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ANIL SURENDRA MODI SCHOOL OF COMMERCE

A STUDY ON THE APPLICATION OF OPERATIONS RESEARCH IN THE AIRLINE INDUSTRY

SUBMITTED TO

SUBMITTED BY

Varun Mittal	74021016430	SYBBA-B
Vidisha Diwan	74021016166	SYBBA-B
Anand Baid	74102150069	SYBBA-B
Sarthak Dua	74102140100	SYBBA-B

ON

SIGNATURE MARKS

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ABSTRACT

This paper on application of Operations Research in Aviation industry discusses some of the well-known problems and their respective solution approaches, review current research in the field and highlight emerging areas of future importance. The paper applies concepts of Operations Research inclusive of Hungarian Assignment model and Critical Path Method on some of the airline companies. It deals with the shortcomings in the schedule of airlines, tries to increase productivity among crewmembers through crew assignment model and reduce time taken for non-critical activities, leading to an increase in profit for the airlines.

OBJECTIVE

To study the assignment of airline crews using Hungarian Assignment Model of Indigo and Air India and Critical Path Analysis of Lufthansa Airlines.

INTRODUTION

Operations research has played a critical role in helping the airline industry and its infrastructure sustain high growth rates and make the transition from a novelty that catered to an elite clientele to a service industry for the masses. It helps the industry continually transform itself to compete effectively in the marketplace to match complex consumer demands. India has become the third largest domestic aviation market globally. With a year on year growth rate of 26.6%, the application of Operations Research in airlines is vital.

Section (1) and (2) deal with the crew assignment model. The objective is to optimize rest time of the crew for Air India and Indigo flights between Mumbai and Delhi, towards optimum utilization of resources, manpower planning and cost efficiency. The situation has been formulated as an assignment problem with ten schedules from Mumbai to Delhi and back. Hungarian method of assignment is used to solve it. Various scenarios were analysed for different crew assignments and flight routes, which revealed that rest time of the crew had scope for considerable deduction.

Section (3) deals with the scheduling of aircraft maintenance activities. The principal purpose is to minimize time taken by operations and increase the flying hours of the airline. To illustrate this, we have taken the scheduling data of Deutsche Lufthansa and Critical Path Method is used for analyzing the maintenance activities.

Critical Path method is used to reduce the time of interrelated jobs. The critical path technique was developed by the US Navy for the reduction of estimated time of any project.

1.1. About Air India

Air India is the flagship passenger airline of India, headquartered in Mumbai. It is owned by Air India Limited, a government-owned enterprise, and operates a fleet of carrier airlines for 90 domestic and international destinations across four continents. Air India is the third largest airline in India with a domestic market share of 18.6 percent after Indigo and Jet Airways. JRD Tata founded it in 1932 as Tata Airlines. After World War II, it became a public limited company and was renamed as Air India. It suffered losses after its merger with Indian Airlines which was an attempt to privatize the company. Between September 2007 and May 2011, Air India's domestic market share declined from 19.2% to 14%, primarily because of stiff competition from private Indian carriers. In March 2013, the airlines posted its positive earnings after almost 6 years.

1.2. Statement of Purpose

There are two major domestic hubs that Air India operates – Indira Gandhi International Airport (Delhi) and Chhatrapati Shivaji International Airport (Mumbai). These two cities are very important for Air India's domestic business and have major impact on its schedules. Air India's current time schedules were analyzed to find that there are 16 schedules planned between Delhi and Mumbai. Out of this, 10 direct schedules from both cities were direct routes for which average flight time was near 2 hours. Assuming all flights and crew based at Delhi, the rest period for crew members at Mumbai was found to be 117 hours and 50 minutes for the existing schedule as shown in Table 1. It was found that changing the schedule was imperative to reduce this.

Table 1. Base at Delhi

Delhi to Mumbai			Mumbai to Delhi			
FLIGHT NO.	DEPARTURE	ARRIVAL	FLIGHT NO.	DEPARTURE	ARRIVAL	REST TIME
AI 0349	3:50	5:55	AI 0348	7:55	10:10	2:00
AI 0665	8:00	10:00	AI 0664	18:00	20:10	8:00
AI 0678	9:00	11:10	AI 0677	13:00	15:10	1:50
AI 0865	10:00	12:10	AI 0866	9:00	11:15	20:50
9I 0628	10:50	15:50	9I 0627	10:30	15:30	18:40
AI 0863	13:00	15:10	AI 0864	7:00	9:05	15:10
AI 0636	15:10	18:25	AI 0635	7:05	10:35	12:40
AI 0102	17:00	19:20	AI 0101	21:00	23:10	1:40
AI 0315	23:00	1:15	AI 0310	19:45	22:00	18:30
AI 0317	23:00	1:15	AI 0314	19:45	22:05	18:30

TOTAL REST TIME	117:50:00

1.3. Methodology

No.	Research/Assumption	Observation/Calculation
1.	The data of flights going back and forth between Mumbai and Delhi was found on the Air India website.	It was found that there were 10 direct schedules between Delhi and Mumbai that flew daily. (As shown in Table 1)
2.	Considering there are two major domestic hubs at Gandhi International Airport (Delhi) and Chhatrapati Shivaji International Airport (Mumbai), it was assumed that crew would start their schedules from Delhi, and rest times calculated henceforth.	For instance, crew members of AI 349 depart from Delhi at 3:50AM and reach Mumbai by 5:55AM and again depart from Mumbai as AI 348 at 7:55AM and reach Delhi by 10:10AM. The rest period in Mumbai being 2 hours.
3.	The total rest period of the crew was calculated for assigned flights for all the routes.	The total rest time of the crew considering the crew base at Delhi, was calculated as 117 hours and 50 minutes.
4.	While calculating the rest period, two tables had to be prepared considering crew base at Delhi (layover in Mumbai) and crew base at Mumbai (layover in Delhi). This is shown in Table 2 and 3 respectively.	Rest times were calculated for both the scenarios for all assigned flights in units for simplification. (5 minutes = 1 unit)
5.	By comparing the two tables, a new table was formed (table 4) with minimum rest time for each combination of flight.	It can be seen that some combinations have less rest time when based in Mumbai.
6.	Rescheduling of crew was done using Hungarian Assignment Method to optimize the rest time.	Table 5 shows the optimal solution with different combinations of flight with minimum rest time.

Rest Period for Crew when they stay in Delhi (Layover time in Mumbai - Base at Delhi)

Table 2.	AI 0348	AI 0664	AI 0677	AI 0866	9I 0627	AI 0864	AI 0635	AI 0101	AI 0310	AI 0314
AI 0349	24	145	85	37	55	13	14	181	166	166
AI 0665	263	96	36	276	6	252	253	132	117	117
AI 0678	249	82	22	262	268	238	239	118	102	102
AI 0865	237	70	10	250	256	226	227	94	91	91
9I 0628	193	26	254	206	224	182	183	50	47	47
AI 0863	201	34	262	214	232	190	191	58	55	55
AI 0636	162	283	223	175	193	151	152	31	16	16
AI 0102	19	272	212	164	182	140	141	20	5	5
AI 0315	80	201	141	93	111	69	70	237	222	222
AI 0317	80	201	141	93	111	69	70	237	222	222

Rest Period for Crew when they stay in Mumbai (Layover time in Delhi - Base at Mumbai)

Table 3.	AI 0348	AI 0664	AI 0677	AI 0866	9I 0627	AI 0864	AI 0635	AI 0101	AI 0310	AI 0314
AI 0349	212	92	152	199	148	225	207	56	70	69
AI 0665	262	142	202	249	198	275	257	106	120	119
AI 0678	274	154	214	261	210	287	269	118	132	131
AI 0865	286	166	226	273	222	11	281	130	144	143
9I 0628	296	176	236	283	232	21	3	140	154	153
AI 0863	34	202	262	21	258	47	29	166	180	179
AI 0636	60	228	288	47	284	73	55	192	206	205
AI 0102	82	250	22	69	18	95	77	214	228	227
AI 0315	154	34	94	141	90	167	149	286	300	299
AI 0317	154	34	94	141	90	167	149	286	300	299

Minimum Rest Period for Crew when they stay at Delhi/Mumbai

Table 4.	AI 0348	AI 0664	AI 0677	AI 0866	9I 0627	AI 0864	AI 0635	AI 0101	AI 0310	AI 0314
AI 0349	24	92	85	37	55	13	14	56	70	69
AI 0665	262	96	36	249	6	252	253	106	117	117
AI 0678	249	82	22	261	210	238	239	118	102	102
AI 0865	237	70	10	250	222	11	227	94	91	91
9I 0628	193	26	236	206	224	21	3	50	47	47
AI 0863	34	34	262	21	232	47	29	58	55	55
AI 0636	60	228	223	47	193	73	55	31	16	16
AI 0102	19	250	22	69	18	95	77	20	5	5
AI 0315	80	34	94	93	90	69	70	237	222	222
AI 0317	80	34	94	93	90	69	70	237	222	222

Optimal Table : Minimum Rest Period for Crew when they stay at Delhi/Mumbai

Table 5.	AI 0348	AI 0664	AI 0677	AI 0866	9I 0627	AI 0864	AI 0635	AI 0101	AI 0310	AI 0314
AI 0349	24	92	85	37	55	13	14	56	70	69
AI 0665	262	96	36	249	6	252	253	106	117	117
AI 0678	249	82	22	261	210	238	239	118	102	102
AI 0865	237	70	10	250	222	11	227	94	91	91
9I 0628	193	26	236	206	224	21	3	50	47	47
AI 0863	34	34	262	21	232	47	29	58	55	55
AI 0636	60	228	223	47	193	73	55	31	16	16
AI 0102	19	250	22	69	18	95	77	20	5	5
AI 0315	80	34	94	93	90	69	70	237	222	222
AI 0317	80	34	94	93	90	69	70	237	222	222

Optimal Table Key	
(green)	Optimal Assignment - Base at Mumbai
(yellow)	Optimal Assignment - Base at Delhi
(pink)	Minimum Rest Time with base at Delhi
(white)	Minimum Rest Time with base at Mumbai

1.4. Findings and Suggestions:

Study revealed the following observations:

- The optimum rest time of the crew as calculated was 21 hours and 20 minutes, nearly 80% reduction from the previous rest time of 117 hours and 50 minutes (Refer Table 1 & Table 6)
- We propose the following schedules to start from Mumbai than from Delhi as was assumed previously - AI 0101, AI 0864, AI 0635, AI 0866 and AI 0664.
- Results revealed that rescheduling could save nearly 96 hours in rest period. Assuming indirect cost of rest period Rs.1000 per hour, that implies saving of Rs 96,000/ day, or Rs 28,80,000/ month considering 30 trips in a month.

Table 6. Reschedule of Direct Flights between Delhi and Mumbai

MUMBAI TO DELHI (LAYOVER AT DELHI), BASE IN MUMBAI

FLIGHT NO.	DEPARTURE	ARRIVAL	FLIGHT NO.	DEPARTURE	ARRIVAL	REST TIME
AI 0101	21:00	23:10	AI 0349	3:50	5:55	4:40
AI 0864	7:00	9:05	AI 0865	10:00	12:10	0:55
AI 0635	7:05	10:35	9I 0628	10:50	15:50	0:15
AI 0866	9:00	11:15	AI 0863	13:00	15:10	1:45
AI 0664	18:00	20:10	AI 0315	23:00	1:15	2:50

DELHI TO MUMBAI (LAYOVER AT MUMBAI), BASE IN DELHI

FLIGHT NO.	DEPARTURE	ARRIVAL	FLIGHT NO.	DEPARTURE	ARRIVAL	REST TIME
AI 0317	23:00	1:15	AI 0348	7:55	10:10	6:40
AI 0102	17:00	19:20	AI 0310	19:45	22:00	0:25
AI 0636	15:10	18:25	AI 0314	19:45	22:05	1:20
AI 0678	9:00	11:10	AI 0677	13:00	15:10	1:50
AI 0665	8:00	10:00	9I 0627	10:30	15:30	0:30

TOTAL REST TIME	
	21:20

2.1. About Indigo

IndiGo is a low-cost airline headquartered at Gurgaon, Haryana, India. It is the largest airline inIndia by passengers carried and fleet size, with a 38.7% market share as of July 2017. It is also the largest individual Asian low-cost carrier in terms of jet fleet size and passengers carried, and the eighth largest carrier in Asia with over 41 million passengers carried in 2016. The airline operates to 46 destinations both domestic and international.
The airline was founded as a private company by Rahul Bhatia and Rakesh Gangwal in 2006. It took delivery of its first aircraft in July 2006 and commenced operations a month later. The airline became the largest Indian carrier in passenger market share in 2012.

2.2. Statement of the Problem

One of the major schedules of domestic destination was the route between Mumbai and Delhi. From the existing time schedule obtained from Indigo it was found that 16 individual schedules were planned from Delhi to Mumbai and back. Out of which 10 schedules from both cities were direct routes for which flight time between the cities was found to be approximately 2 Hours. The rest period for crew members was found to be 48 Hours for the existing schedule. The schedule of flights is shown in table1. Hence the re-scheduling the schedules of flights was found essential.

Table 1: Schdeule of flights between Delhi to Mumbai										
Mumbai To Delhi					Delhi To Mumbai					
Flight No.	Origin	Destination	Departure	Return	Flight No.	Origin	Destination	Departure	Return	Rest period In hours
6E 154	Mumbai	Delhi	2:00	4:15	6E 155	Delhi	Mumbai	22:30	0:35	18:15
6E 3612	Mumbai	Delhi	6:10	8:15	6E 3175	Delhi	Mumbai	13:05	15:10	4:50
6E 964	Mumbai	Delhi	7:55	10:10	6E 957	Delhi	Mumbai	11:30	13:35	1:20
6E 205	Mumbai	Delhi	8:30	10:45	6E 189	Delhi	Mumbai	15:00	17:05	4:15
6E 5126	Mumbai	Delhi	9:30	11:45	6E 181	Delhi	Mumbai	16:30	2:35	4:45
6E 6617	Mumbai	Delhi	10:55	13:00	6E 191	Delhi	Mumbai	16:55	19:05	3:55
6E 168	Mumbai	Delhi	12:40	15:00	6E 129	Delhi	Mumbai	17:30	19:35	2:30
6E 176	Mumbai	Delhi	13:30	15:40	6E 843	Delhi	Mumbai	18:35	20:35	2:55
6E 5448	Mumbai	Delhi	14:30	16:40	6E 197	Delhi	Mumbai	19:30	21:35	2:50
6E 5097	Mumbai	Delhi	15:20	17:35	6E 185	Delhi	Mumbai	20:30	22:40	2:55

2.3. Methodology

Research/Assumption	Observation
1.The details of flight going back from Mumbai to Delhi were found on the Indigo Website	It was found that there were 10 schedules between Mumbai and Delhi that flew daily. (As shown in Table 1)
2. Indigo has one major domestic hub Airport at Chhatrapati Shivaji International in Mumbai. and it operates flights to another major international airport Indira Gandhi International Airport In Delhi. It is assumed that all members of crew will start their flights from Mumbai.	For example: Crew members of 6E 154 will depart at 2 AM and reach Delhi at 4:15 AM and return back by 22:30 PM and reach Mumbai by 0:35 AM with a rest period of 14 Hours. Similarly rest period for remaining routes were analysed and listed in table 1.
3. The rest period for crew members is calculated for assigned flight.	The total rest time for the crew travelling Mumbai To Delhi was calculated too be 48 Hours.
4.While calculating the rest period, two tables had to be prepared considering crew base at Delhi (layover in Mumbai) and crew base in Mumbai (layover at Delhi)	Rest times were calculated for both the scenarios for all assigned flights in units for simplification (5 minutes = 1 unit)
5. By comparing the two tables, a new table was formed (table 4) with minimum layover time for each combination of flight.	It can be seen that some combinations have less rest time when based in Delhi.
6. Rescheduling of crew was done using Hungarian Assignment Method to optimize the rest time.	Table 5 shows the optimal solution with different combinations of flight with minimum rest time.
7. Rescheduling of Flights were done and final table was shown in Table 6	

Table 2: Rest Period For crew when they stay in Delhi(Mumbai-Delhi)

	6E 155	6E 3175	6E 957	6E 189	6E 181	6E 191	6E 129	6E 843	6E 197	6E 185
6E 154	219	106	87	129	147	152	159	172	183	195
6E 3612	171	58	39	89	109	114	121	134	143	153
6E 964	148	35	16	58	76	81	88	101	110	124
6E 205	141	28	9	51	69	74	81	94	103	117
6E 5126	129	16	285	39	57	62	69	82	93	105
6E 6617	114	1	255	24	42	47	54	67	78	90
6E 168	90	265	246	0	18	23	30	43	54	66
6E 176	82	257	238	280	10	15	22	35	46	58
6E 5448	70	245	226	268	286	3	10	23	34	46
6E 5097	59	234	215	257	275	280	287	12	23	37

Table 3: Rest Period For crew when they stay in Mumbai(Delhi-Mumbai)										
	6E 155	6E 3175	6E 957	6E 189	6E 181	6E 191	6E 129	6E 843	6E 197	6E 185
6E 154	17	130	149	107	89	83	77	65	53	40
6E 3612	67	160	199	155	139	133	127	115	103	90
6E 964	88	181	220	176	160	154	148	136	124	111
6E 205	95	188	227	183	167	161	155	143	131	118
6E 5126	107	200	239	195	179	173	167	155	143	130
6E 6617	124	217	256	212	196	190	184	172	160	147
6E 168	145	238	279	233	217	211	205	193	181	168
6E 176	155	248	287	243	227	221	215	203	191	178
6E 5448	167	260	11	255	239	233	227	215	203	190
6E 5097	177	2	21	265	249	243	237	225	213	200

Table 4: Minimum Layover time										
	6E 155	6E 3175	6E 957	6E 189	6E 181	6E 191	6E 129	6E 843	6E 197	6E 185
6E 154	17	106	87	107	89	83	77	65	53	40
6E 3612	67	58	39	89	109	114	121	115	103	90
6E 964	88	35	16	58	76	81	88	101	110	111
6E 205	95	28	9	51	69	74	81	94	103	117
6E 5126	107	16	239	39	57	62	69	82	93	105
6E 6617	114	1	255	24	42	47	54	67	78	90
6E 168	90	238	246	0	18	23	30	43	54	66
6E 176	82	248	238	243	10	15	22	35	46	58
6E 5448	70	245	11	255	239	3	10	23	34	46
6E 5097	59	2	21	257	249	243	237	12	23	37

Table 5: Optimal assignment										
	6E 155	6E 3175	6E 957	6E 189	6E 181	6E 191	6E 129	6E 843	6E 197	6E 185
6E 154	17	106	87	107	89	83	77	65	53	40
6E 3612	67	58	39	89	109	114	121	115	103	90
6E 964	88	35	16	58	76	81	88	101	110	111
6E 205	95	28	9	51	69	74	81	94	103	117
6E 5126	107	16	239	39	57	62	69	82	93	105
6E 6617	114	1	255	24	42	47	54	67	78	90
6E 168	90	238	246	0	18	23	30	43	54	66
6E 176	82	248	238	243	10	15	22	35	46	58
6E 5448	70	245	11	255	239	3	10	23	34	46
6E 5097	59	2	21	257	249	243	237	12	23	37

2.4. Findings and Suggestions

The following observations can be interpreted:

- Rest Period for the crew was reduced from 48 Hours to 27 Hours. (Refer table 1 and Table 6)
- It was found that seven schedules 6E 154 and 6E 3612 were proposed to start from Delhi than at Mumbai.
- Rescheduling was resulting in saving of 21 Hours of rest period. Assuming indirect cost of rest period Rs.1000 per hour, there will be saving of Rs.21,000/- per for day. Since, the flights will run regularly on all the days, considering 30 trips in a month results in saving of Rs 6.3 Lakhs.

Table 6: Reschedule of Direct flights Between Mumbai And Delhi

Flight No.	Origin	Destination	Departure	Return	Flight No.	Origin	Destination	Departure	Return	Rest period In hours
Delhi To Mumbai and Back										
6E 155	Delhi	Mumbai	22:30	0:35	6E 154	Mumbai	Delhi	2:00	4:15	1:25
6E 185	Delhi	Mumbai	20:30	22:40	6E 3612	Mumbai	Delhi	6:10	8:15	7:30
Mumbai To Delhi and Back										
6E 964	Mumbai	Delhi	7:55	10:10	6E 197	Delhi	Mumbai	19:30	21:35	9:20
6E 205	Mumbai	Delhi	8:30	10:45	6E 957	Delhi	Mumbai	11:30	13:35	0:45
6E 5126	Mumbai	Delhi	9:30	11:45	6E 3175	Delhi	Mumbai	13:05	15:10	1:20
6E 6617	Mumbai	Delhi	10:55	13:00	6E 181	Delhi	Mumbai	16:30	2:35	3:30
6E 168	Mumbai	Delhi	12:40	15:00	6E 189	Delhi	Mumbai	15:00	17:05	0:00
6E 176	Mumbai	Delhi	13:30	15:40	6E 129	Delhi	Mumbai	17:30	19:35	1:50
6E 5448	Mumbai	Delhi	14:30	16:40	6E 191	Delhi	Mumbai	16:55	19:05	0:15
6E 5097	Mumbai	Delhi	15:20	17:35	6E 843	Delhi	Mumbai	18:35	20:35	1:00

3.1. Application of Critical Path Method in Aviation

Critical Path Method (CPM) has been used since a long time in aviation industry to minimize time of operations and increase flying hours of an airline. One method of increasing utilization is to reduce the maintenance downtime of the aircraft.
CPM is characterized by a network of activities, which constitutes a project. Each arrow in the network chart represents one single activity; each node represents a start or end of activity or activities.

The activities represent a certain relationship between and must always be executed in the said relationship example: C preceding activity A, F succeeding activities C and D et cetera.

Each activity has two nodes – a head node (the completion of an activity marked by the arrow) and a tail node (the beginning of an activity).

Each activity in the project has the following:

1. **Earliest Start (E.S)** – The earliest time that an activity can start, for the beginning of the project this value is zero.
2. **Earliest Finish (E.F)** – The latest time that an activity can finish. EF = ES + Duration.
3. **Latest Start (L.S)** – The latest time the activity can start with affecting the total completion time of the project.
4. **Latest Finish (L.F)** – The latest finish time of an activity without affecting the total completion time of the project. LF = LS + Duration.
5. **Total Float (T.F)** – The total time available between latest finish and earliest start. TF = LF-ES.
6. **Free Float (F.F)** – The maximum time an activity can be delayed without delaying the earliest start of the following activity.
7. **Tail Slack**: Difference between Latest Start and Earliest Start.
8. **Head Slack**: Difference between Latest Finish and Earliest Finish.

Dummy:
In a network no two activities can have same starting point and same ending point, in case if the relationship of two activities is defined in such a manner, a dummy is used. The duration of dummy is zero.
A dummy is incorporated under the below conditions:
1. When the relationship between the activities has been violated.
2. When two activities have the same starting point.

3.2. Benefits of Critical Path Method:

1. **Reduction in Elapsed Time:** All the critical and non-critical jobs will be performed in a shortest elapsed time. Equipment earns a return for its owners only when the equipment is operating productively. Non-productive hours are non-revenue hours. Also, it is important to make full use of output capacity if there is a high cost of output. As long as the revenue of each flight is greater than the out-of-pocket costs for that flight, profits of the airlines will rise considerably.
2. **Reduction in Man-hours:** The duration of certain jobs will be shortened and the man-hour requirements for these jobs will be affected. Efficient mechanic would realize the job he is working on is critical and will be performed more quickly.
   In case of a delay, when critical and non-critical jobs cannot be distinguished .it may result in inefficient use of manpower. With the help of CPM, the non-critical jobs will be indicated and misuse of manpower won't take place. CPM lays out a scheduling of jobs, which helps in forecasting job loads.
3. **Reduction in Costs:** Reduction in elapsed time indicates additional flying hours, which can be used for flight to earn revenue. Due to Critical path analysis, more cost will be incurred on executing critical jobs. though revenue from additional flights are far greater than the cost incurred.
4. **The Less Tangible Benefits:** CPM enables better planning, scheduling, control and allocation of manpower.it increases management's ability to co-ordinate the activities in a order and makes them evaluate what was done and what should be done during analysis.

3.3. Lufthansa Airlines:

Deutsche Lufthansa is the largest German Airlines and when combined with its Subsidiaries is the largest airline in Europe. Lufthansa is one of the five founding members of Star Alliance, the world's largest airline alliance founded in 1997.

Lufthansa was founded on 6th January, 1953 and is headquartered in Cologne, Germany.
The Scheduling Procedure of Lufthansa is used for the illustration of the Critical Path Method. For the better understanding of the concept, other crucial *backend* processes are also incorporated along with the core Lufthansa procedure.

Here is the set of activities given for the process involved before a flight with all the necessary variables calculated (all the activities are measured in minutes):

Activity	**Description**	**Preceding**	**Duration**	**E.S**	**E.F**	**L.S**	**L.F**	**Tail Slack**	**Head Slack**
A	Deboarding	-	15	0	15	5	20	5	5
B*	Propeller off	-	5	0	5	0	5	0	0
C	Inspect Firewall	-	10	0	10	10	20	10	10
D	Cleaning	A	10	15	25	20	30	5	5
E*	Prepare new Engine	B	20	5	25	5	25	0	0
F	Clean Firewall	C	15	10	35	20	35	10	0
G	Catering	D	10	25	35	30	40	5	5
H*	Engine In	E	10	25	35	25	35	0	0
I	Fueling	G	15	35	50	40	55	5	5
J*	Boarding	H,F	25	35	60	35	60	0	0
K	Loading	I	10	50	65	55	65	5	0
L*	Pushback	J	5	60	65	60	65	0	0

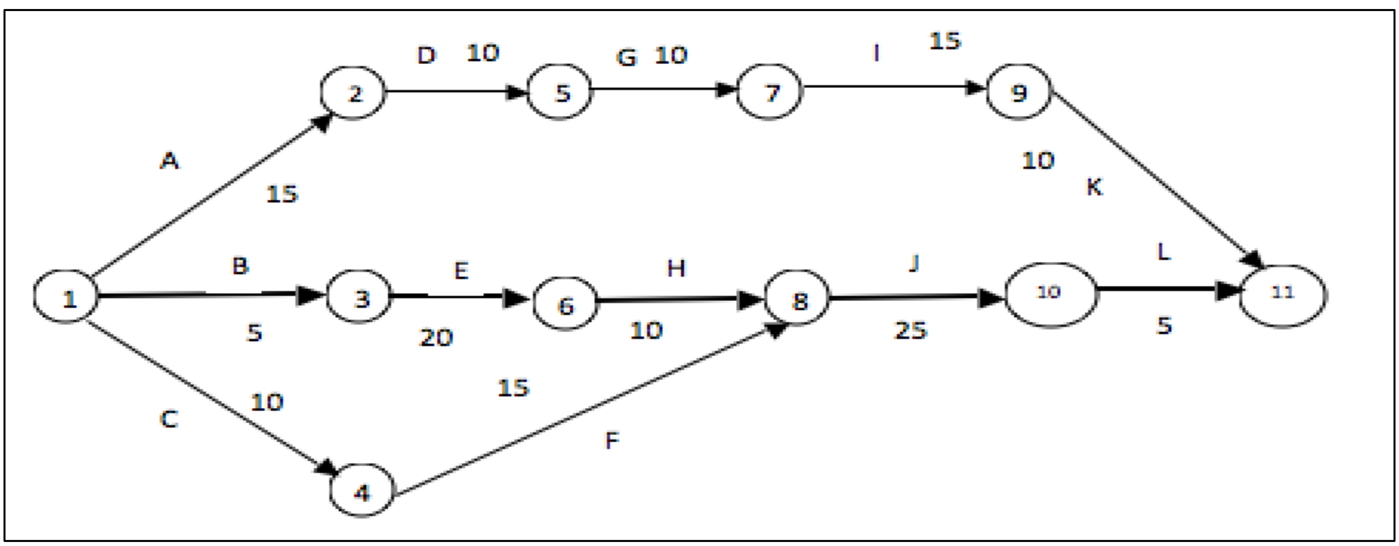
Calculation of Floats:

*Represents Critical Activities.

T.F	F.F	IND.F	I.N.F
5	0	0*	5
0	0	0	0
10	0	0*	10
5	0	0*	5
0	0	0	0
10	10	0	0
5	0	0*	5
0	0	0	0
5	0	0*	5
0	0	0	0
5	5	0	0
0	0	0	0

3.4. Critical Path Network Diagram

Represents Critical Activities



Paths	Duration	
A-D-G-I-K	60	
B-E-H-J-L	65*	*Critical*
C-F-J-L	55	

4. Conclusion

Operations Research techniques can be very helpful in route optimization and improvement of resource utilization. It provides easy and convenient solution for better decision-making, saving time, resources and cost for organizations. In this study, we applied Hungarian method of assignment algorithm to optimize rest time of the crew for a certain flight operator for flights between Mumbai and Delhi, by re-routing the flights. Thus OR techniques can be extremely helpful in scheduling flight times and routes in order to improve cost of operations. After analyzing the Aircraft maintenance activities of Deutsche Lufthansa through Critical Path Analysis it can be concluded that CPM is a valuable tool to reduce time elapsed and increase flying hours of the airline, which ultimately boosts the profits of the airline.

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6. Appendix

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