59.25	32.57	1
50	20	1	2	72.25	42.39	1
30	13	1	3	80.84	48.71	1
35	20	1	4	73.00	42.94	1
40	20	1	5	36.75	16.28	1
40	15	1	6	65.61	37.51	1
30	10	1	7	30.11	11.40	1
35	15	1	8	36.06	15.78	1
35	17	1	9	88.66	54.46	1
47	25	1	10	69.66	40.48	1
37	25	1	11	41.59	19.85	1
30	15	1	12	61.60	34.56	1
32	15	1	13	6.65	-5.85	0
60	15	1	14	58.36	32.17	1
25	15	1	15	62.27	35.05	1
30	20	1	16	35.18	15.13	1
50	25	1	17	55.435	30.03	1
90	60	1	18	29.82	11.19	1
37	20	1	19	63.19	35.73	1
45	25	1	20	60.38	33.67	1
55	25	1	21	61.32	34.36	1
50	25	1	22	44.95	22.31	1
55	15	1	23	29.36	10.86	1
50	25	1	24	37.71	16.99	1
80	47	1	25	117.35	75.55	1
55	15	1	26	-12.53	-19.95	0
40	20	1	27	35.01	15.01	1
80	20	1	28	52.79	28.08	1
50	20	1	29	55.14	29.81	1
47	15	1	30	24.57	7.33	1
35	20	1	31	90.15	55.55	1
45	15	1	32	43.48	21.23	1
40	30	1	33	18.51	2.88	1
46	35	1	34	43.13	20.97	1
45	20	1	35	47.31	24.05	1
60	20	1	36	63.66	36.08	1
20	10	1	37	59.74	33.19	1
30	16	1	38	63.38	35.87	1
90	65	1	39	44.90	22.28	1
35	18	1	40	24.96	7.62	1
20	20	1	41	51.30	26.98	1
25	15	1	42	57.61	31.62	1
30	20	1	43	56.76	31.00	1

30	15	1	44	53.46	28.57	1
40	20	1	45	61.43	34.43	1
50	20	1	46	25.35	7.91	1
76	43	1	47	77.01	45.89	1
51	35	1	48	13.52	-0.80	0
45	35	1	49	74.10	43.75	1
88	28	1	50	19.28	3.44	1
30	15	1	51	47.80	24.41	1
40	10	1	52	32.01	12.80	1
40	15	1	53	32.89	13.45	1
55	27	1	54	32.36	13.06	1
35	18	1	55	49.20	25.44	1
40	20	1	56	69.58	40.42	1
38	15	1	57	54.60	29.41	1
51	20	1	58	-20.93	-26.13	0
25	18	1	59	54.30	29.19	1
85	48	1	60	58.69	32.42	1
63	25	1	61	85.60	52.21	1
50	22	1	62	82.75	50.11	1
55	20	1	63	49.28	25.50	1
80	40	1	64	47.60	24.27	1
65	20	1	65	85.26	51.95	1
50	25	1	66	47.30	24.04	1
27	18	1	67	45.23	22.52	1
68	35	1	68	27.32	9.35	1
60	20	1	69	33.61	13.98	1
75	15	1	70	80.14	48.19	1
50	20	1	71	53.21	28.39	1
45	15	1	72	23.55	6.58	1
40	17	1	73	67.98	39.25	1
45	19	1	74	45.65	22.83	1
52	16	1	75	22.21	5.60	1
55	15	1	76	-16.65	-22.98	0
74	14	1	77	61.61	34.57	1
30	16	1	78	25.96	8.36	1
96	65	1	79	20.74	4.52	1
70	58	1	80	76.32	45.38	1
50	38	1	81	41.00	19.41	1
25	27	1	82	103.11	65.08	1
50	15	1	83	35.69	15.51	1
90	60	1	84	73.65	43.42	1
15	10	1	85	47.54	24.22	1
75	15	1	86	52.23	27.67	1
73	38	1	87	85.70	52.28	1
135	94	1	88	82.04	49.59	1
72	40	1	89	95.72	59.64	1
30	23	1	90	63.73	36.13	1
30	15	1	91	42.18	20.28	1
25	22	1	92	60.15	33.49	1
50	25	1	93	23.27	6.38	1
55	33	1	94	59.89	33.30	1
105	60	1	95	82.31	49.79	1
20	16	1	96	63.13	35.68	1
80	39	1	97	73.69	43.45	1
65	45	1	98	52.29	27.72	1
30	20	1	99	46.63	23.55	1
25	18	1	100	50.47	26.38	1
47	20	1	101	37.49	16.83	1
45	23	1	102	56.94	31.13	1
18	18	1	103	42.76	20.70	1
20	19	1	104	56.22	30.60	1
80	44	1	105	51.92	27.44	1
32	18	1	106	27.91	9.79	1
55	15	1	107	48.57	24.98	1
30	16	1	108	30.22	11.49	1
30	23	1	109	87.39	53.52	1
75	40	1	110	59.38	32.93	1
140	85	1	111	46.21	23.24	1
75	40	1	112	7.97	-4.88	0
50	35	1	113	55.86	30.34	1
30	19	1	114	56.48	30.80	1

100	43	1	115	56.64	30.91	1
57	30	1	116	93.51	58.02	1
56	14	1	117	18.47	2.84	1
40	15	1	118	24.45	7.24	1
45	20	1	119	59.09	32.71	1
80	39	1	120	44.21	21.78	1
43	15	1	121	95.12	59.20	1
50	25	1	122	32.02	12.81	1
84	50	1	123	70.08	40.80	1
43	20	1	124	-6.28	-15.35	0
35	17	1	125	58.08	31.97	1
97	60	1	126	32.18	12.93	1
30	23	1	127	57.68	31.68	1
15	10	1	128	82.54	49.96	1
55	15	1	129	26.58	8.81	1
35	10	1	130	56.95	31.14	1
40	25	1	131	62.67	35.35	1
50	20	1	132	-23.87	-28.29	0
68	35	1	133	94.20	58.53	1
25	20	1	134	72.95	42.91	1
20	15	1	135	60.27	33.58	1
25	15	1	136	93.92	58.32	1
20	10	1	137	46.67	23.58	1
20	15	1	138	62.95	35.55	1
15	10	1	139	61.57	34.54	1
60	20	1	140	45.58	22.78	1
80	40	1	141	32.81	13.39	1
75	44	1	142	62.53	35.24	1
50	26	1	143	41.13	19.50	1
55	15	1	144	43.08	20.94	1
30	15	1	145	29.56	11.00	1
120	60	1	146	45.19	22.49	1
35	10	1	147	44.95	22.32	1
40	28	1	148	45.80	22.94	1
60	25	1	149	34.80	14.86	1
58	30	1	150	50.09	26.10	1

As the study has shown that the cockpit crew activity are the critical path and an increase in their times can consequently increase the total turnaround time as well as delay time for flight.

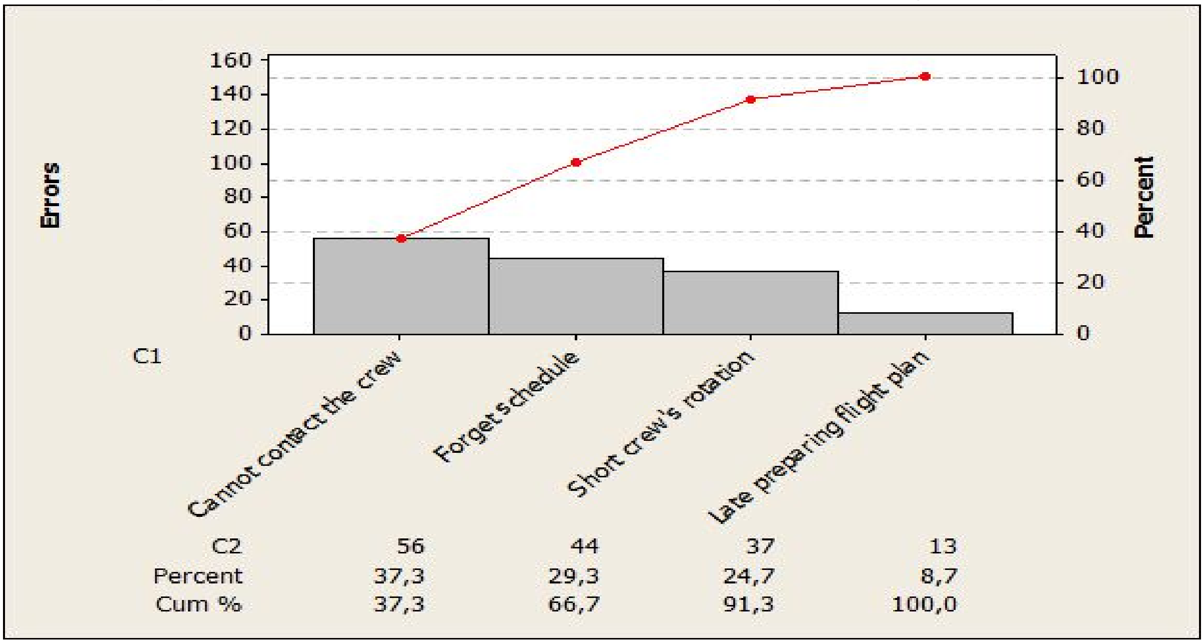


Figure6. Late cockpit crew defect

After applying these solutions to minimize the defect, researcher believes that the mean and standard deviation couldbe reduced to 20.5 and 8.3, respectively.

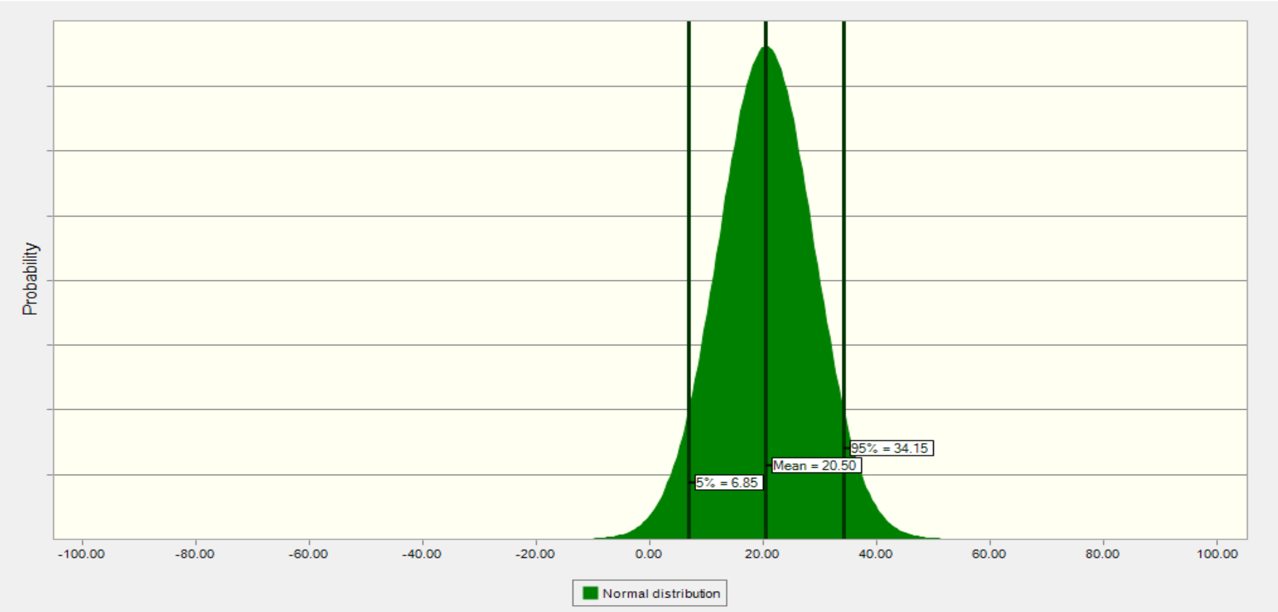


Figure7. Normal distribution for 'late cock pit crew' defects after applying solutions

A set of 150 random numbers of T (late cockpit crew) are created and T (flight delay) are calculated by using the equation of multiple linear regressions T (flight delay) = {T (late cockpit crew) – 13.9} / 1.39

The researchers count that there are 117 errors for this defect in Table 6. Thus, these above solutions are accepted and can apply to improve the punctuality of cockpit crew.

Descriptive statistic of late cockpit crew

Use the data of Table 7, the mean and standard deviation of T (late refueling tanker positioning) as computed as below:

Mean = 33.3088

Standard deviation = 10.7859

Supplier management is vital for on-time performance and VINAPCO Company is a key supplier. If key supplier does not finish their processes on time, the resulting punctuality will drop significantly. For airlines, the refueling procedure cannot begin until the disembarking has ended, as well as boarding cannot start until refueling has finished due to safety regulation. In VNA, if flights have fire truck, the refueling procedure can start during the disembarking and embarking activities. Hence, this process might not be on the critical path because it mayaffect on-time performance or not depending on anti-fire activity at TSN airport. However, VNA must pay $70 to TSN airport for each time operating anti-fire activity [18]. Thus, a lot of money will be wasted and it can affect to punctuality performance if this defect occurs frequently. Mean shows that the time for this defect takes more than a half of hour. Standard deviation indicates that the data points tend to be close to the mean. This result is still not good for passengers as well as VNA Company.

Multiple linear regressions

For each data of T (late refueling tanker positioning), T (flight delay) is resulted in Table 7. Hence, researchers use multiple linear regression to model the relationship between T (late refueling tanker positioning) and T (flight delay) by using data in Table 7.

Predictor	*Coefficients*	*Standard Error*	*t Stat*	*P-value*
T(late refueling tanker pos.)	11.87823577	1.782995268	6.661956	6.44E-09
T(flight delay)	1.070742078	0.082011538	13.05599	5.89E-20

S = 5.7413 R-Sq = 72.7% R-Sq(adj) = 72.1%

Analysis of variance:

Source	DF	SS	MS	F	P
Regression	1	5618.923753	5618.924	170.459	6E-20
Residual Error	66	2175.590953	32.9635		
Total	67	7794.514706			

The regression equation is:
T (late refueling tanker pos.) = 11.88 + 1.07 * T (flight delay)

Reliability simulation and test mode
For mean = 33.3088 and standard deviation = 10.7859

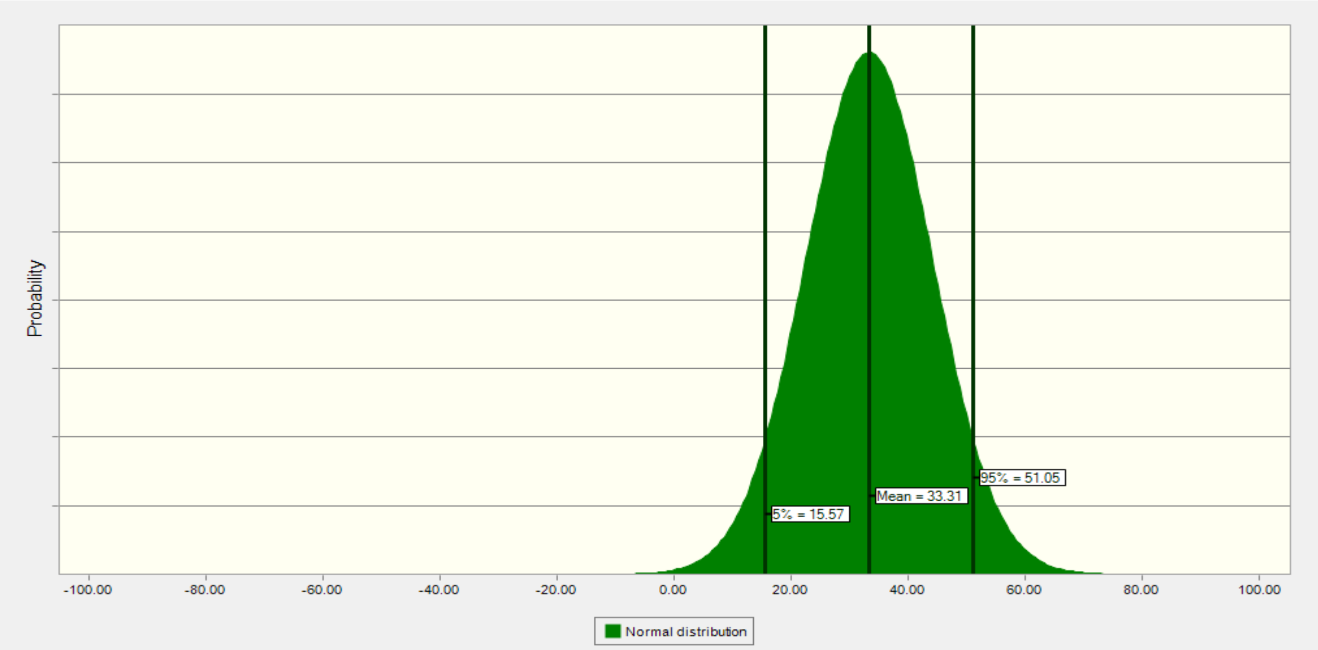


Figure8. Normal distribution for 'late refueling tanker' defects before applying solutions

A set of 68 random numbers of T (late refueling tanker pos.) as well as 68 errors of this defect are created. By using above equation of multiple linear regressions
T (flight delay) = {T (late refueling tanker pos.) – 11.88} / 1.07

The researcher compute the T (flight delay) and count error based on T (flight delay) again (positive = delay and negative = punctuality). Table 8 shows that, there are64 errors after simulating and the result are accepted.

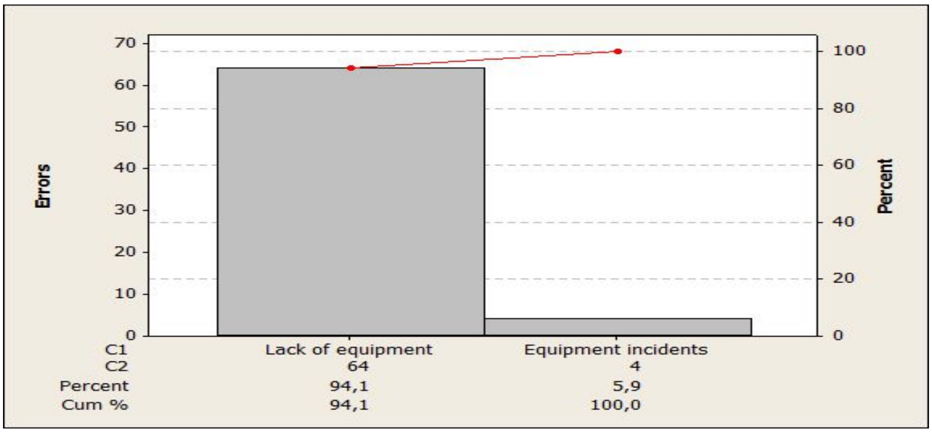


Figure9. Late refueling tanker truck positioning

After applying these solutions to minimize the defect, researcher believes that mean and standard deviation could reduce to 10 and 5.

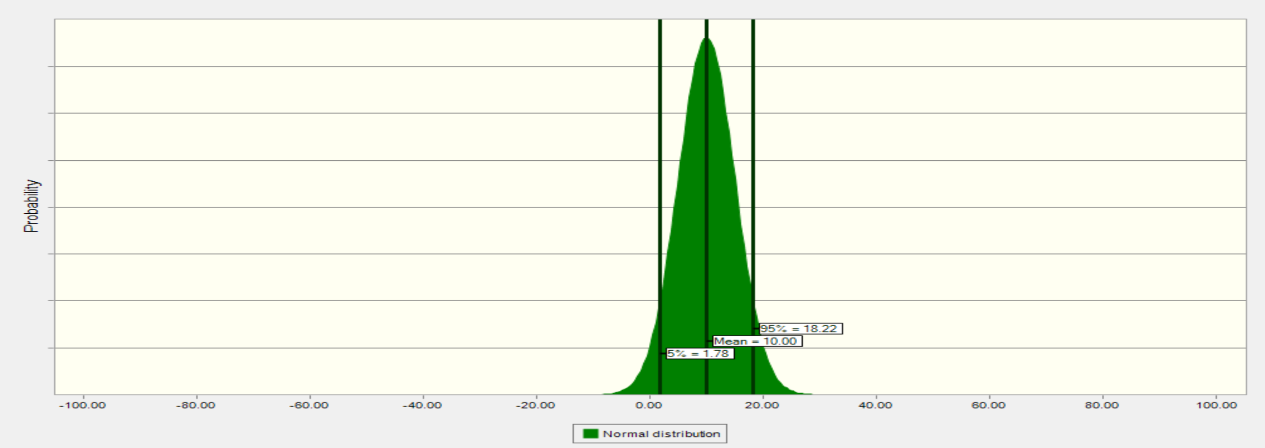


Figure 10. Normal distribution for 'late refueling tanker' defects after applying solutions

A set of 68 random numbers of T (late refueling tanker pos.) are created and T (flight delay) are calculated by using the equation of multiple linear regressions

T (flight delay) = {T (late refueling tanker pos.) – 11.88} / 1.07

The researchers count that there are 35 errors for this defect (Table 9). Thus, these above solutions are accepted and can apply to improve the punctuality of refueling tanker activity.

'Late cabin crew' defect

Descriptive statistic of late cockpit crew

Use the data of Table10, the mean and standard deviation of T (late cabin crew) are computed as below:

Mean = 40.0345

Standard deviation = 16.7677

For VNA's flights, the cabin crew must arrive at the aircraft at least an hour before departure (one hour and a half for VIP flights). When the cabin crew members aboard the aircraft they shall immediately perform an emergency equipment check at their station, lavatories, overhead bins, cupboards and seat. After that, they are to make sure with VN/CX Company that all catering items, food, dry-goods, bars and duty-free are counted and on board and are stowed in their appropriate places before passengers arrive. Then they are to ensure that the cabin is safe for take-off. They will do security checks in cabin, galleys and lavatories, anything suspicious. Thus, the more time cabin crew comes late to the aircraft, the more delay time flights become. Mean shows that the time for this defect takes more than a half of hour. Standard deviation indicates that the data points tend to be spread out a large range of values. If this defect occurs, the time for cabin crew come late to aircraft could be large. Thus, flight could be delayed more than one hour.

Multiple linear regressions

For each data of T (late cabin crew), T (flight delay) is resulted in Table 10 because the cabin crew activity belongs to critical path and any delay of this activity directly impacts the flight departure time. Thus, researcher uses multiple linear regression to model the relationship between T (late cockpit crew) and T (flight delay) by using data in Table 10.

Predictor	*Coefficients*	*Standard Error*	*t Stat*	*P-value*
T(late refueling tanker pos.)	12.99750195	1.816312807	7.155982	1.91E-09
T(flight delay)	1.028966461	0.060230728	17.08375	7.12E-24

S = 6.7875 R-Sq = 83.9% R-Sq(adj) = 83.61%

Analysis of variance

Source	DF	SS	MS	F	P
Regression	1	13445.96601	13445.97	291.8544	7E-24
Residual Error	56	2579.965027	46.0708		
Total	57	16025.93103			

The regression equation is:

T (late cabin crew) = 12.99 + 1.03 * T (flight delay)

Reliability simulation and test mode

For mean = 40.0345 and standard deviation = 16.7677

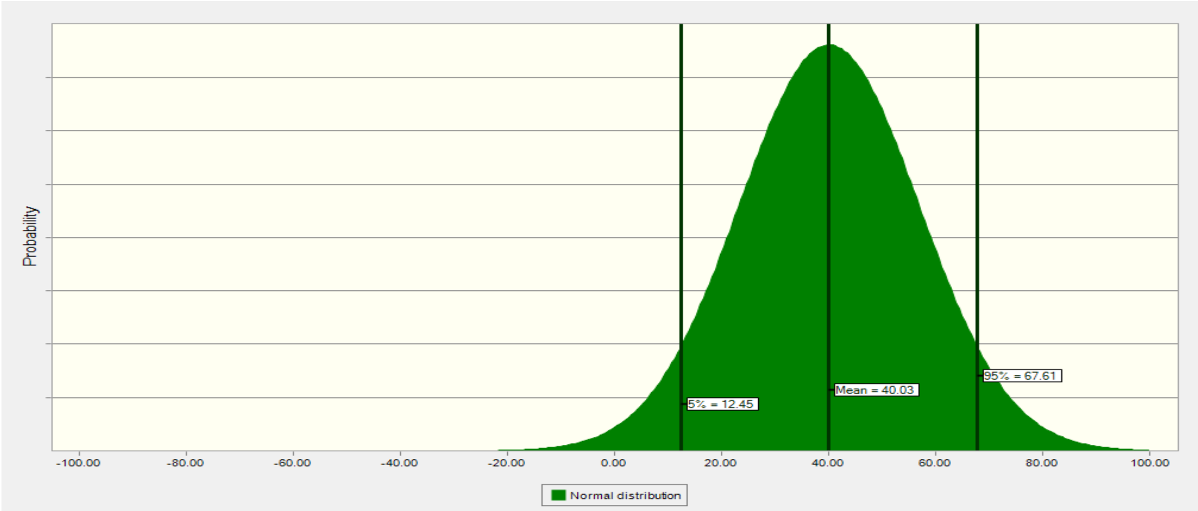
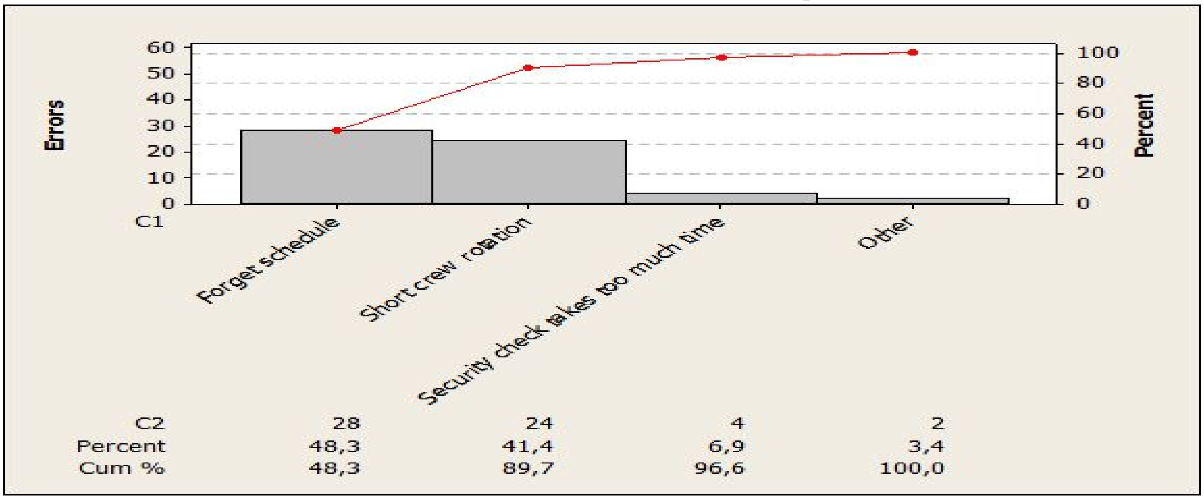


Figure11. Normal distribution for 'late cabin crew' defects before applying solutions

A set of 58 random numbers of T (late cabin crew) as well as 58 errors of this defect are created. By using above equation of multiple linear regressions T (flight delay) = {T (late cabin crew) – 12.99} / 1.03

The researchers compute the T (flight delay) and count errors based on T (flight delay) again (positive = delay and negative = punctuality). Table 11 shows that, there are 55 errors after simulating and the result are accepted.



After applying these solutions to minimize the defect, researcher believes that mean and standard deviation could reduce to 10 and 5.

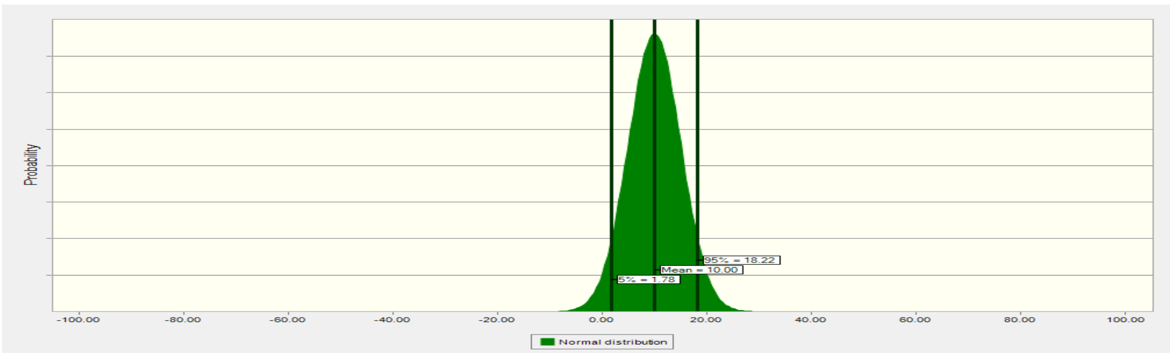


Figure12. Normal distribution for 'late cabin crew' defects after applying solutions

A set of 58 random numbers of T (late refueling tanker pos.) are created and T (flight delay) are calculated by using the equation of multiple linear regressions

T (flight delay) = {T (late cabin crew) – 12.99} / 1.03

The researchers count that there are 15 errors for this defect (Table12). Thus, these above solutions are accepted and can apply to improve the punctuality of cabin crew.

4.1.4 ‘Move aircraft from hangar to parking late” defect

Descriptive statistic of moving aircraft from hangar to parking late
Use the data of Table 13, the mean and standard deviation of T (move aircraft from hangar to parking late) are computed as below:
Mean = 29.8
Standard deviation = 12.5856
A ramp area at TSN airport is not large, it can keep a medium number of aircraft (around 40 aircrafts), but there’s not nearly enough space for the 60 to 80 aircraft in rush hours. When they need to perform maintenance, repair or are not in use, most of the aircrafts are secured in the hangar. Thus, the more time aircraft come for parking, the more delayed the flight becomes.
Multiple linear regressions
For each data of T (move aircraft from hangar to parking late), T (flight delay) is resulted in Table 10. Hence, researcher uses multiple linear regression to model the relationship between T (late refueling tanker positioning) and T (flight delay) by using data in Table 13.

Predictor	Coefficients	Standard Error	t Stat	P-value
T (late refueling tanker pos.)	4.8061	0.8407	5.72	0
T(flight delay)	1.00499	0.03371	29.81	0

S = 3.02487 R-Sq = 95.4% R-Sq(adj) = 95.3%
Analysis of variance

Source	DF	SS	MS	F	P
Regression	1	8130.5	8130.5	888.59	0
Residual Error	43	393.4	9.1		
Total	44	8523.9			

The regression equation is:
T (move aircraft ...) = 4.81 + 1.00 * T (flight delay)
Reliability simulation and test mode
For mean = 29.8 and standard deviation = 12.5856

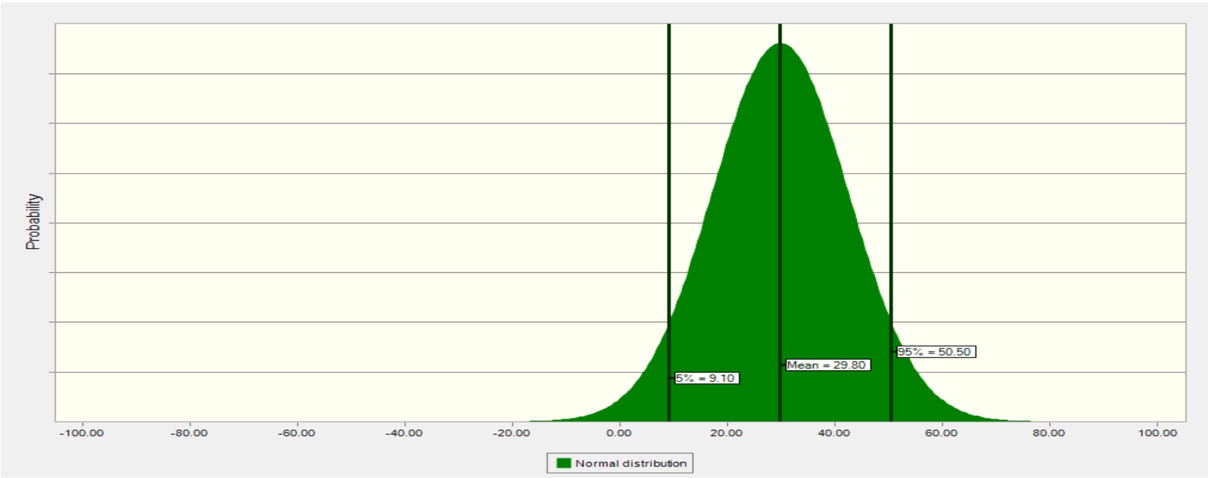


Figure 13. Normal distribution for 'late cabin crew' defects before applying solutions

A set of 45 random numbers of T (late cabin crew) as well as 45errors of this defect are created by using above equation of multiple linear regressions
T (flight delay) = {T (move aircraft ...) – 4.81} / 1.00
Researchers compute the T (flight delay) and count errors based on T (flight delay) again (positive = delay and negative = punctuality). Table14 shows that, there are44 errors after simulating and the result are accepted.

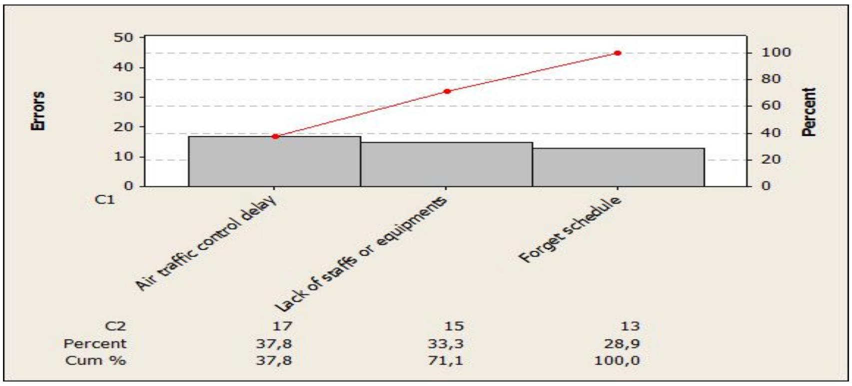


Figure 14.Late moving aircraft from hangar to parking

After applying these solutions to minimize the defect, researcher believes that mean and standard deviation could reduce to 5 and 5.

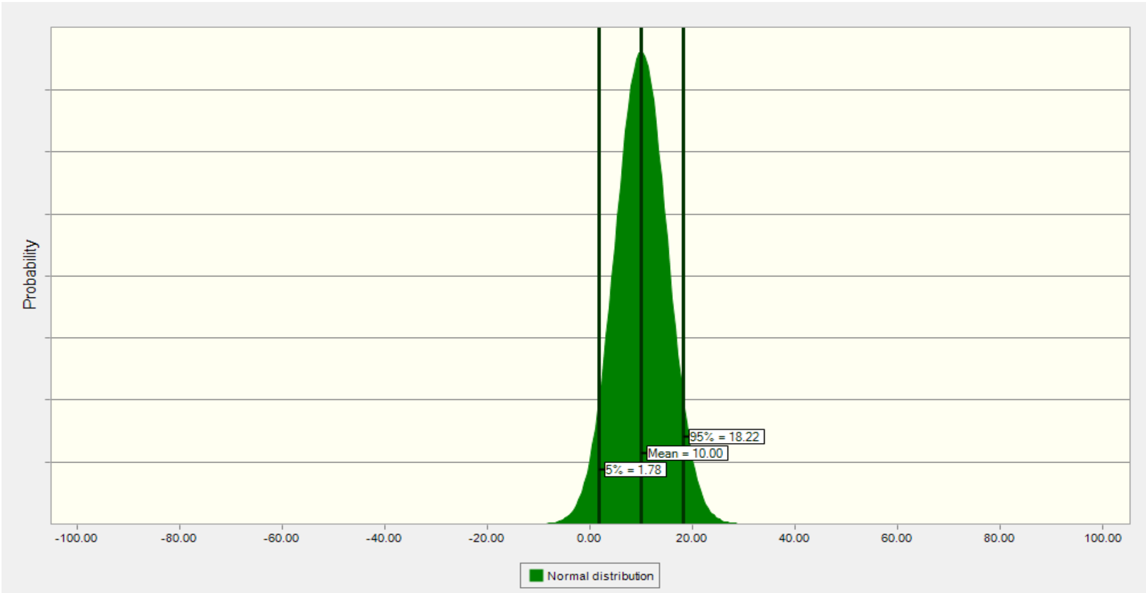


Figure 15. Normal distribution for 'late cabin crew' defects after applying solutions

A set of 45 random numbers of T (move aircraft ...) are created and T (flight delay) is calculated by using the equation of multiple linear regressions

T (flight delay) = {T (move aircraft ...) – 4.81} / 1.00

Researchers count that there are 28 errors for this defect (Table 15). Thus, these above solutions are accepted and can apply to improve the punctuality of moving aircraft from hangar to parking.

6.3. Ground Handling Cost

Ground handling costs have an influence on the total DOC of the aircraft, which is not very big in comparison with aircraft price or depreciation, but it has its importance in the overheads of the company. So, any improvement in the aircraft ground handling will reduce in the ground handling costs, since a cost reduction at one single ground handling process can be seen on the total ground handling costs. However, improving one single ground handling process might not lead to an overall improvement in turnaround time. Only by improving ground handling processes which are on the critical path, an improvement in the overall turnaround time can be achieved. Since the study has reviewed in chapter 2, the DOC is sum of these cost elements:

$$C_{DOC} = C_{DEP} + C_{INT} + C_{INS} + C_F + C_M + C_C + C_{FEE}$$

These above defects {cabin crew (C_C), cockpit crew (C_C), refueling tanker truck (C_F), moving aircraft from hangar (C_M)} belong to the above formula. Thus, when these defects are controlled and decreased, researcher believes that the ground handling cost will be reduced.

7. Conclusion and Recommendations

Today's aerospace supply chain is complex, global, and more vulnerable than ever. The main objective of this study is to examine the factors that affect the aircraft ground handling activities that cause flights delay. The core objective of this study was established to find solutions that control these factors. Based on data analysis, the factors that have influenced strongly to flights delay in aircraft ground handling are cockpit crew, cabin crew, refueling tanker truck and moving aircraft from hangar to parking. The solutions that minimize these factor's defects are introduced and the study shows that these solutions can be obtained. Since the turnaround process is a complex process where several equipment and staff are in constant interaction, a simulation can be very useful to estimate the performance of the process taking into account interactions and allowing exploring new solutions.

8. Limitations

Like all research, this research has several limitations to the interpretation of the result. Firstly, the limitation relates to the data. The solutions were given and tested by using Monte Carlo method. Then the solutions will be more accurate and convincing if it is applied to aircraft ground handling in reality.Secondly, DOC should be more focused on this study. Since the amount of data about DOC is not enough, therefore researcher gave a conclusion about DOC based on DOC's equation reviewed in literature review. Hence, the results that DOC might be proven clearly by implementing more real data of the DOC.

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