Feasibility Study and Mission Requirement for HSCT

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Abstract. The feasibility of HSCT development program is assessed on the future air transportation market by assuming the required advanced technology level and its development cost. Generally, the operating economics and value of saved travel time define the market share and required units of HSCT competing with subsonic airplanes, and determine the feasibility. The major motivation for the huge investment to develop HSCT is, however, not to take away the future subsonic airplane business but to create new long-range air transportation market by stimulation effect of the shorten travel time of HSCT. Under this consideration, higher cruising speed and longer range-capability for HSCT are emphasized.

1. Air Traffic Forecast

World air traffic has grown at the average yearly rate of 6.1% for the past 20 years, which has been mainly supported by the world economic development and the decrease of the air transportation cost. due to the advanced aircraft technology. For the next 20 years , while the world economy will continue the steady growth, the speed of the cost reduction will not be so fast as it was.The new technology for such as Ultra-High-Bypass engine, Ultra-High-Capacity aircraft etc seems not to be so promising in near future. The cost will be reduced not by the technology advancement but by the rationalization of manufacturers and operators promoted by the aviation liberalization. As a result, air traffic will grow at 5.4% p.a. till 2015, slightly slower than the past, and reach 3.5 times of the current volume. However, the long range international market, 1500 nm or longer and fitted for SCT operation, will grow much faster than other, reach 4 times and become 50% of total air traffic.(fig.1)

2. Stimulation effect

The above forecast is based on the past air traffic trend where only subsonic airplanes were operated. If SCT operation is assumed to spread over the future network and to halve the travel time,the traffic forecast should be significantly different from the above one. Between cities closely located each other, people can commute every day and there is a heavy traffic but between distant cities, traffic is less. Generally speaking, for city-pairs with the same population and the same economic activity, the traffic is inversely proportionate to the travel time between those cities. Therefore,when the high speed transportation becomes available and the travel time is reduced for a city-pair,the traffic increases.This is called as stimulation effect. Japanese railway network had been well developed and its maximum speed used to be 80 km/hr.The stimulation effect. at the introduction of the high speed railway with the maximum speed of 200km/hr is shown on Fig.2. The observed stimulation effect is not exactly inversely proportionate to the travel time but roughly Exp(-0.7). The high speed transportation not only eases travellers' fatigue but also create a lot of traffic by increasing business chance between cities and by making distant sightseeing places familiar

3. Time value

The other impact of the high speed transportation is the increase of time value. The traffic volume is also considered to be inversely proportionate to the travel cost. Just after the introduction of the high speed railway system,only peoples who's time value is high, such as businessmen, traveled by the system at 70 to 80% of surcharge and price-conscious pleasure purpose people used the old system. Nowadays,however, no one uses the old system except for city-pairs of 2 hours or less to travel. People realized how the high speed transportation was convenient and increased their time value. This story may not be directly applicable to the long range air travel because the basic railway fare is up to a few hundred dollars compared with the air fare from a few hundred dollars for the inclusive tour to a few thousand dollars for the business or first class service. Nevertheless,it will be true that future SCT travellers are willing to pay significantly higher surcharge than that based on our current time value.(Fig.-3)

4. Next Generation SCT

Anglo-Franco Concorde has established the technology for safe and reliable supersonic transportation through the past 20 years operation. The technical requirement for the next generation SCT is to give the Concorde environmental compatibility and commercial viability.
Although engine technology will play the important role to reduce NOx emission and airport noise, airframe technology to minimize aircraft total weight by light structure and efficient aerodynamic configuration will play the greatest role not only for commercial viability but also for environmental compatibility.
Assuming low-bypass engine with ejector-mixer silencer and low NOx combustor and very light major structure made of polymeric composites material, SCT's with 300 seats and 5500 nm range capability were conceptually designed at cruise Mach number of 2.0, 2.2 and 2.4 as shown on Fig.-4. Because of higher fuel consumption due to higher speed, those are considerably heavier than subsonic counterparts with the same payload-range capability.

5. SCT Network and Operation

In order to assess SCT productivity, their operation was simulated on the network specified for the year of 2015. Because of early stage of SCT introduction, the network includes only 239 major city-pairs with 1500nm or longer range and 1600 billion RPK or 21% of total RPK forecast for 2015. On this network, the productivity of designed SCT's is about 60% higher than subsonic ones (See Fig.-5).
Although average trip distance along Great Circle, weighted by passenger demand, is 3670nm, SCT with 5500 nm range-capability has to fly 4060 nm because of detour for refueling or for avoiding sonic boom impact on the habitation area. 23% of total trip require 1.5 hr-stop for refueling. Therefore the improvement in productivity for SCT against subsonic airplanes is not proportionate to the increase of cruise speed.

6. SCT Price and Operating Economics

Considering higher speed, heavier weight, severer operating environment and more complicated process to build SCT of polymer composite material, the development cost and manufacturing cost are assumed to be significantly higher, ranged from 2.5 - 4.5 times, than subsonic ones.
Those costs and manufacturers profit determine SCT price, which depends on required unit and results in 2 to 3 times per seat of subsonic one. SCT fare is composed of DOC, IOC and operators margin, divided by number of seat and load factor. It is ranged from 40 to 80% higher than subsonic one (See Fig.-6).

7. SCT Viability

SCT viability is examined by closing the loop of cost (manufacturing cost and operating cost), price (airplane price and fare) and market (SCT passenger share and required units).
All cases analyzed and shown on Fig.-6 give reasonable market share, required units, airplane price and fare. This means that all cases could close the loop.
However, the case of Mach 2.4 SCT without stimulation indicates 77% higher fare, only 35% passenger share and 364 required units, and suggests relatively marginal viability compared with other cases.
Fig.-6 also shows that the stimulation effect significantly improves SCT viability, especially for Mach 2.4 SCT.

8. Conclusion

As shown on Fig.-7, even if stimulation and high time value caused by SCT are neglected, it could penetrate into subsonic airplane market by getting 35 to 50% of total passengers on the network and showed its viability.
Question is if it is worth to develop those SCT by investing huge money and taking large risk for the sake of pulling out a part of subsonic airplane business. Answer may be "no". SCT development is justified only by additional passengers created by stimulation effect and high time value due to shorten travel time.
These two factors create passengers equivalent to 35 to 40% of long-range market in addition to the penetration into the traditional subsonic market. In this study, the higher speed SCT penetrates into subsonic market to less extend but create the more passengers. And, as far as SCT's analyzed in this study concern, it is hard to judge which is the best.

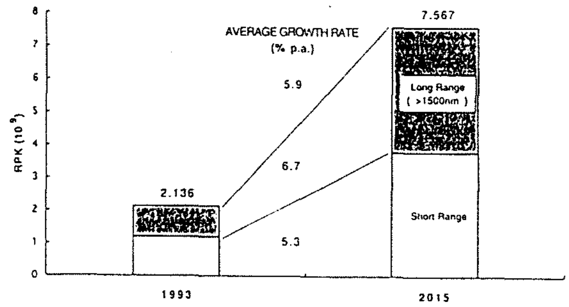

Fig.-1 AIR TRAFFIC FORECAST

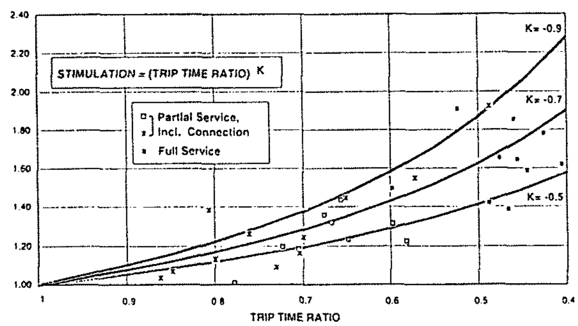

Fig.-2, STIMULATION EFFECT
(High Speed Railway in Japan)

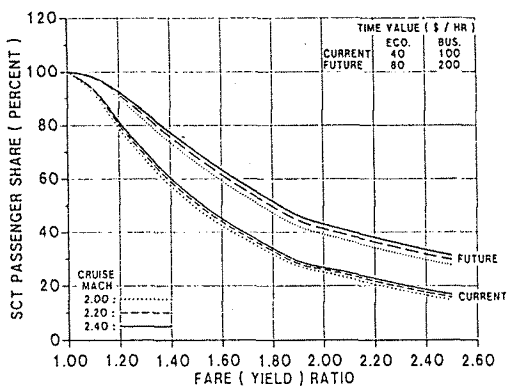

FIG. -3, FARE ELASTICITY

Airplane		SCT-1	SCT-2	SCT-3
Cruise Speed	(Mach)	2.0	2.2	2.4
Max T/O Weight	(LBS.)	786,900	879,800	956,000
Payload	(LBS.)	63,800	63,800	63,800
O. E. W.	(LBS.)	251,500	280,800	317,000
Airframe	(LBS.)	136,900	153,600	176,800
Engine x 4	(LBS.)	67,900	77,300	85,700
Others	(LBS.)	46,700	49,900	54,500
Fuel (*1)	(LBS.)	471,600	535,200	575,200

Note (*1), Include Reserve Fuel

Fig. -4. 1, Max Take-off Weight Breakdown

(300 Seats, 5,500 NM)

Network ; Major 239 City-Pairs, ≥1500 NM, 1600 Billion RPK at 2015 (2750 Billion RPK in IWG Study)

Airplane		Subsonic	SCT (Subsonic Overland)		
Design Range (NM)		7,500	5,500		
Cruise Speed (Mach)		0.9	2.0	2.2	2.4
Ave. Trip	Dist. (NM)	3,670	4,060		
	Time (HR)	7.62	4.75	4.49	4.28
Ave. Flight	Dist. (NM)	3,660	3,290		
	Time (HR)	7.59	3.56	3.35	3.18
Flight / Trip		1.003	1.234		
Yearly Trip / Airplane		727	1,123	1,146	1,181
Relative Productivity		1.00	1.55	1.58	1.63

Fig. -5, SCT Network & Operation

Airplane	NLA (Ref.)	SCT					
Seat	600	300					
Design Range (NM)	7,500	5,500					
Cruise Speed (Mach)	0.9	2.0		2.2		2.4	
Development Cost ($B.)	8.3	16.2		18.1		19.9	
Production Cost (*1) ($M.)	135	166		181		197	
Stimulation	No	No	Yes	No	Yes	No	Yes
Equiv. Pax. Share (*2 (%)	100	51	87	43	80	35	74
Required Units (*2)	820	550	943	452	847	364	761
Airplane Price (*3) ($M.)	186	248	205	293	231	354	263
Fare Ratio (*4)	-	1.48	1.39	1.62	1.50	1.77	1.60

Note (*1), Cumulative Average of 400 units.
(*2), See Fig.-7
(*3), Include 15% ROI for Manufacturers.
(*4), Include Op. Cost & 15% ROI for Operators.

Fig. -6, SCT Operating Economics

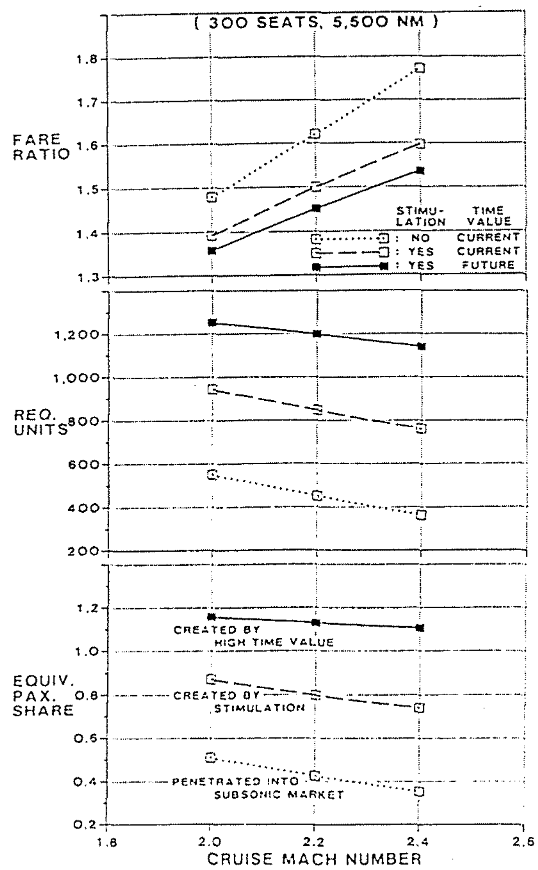

Fig. -7, SCT Viability Study