

A RE-ASSESSMENT OF THE GERMAN ARMAMENTS PRODUCTION DURING WORLD WAR II

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Abstract

The German armaments production during World War II (1939-1945) is a highly debatable issue. Many studies point out that it was a success story since the overall production increased in spite of the heavy Allied air bombing campaign during the period 1943-1945. Others point out that the size of the production could not balance the aggregate production of Britain, USA, and the USSR. This study points out that by the end of 1941 with the entry of the USSR and the US in the war Germany had to plan for two different types of war. One was a land war against the USSR and the second was a naval-air war against the Anglo-Saxon Powers (Britain and the USA). German industry did quite well with the first challenge (with the assistance of captured material and industrial power of occupied Europe) but failed in the naval-air war against the Anglo-Saxon Powers.

1. Introduction

The German armaments production during World War II (1939-1945) is a highly debatable issue. The debate is focused on the following issues:

The first is the volume of the production. Many economists and historians observe a high volume of production even under the constraint of allied bombing. Others hold the view that the production levels, for the most industrialized European power, were quite low and could not match the combined armaments production of Great Britain and USSR, let alone the considerable production of the United States.

The second issue is the wide range of the types of material produced. The argument points out that the outcome of the production process was not standardized equipment but multiple types of weapons, all produced in small quantities. This meant an absence of economies of scale and of scope.

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The structure of the article is as follows: The first section is a critical overview of the existing literature, noting strengths and limitations of previous studies. This helps provide an overview of the size of production and the multiple types of weaponry. The second section develops an original perspective by applying the best available data about the costs of armaments procurement. Here we follow a cost-benefit analysis rationale in order to determine the efficiency (or inefficiency) of the production process. The next section provides an analysis of the German military doctrines and the available armaments equipment. The nexus between the two is crucial in order to determine the success or failure of the German armaments industry. The conclusions of the study follow.

2. German armaments policy: Size of production and types of weaponry

This section provides an overall presentation and assessment of the studies on the size of the German armaments industry during the war. We begin with studies in English by English speaking academics or studies by Germans translated into English, before looking at German sources.

2a. Studies in English or English translations

The first wave of studies is associated with Milward (1965, 1977).² Milward (1965) notes that the war industry was closely related to the Blitzkrieg type of warfare of the German army. Germany did not have the manpower resources or the raw materials for a prolonged war. The defence industry (and its production) was therefore organised in such a way as to supply the armed forces for quick wars. Thus during the period September 1939-July 1940 the priority was given to the army. But, with the fall of France, priority shifted from land systems to aircraft for the Luftwaffe.³ However, between September and December 1940, priority shifted from aircraft to submarines in order to beat Britain. The German invasion of the USSR in June 1941 saw priorities change to ammunition, guns, tanks and aircrafts; and thus submarine production was reduced.

Throughout the war years Germany enjoyed a complete machine tools advantage in its industry when compared with those of other European states and the US. To illustrate, in 1938 Germany had 3 795 000 machine tools of various types; whereas France had 550 000 and Italy had 207 000 (for 1939). The figures for 1945 were 5 152 000 to 6 647 000 machine tools for Germany, 800 000 for Britain, 600 000 for France, 290 000 for Italy, and 1 883 000 for the USA.⁴ This machine tool superiority was not exploited, according to Milward (1965, 1977), as German industry did not work for three eight hour shifts, but also as it came under

bombardment by the allied air forces. Despite these limitations, Milward notes the industry could supply 250 infantry divisions and 40 armour divisions in 1944. In comparison to the Allies however, overall German production was lower. Germany produced 111 767 aircraft during the 1934-1944 period, whereas Britain produced 123 819 during the 1934-1945 period, and American production was nearly 300 000 in 1940-1945. Also US tank production was double that of Germany's.⁵

	1940	1941	1942	1943	1944
Rifles	1 351 700	1 358 500	1 370 180	2 244 100	2 585 600
Ammunition (in tons)	865 000	540 000	1 270 000	2 558 000	3 350 000
Medium tanks	1 359	2 875	5 595	9 398	12 096
Submarines	40	196	244	270	387
Single engine fighters	1 870	2 852	4 542	9 626	25 860

Table 1: Defence Industry Production 1940-1944⁶

Mierzejewski (1988) is an essential source and the data on defence production for the 1940-1944 period, appear in Table 1. Mierzejewski explains the increases in production volumes as associated with higher productivity. The labor productivity index increased as follows: 1941-1942=100, 1942-1943=157, 1943-1944=189. Specifically, for June-July 1944 the index was 234. A second reason is is that the raw materials were used more efficiently. Thus between 1941-1944 the ratio per weight between raw materials to final product was reduced from 4:1 to 2:1. A third reason is associated with administrative reforms. Until 1939 the army, the navy and the air-force had different procurement branches, all under the auspices of the Wirtschaft Rüstung Bureau (Armaments and Economics Department). In March 1940 the post of Minister of Armaments and Ammunition was established. Initially given to Fritz Todt, it was given to Albert Speer in February 1942. Speer introduced major administrative changes.⁷

Ranki (1993) is the first study providing detailed numbers of defence article production according to type. To illustrate, the author, points out, that between the years 1939-1945, the following types were procured: 31 898 Me-109 fighters; 16 911 Ju-88 planes; 7 647 FW-190 fighters; 6 247 Me-110 night fighters; 5 678 He-111 bombers; 4 890 Ju-87 Stuka dive bombers; 2 804 Ju-52 transport planes. The study provides aggregate numbers for tank production, self-propelled (S/P) gun production, and armour vehicle production during 1940-1944. According to these figures the number of tanks produced was 23 181 units, the number of armoured vehicles was 14 162 and the number of S/P guns was 5 335 units. The study differentiates between different types of tanks such as light Mark-I and Mark-II types

(1 168 and 632 respectively) versus the medium Mark-III and heavy Mark-IV types (5 672 and 8 168) and the super-heavy Tiger I (1 398 pieces) and Tiger II (379) types and the Panther S/P guns (5 814 pieces). According to Ranki (1993) the increased armaments production is associated with massive investments in machinery until 1942. Between the years 1939-1941, the annual machine tools production was 195 000-200 000 tools. In 1942 it was 162 000 tools, in 1943 it was 140 000 and in 1944 it was 110 000.⁸

Overy (1994, 1995, 1996, 2005)⁹ is an essential contribution. Overy notes that though Hitler had a long term plan for war he did not anticipate a prolonged war in 1939, and that nevertheless between September 1939 and December 1941 investments in the defence industry in fact increased. Total investments during the September-December 1939 period were 1 318 million RM (Reichsmarks), increasing in 1940 to 5 841.6 million, and 7 599.6 million in 1941.¹⁰ These massive investments explain the increase in armaments production during subsequent years. Overy provides a different picture from Mierzejewski (1988) on productivity. According to Overy (1994) the productivity index was as follows: 1939=100, 1940=87,6; for 1941=75,9; for 1942=99,6; for 1943=131,6 and for 1944=160.¹¹ Overy notes that the lower productivity of the 1940-1942 period slowed armaments production and thus Hitler's demands could not be reached before 1944. The productivity increase during the 1943-1944 period could not compensate for the complexity of defence procurement. For example, a Ju-88 bomber needed 4 000 different types of screws and ball bearings. To simplify complexity, in 1942 the designers proposed 18 000 amendments to the plane production. Similarly, the designs (types) of trucks decreased from 151 in 1939 to 23 in 1942; and of motorcycles from 150 to 26 in the same period.¹²

Harvey (1994) highlights structural rigidities and inefficiencies. For instance, in 1940, Germany was spending 58 percent more money on defence procurement compared to Britain; yet the actual size of the production was smaller. Labour force productivity was low. To illustrate, in 1942 only the 1/10 of the labour force in tank, artillery, armour vehicles and small arms industries was working double shifts. In the aircraft industry only 33 percent worked double shifts. He points out that the civil-military relations of the 1939-1945 era were similar to those of the 1914-1918 era. Thus in the First World War the German industrialists enjoyed a "blank cheque" by the state. In the Second World War, initially they had to face a state and Nazi Party intervention (Nazi Party, Gestapo, SS) but thereafter the Armaments Minister Speer established a very good working relationship with the German industry.¹³

There is some confusion when it comes to the numbers. Overy (1995) provides the following aggregate estimates of production for the period 1939-1945: Aeroplanes: 117,881 units; Tanks: 63 800 units (including S/P guns); Artillery: 625 000 guns; and 954 submarines.¹⁴ Ellis (1995) notes that between 1939-1945 Germany produced: 46 857 tanks and S/P guns; 159 144 artillery units; 674 280 machine-guns; 73 484 mortars; 345 914 trucks; and 189 307 aeroplanes. From those, 55 727 (29.4 percent) were fighters, 18 235 (9.6 percent) were bombers, 12 539 (6.6 percent) were ground support, 6 299 (3.3 percent) were reconnaissance, 3 079 (1.6 percent) were transports, and 11 546 (6.09 percent) were trainers. Turning to naval armaments. Ellis points out that Germany procured 17 destroyers and an astonishing number of 1 141 submarines during the war.¹⁵ According to a different source, German production totalled 10 328 000 rifles; 1 257 000 pistols; 1 176 000 machine-guns; 320 000 artillery pieces; 78 800 mortars; 46 300 tanks and S/P guns; 89 500 fighter planes; and 954 submarines.¹⁶ To add to the confusion of numbers, the study of Murray and Millett (2000) provides the following figures for the 1940-1945 period: 97 810 aeroplanes; 50 800 tanks and S/P guns; 85 000 artillery pieces; 20 naval ships; and 981 submarines.¹⁷

The first study on the subject was by Hitler's armaments minister Albert Speer (2002). Speer pointed out that the tank production was multiplied by a factor of five between 1940-1944 and the gross weight increased by 7.7 times. The index of artillery, was increased by 3.3 times, between the years 1941-1944. The aggregate ammunition index (combined production for army, navy, air-force) in 1941 was 102 and by 1944 it was 306. In spite of the increase, ammunition production was lower compared to that of 1914-1918. The average monthly production in 1941 of selected defence articles was as follows: 133 000 rifles, 7 100 machine guns, and 79 000 mines. In November 1944 the numbers were as follows: 307 000 rifles, 28 700 machine guns, and 3 820 000 mines.¹⁸

The study of Tooze (2006) provides a departure from the previous literature. Tooze (2006) points out that when the war erupted the Naval Z plan was abolished and the only naval priority was that of submarine production. The priority was given to the procurement of ammunition and Ju-88 bombers. Thus, between September 1939 and June 1940, 70 percent of raw materials was absorbed by the ammunition and the aircraft industry. During the period June 1940-June 1941, in preparation for the invasion of USSR, priority went to the production of tanks, artillery guns, small arms and machine guns. However although in July 1940 ammunition production was 36 percent of total armaments production, in the summer of 1941 it was just 20 percent. The reduction of ammunition production was associated with the high stock piles of shells which the German army had available from 1940 and the shift allowed the procurement of 12 000 aeroplanes in 1941 as opposed 10 826 in 1940. The study

points out that the investments in the aircraft industry increased between December 1940 to March 1941 by 762.8 million RM and the aggregate investments in the aircraft industry, between September 1939 and January 1942 reached 5.18 billion RM. Turning to the tank industry, millions of RM were also invested. To illustrate, the Henschel & Sohn industry in Kassel alone increased its capacity by 100 000 square meters, and other major facilities were constructed in Sankt Valentin in Austria, and in Plauen (Maschinenfabrik Niedersachsen).¹⁹ Thus the increases of 1942-1944 were associated with previous massive investments and with the more efficient use of resources.

Other studies focus only on Luftwaffe strength. Three examples illustrate. Bekker (2001) points out that the total German aircraft production was 113 514 airplanes (53 728 fighters, 18 235 bombers, 12 359 ground support, 6 299 reconnaissance, 1 190 naval aviation, 3 079 transports, 3 145 gliders, 2 549 telecommunications, 10 942 trainers, and 1 988 jet engine fighters).²⁰ Pavelec (2010) provides the following figures for aircraft production: 1939: 8 300 (annual production); 1940: 10 800; 1941: 11 800; 1942: 15 600; 1943: 25 500; 1944: 39 800; 1945: 7 500. Thus an aggregate production of 119 300 aeroplanes (18 449 bombers, 53 339 fighters, 12 459 ground support, 3 118 transports, 6 293 reconnaissance, 1 186 maritime patrol).²¹ A third source provides the aggregate estimate of 117 881 aeroplanes.²²

2b. Studies in German

Wagenführ (1954) was the first study to evaluate the German armaments production.²³ This study does not provide data about the quantities of production but provides monthly indexes for the 1942-1945 period as well as annual indexes for the 1941-1944 period. Wagenführ (1954) uses the same indexes produced by Albert Speer. The statistical basis is the production of the January-February 1942(=100). The annual indexes are presented in Table 2 below and demonstrate a constant increase of aggregate production from 97-98 index number in 1941, to 133-142 in 1942, 216-222 in 1943, and 277 in 1944. The selection of January-February 1942 as the basis was criticized: using that month's low aggregate production deliberately as the basis demonstrates high increases. The second wave of studies is that of Boelcke (1969, 1983).²⁴ In Boelcke (1969) essential data are presented for the war economy of the 1942-1945 and for the war industry of the 1940-1945.²⁵ The third study is that of Eichholtz (2003).²⁶ These studies associate the German industrial production with the exploitation of the occupied territories and they point out that the German administrative system was rather inefficient due to complex and conflicting administrative hierarchies.

Year	AP (#)	Guns	Tanks	Vehicles	Aeroplanes	Ships & submarines	Ammunition	Powder	Explosives
1941	98 (97)	06	1	-	7	110	02	6	03
1942	142 (133)	37	130	20	33	142	66	29	32
1943	222 (216)	34	30	38	216	182	47	00	91
1944	277 (277)	48	36	10	77	157	06	12	26

Table 2: Annual Indexes of Industrial Production²⁷ AP=Aggregate Production, numbers in brackets refer to Speer indexes and not to those of Wagenführ.

2c. The study of the German Institute for Military History

The question about the exact size of the German armaments production was fully addressed by the data provided by the German Institute for Military History in the monumental publication on the History of the Second World War.²⁸ The German Institute for Military History provided accurate data across all types of weaponry procured throughout the war.

During the period August-December 1939 the industry produced 53 983 pistols, 414 586 rifles, 7 910 submachine guns, 16 893 machine guns, 1 533 anti-tank guns, 2 300 anti-aircraft guns, 4 973 medium and heavy guns.

For 1940 the production was as follows: 204 852 pistols, 1 293 719 rifles, 125 879 submachine guns, 56 274 machine guns, 3 868 anti-tank guns, 7 720 anti-aircraft guns, 14 530 medium and heavy guns.

For 1941: 457 876 pistols, 1 271 263 rifles, 236 041 submachine guns, 79 212 machine guns, 4 269 anti-tank guns, 10 646 anti-aircraft guns, and 14 688 medium and heavy guns.²⁹

For 1942: 467 343 pistols, 1 149 593 rifles, 152 683 submachine guns, 81 199 machine guns, 9 142 anti-tank guns, 16 555 anti-aircraft guns, 2 618 medium and heavy guns, and 3 864 rocket artillery.

For 1943: 959 540 pistols, 1 946 200 rifles, 240 073 submachine guns, 165 509 machine guns, 16 105 anti-tank guns, 25 740 anti-aircraft guns, 4 575 medium and heavy guns, and 1 706 rocket artillery systems.

For 1944: 1 038 340 pistols, 2 282 380 rifles, 500 074 submachine guns, 278 164 machine guns, 14 209 anti-tank guns, 23 689 anti-aircraft guns, another 10 110 medium and heavy guns, and 3 767 rocket artillery.

For the first two months of 1945: 145 140 pistols, 310 118 rifles, 131 672 submachine guns, 56 089 machine guns, 985 anti-tank guns, 1 771 anti-aircraft guns, 1 351 medium and heavy guns, and 460 rocket artillery systems.³⁰

Thus the aggregate production levels for the whole 1939-1945 period were: 3 327 074 pistols, 8 667 859 rifles, 1 943 332 sub-machine guns, 733 340 machine guns, 50 111 anti-tank guns, 78 786 anti-aircraft guns, 52 845 medium and heavy guns, and 9 797 rocket artillery systems. To these numbers we have to add more than 326 683 bazookas, more than 16 325 light artillery guns, 342 super heavy guns, and more than 78 429 mortars.³¹ Tank and armour vehicle production during August-December 1939 was 790 tanks and vehicles. In 1940 total production was 2 808 tanks and armour vehicles, in 1941 it was 6 008.³² In 1942 the production increased to 9 278 in 1943 to 19 824 and in 1944 to 27 340. Thus an aggregate production of 66 048 tanks and armour vehicles took place during the war.³³

2d. Re-assessment of existing literature

The above sources can confuse. Anyone can ask: “What was produced by Germany during the war years?” All the above sources provide different production data on all types of defence articles (aeroplanes, guns, tanks, etc). Different estimates occur because the literature was built over years with different information from national or industrial archives. In addition, exact specification of any war production is difficult due to: a) propaganda can falsify data in order to boost morale of the civilian population, b) production figures may include repairs of aeroplanes, aeroplane engines, guns, howitzers etc. Thus the figures are overstated, and c) captured material from the enemy can also be included in the statistics or it may actually reduce the war production effort, which is exactly what happened with the German case. The figures of the German Military Institute are the best ones available.

3. The question of efficiency

In order to cast light on the efficiency of the German arms production we use the best available cost figures in order to demonstrate that the procurement priorities were wrong. We also highlight that the looting of occupied Europe was an economic error, as the looting was associated with raw materials and civil goods and not with the maximization of the war effort.

3a. The available economic data and the mistaken procurement strategies

In order to answer the question we need to use the best available data related to the production cost of various defence articles. The available data on cost do not cover all types of weapon systems. The data may also not reflect the final price due to inflation pressures, research and development costs, modification costs, etc. However, we use the best possible and available data. Table 3 has the cost of machine guns and small arms and Table 4 more advanced weapon systems. Turning to the cost of the artillery production we have the data of Table 5. The cost of some airplanes is demonstrated in Table 6. The cost of naval ships is demonstrated in Tables 7 and 8.

Type	Price in RM/ unit
MG 34	312-327 (400 RM for tripod)
MG 42	250
K-98	56
MP-38	57
MP-40	60
MP-44	66

Table 3: Per Unit Cost of Small Arms and Machine Guns³⁴

Type	Per unit price cost in RM	Cost in man-hours	Cost in Raw Materials *	Observations
Tanks				
Panzer I	38 000	n/a	n/a	Model PzKpfw I Ausf B without arms
Panzer IIA	52 640	n/a	n/a	Model PzKpfw II
Panzer IIB	49 000	n/a	n/a	
Panzer IIF	52 728	n/a	n/a	
Panzer III	96 163 96 200 103 163	In 1943 reduced from 4 000 to 2 000	n/a	The third price refers to model PzKpfw III Ausf without radio communications
Panzer IV	103 500 115 962 116 000 117 000	n/a	39.000 kg of steel, 238 kg of aluminum, 195 kg of copper, 116 kg of rubber, 66 kg tin, 63,5 kg lead, 0,23kg magnesium	Raw materials for tank production of early models without gun and telecommunications equipment. The second item refers to model PzKpfw IV Ausf G with the KwK 40 L/43 gun.
Panther	117 000	150 000	n/a	No armament
Tiger-I	300 000	300 000	n/a	Fully armed. Without arms the cost was 250 000 RM
Tiger-II	321 500	n/a	n/a	
StuG III	82 500	n/a	n/a	Model StuG III Ausf G
Sturmgeschutz III	82 500	n/a	n/a	
Jadgpanther	21 000+			Price only of the value of the gun
Sdkfz 9 Halbtrack	60 000	n/a	n/a	

Table 4: Per Unit Cost of Tanks and S/P Guns Procurement^{35(*)} During 1942 the German side produced a special material called Zimmerit, which protected all types of vehicles from magnetic mines, which were used by the Soviets. From 1943 until 1945 one Tiger I tank needed 200 kg of the material, a Panther tank needed 160 kg, a Panzer IV 100 kg, and a StuG III needed 70 kg.

Type	Per unit price cost in RM	Observations
s10cm K 18	37 500	Medium gun
s10cm K 42	50 000	Medium gun
10,5cm leFH 18	16 400	Anti-tank gun
3,7cm Pak 35/36	5 730	Anti-tank gun
7,5cm Pak 97/38	8 000	Anti-tank gun
5 cm Pak 38	10 600	Anti-tank gun
Pak 40	12 000	Anti-tank gun
Pak 41	15 000	Anti-tank gun
15 cm K 18	108 000	Heavy gun
21 cm K 12 (E)	1 500 000	Heavy gun on rail
80 cm K (E)	7 000 000 (*)	Super heavy gun on rail
15cm Nebelwerfer 41	3 350	Rocket system
12,8cm Flakzwilling 40	202 000	Anti-aircraft gun

Table 5: Per Unit Cost of Artillery Guns³⁶ (*) Refers only to the gun and the wagon and not to the complete weapon-system.

	Basic Price	Price with engine
Me-109E	58 800	85 970
Ju-88 A	245 200	306 950
He-111 H	203 900	265 650
Ju-87 B	100 300	131 175
Ju-52	125 000	163 000

Table 6: Per Unit Cost of Aeroplanes (Rm/ Per Unit In 1941)³⁷ The cost of one engine for the Me 163 Komet fighter plane, was 400 000 RM.³⁸

From the data, the expensive types of armament such as the Tiger and Panther tanks were not only a military irrationality (since they were procured in small numbers) but an economic irrationality - since one Tiger tank had three times the cost of a Panzer IV. One of the last material assessments, March 15th 1945, gave the following operational levels: 62 per cent of the Panzer IV were operational, while 59 per cent of the Tiger-II tanks were operational.³⁹ Thus the production of 489 Tiger-II tanks cost 157 213 500 RM an amount which could hypothetically have produced 1 355 Panzer IV tanks - triple the number, with a higher operational level, in the spring of 1945. Turning to the artillery arm we again observe that the production of the super heavy guns of 800mm (80cm) K (E), was another inefficiency. With a cost of 7 million RM the German artillery could have been supplied with immense numbers of Nebelwerfer rocket systems which had higher mobility and firepower. The Nebelwerfer systems had a devastating effect on the battlefield and in some cases they could even be launched from their boxes without even taking them out. Thus for each super heavy gun 2 089 Nebelwerfer systems could have been produced alternatively.

Ship	Cost in RM
Bismarck	197 000 000
Tirpitz	181 000 000
Scharnhorst	143 000 000
Gneisenau	146 000 000
Graff Zeppelin	92 700 000
Rugzeugrater B	92 400 000
Deutschland	80 000 000
Admiral Sheer	90 000 000
Admiral Graff Spee	82 000 000
Admiral Hipper	85 000 000
Blucher	87 800 000
Printz Eugen	104 500 000
Seydlitz	84 100 000
Lutzow	83 600 000
Grand Total	1 549 100 000

Table 7: Construction costs-Major Surface Vessels⁴⁰

Turning to the Navy, we note that the construction of the 14 major ships (battleships and battle-cruisers) cost almost 1 550 million RM. This number of ships was not a major threat to the allied shipping and the 14 major German ships could not face 290 ships of the Royal Navy. Alternatively this amount could have produced 83 light cruisers, destroyers and torpedo boats. Turning to the Air-force, we can note that the Me-109 fighters were cheaper to procure compared to the bombers or the transport planes.

Type of ship	Cost in RM
Light Cruiser K class	38 000 000
Light Cruiser Leipzig Class	40 000 000
Destroyer 1934 Type	13 700 000
Destroyer 1934A Type	14 100 000
Destroyer 1936 Type	12 870 000
Destroyer 1936A Type	13 180 000
Torpedo boat 1935 Type	7 800 000
Torpedo boat 1937 Type	9 300 000
Average cost	18 618 750

Table 8: Construction cost of Smaller Surface Vessels⁴¹ The per unit cost of submarine construction is not known, however just the Deschimag shipyards in Bremen during the war produced submarines with total value 1 084 305 731 RM.⁴²

Germany during the 1942-1945 period was under allied bombing and the rational armaments priority was for the fighter production. Although fighters were the airplanes most produced, their overall numbers (53 000 fighters) were inadequate to escort the Luftwaffe bombers to various offensives and also to support the ground forces of the German army. In addition the fighters had to defend the skies of Germany and occupied Europe against the allied bomber offensive. The massive

investments in the anti-aircraft artillery were also inefficient. To illustrate, every light anti-aircraft artillery, needed in average to use 4 940 shells in order to shoot down one allied bomber. The cost of this activity to the German economy was 37 050 RM (\$14 820). The cost for a heavy anti-aircraft gun was 267 440 RM (\$106 976).⁴³ By comparison the Luftwaffe fighters needed only 4-5 bullets of 20mm or 1 bullet of 30mm in order to shoot down 1 B-17 US bomber, from the front side. The fighters needed alternatively 20 bullets of 20mm or 3 bullets of 30mm in order to shoot down one B-17 US bomber from the tail. In 1943 the German fighters needed 10 sorties in order to shoot down one B-17.⁴⁴

Another defence project to consider is the “Atlantic Wall”, a series of fortifications from Norway to France, which aimed to repel an allied invasion of occupied Europe. Until May 1944 there were more than 8 482 fortified positions with more than 2 719 guns organised in 700 batteries.⁴⁵ During the 1942-1944 period, the value of the cement alone amounted to an astonishing 3.7 billion RM.⁴⁶ These fortifications did not stop the Normandy invasion. Considering the opportunity cost of the cement, if used for the finance of fighter production, could hypothetically have delivered 43 000 fighters. Without air superiority the allies would not been likely to invade then. Similarly, the V-1 and V-2 missile systems which were used extensively during the 1944-1945 period against London in an attempt to break the morale of the civilian population, cost \$2 billion. This amount could have hypothetically produced 24 000 fighters.⁴⁷

The planning of the German armaments production was directly associated with Hitler’s knowledge, and, as Speer points out:

Hitler’s technical horizon ...was limited by the First World War. His technical interests were narrowly restricted to the traditional weapons of the army and the navy. In these areas he had continued to learn and steadily increase his knowledge...but he had little feeling for such new developments as for example, radar, the construction of an atom bomb, jet fighters and rockets...very often ...Hitler would lecture his military advisers on the technical know-how he had just acquired [from them]. He loved to present such pieces of information with a casual air, as if the knowledge were his own...Hitler’s decisions led to a multiplicity of parallel projects. They also lead to more and more complicated problems of supply. One of his worst failings was that he simply did not understand the necessity for supplying the armies with sufficient spare parts ... From 1944 ...his programs became totally unrealistic. Our efforts to push these through in the factories were self-defeating.⁴⁸

At this point one could argue that looking at the figures of German armaments production and cost prices requires comparison with the allied figures and prices. Comparing Germany to the USSR, Soviet production focused on a handful of armaments, produced more weapons, cheaper and faster. Thus between June 1941 to August 1945 (some months after German surrender of May 1945) the USSR produced: 12 139 000 rifles and carbines, 1 516 000 machine-guns, 482 000 artillery guns of all calibers, 102 800 tanks and Self Propelled guns and 112 100 airplanes. Moreover, production costs decreased during the war. Thus the cost of one airplane Il-4 in 1941 was 800 000 rubles, but in 1943-1945 it was 380 000. The cost of one airplane P-2 in 1941 was 420 000 but during 1943-1945 it was down to 265 000. The cost of one T-34 tank in 1941 was 270 000 rubles but in 1943-1944 it was just 135 000. One heavy tank KV had a cost of 635 000 in 1941 but in 1943 it was down to 225 000. The price of one 7.62mm rifle was 163 rubles in 1941 but down to 100 rubles in 1943-1945.⁴⁹

British production, according to one source for the period September 1939 to June 1944 period was: 2 457 000 rifles and carbines, 939 000 machine-guns, 390 000 guns of all calibers, 29 300 tanks and self-propelled guns, 1 156 main warships, and 94 600 airplanes. According to other sources the total cost of aircraft production during the war was £3 892.5 million. Throughout 1939-1943 British aircraft production surpassed German production both in terms of numbers and weight. In addition British bomber aircrew training was the most expensive in the world (£10 000 per individual). The construction cost of major battleships during the war was between £7.5 and £10 million, equal to the cost of the army radar programme in 1940.⁵⁰

American production, according to two sources was as follows: 6 552 290 rifles, 2 679 819 machine guns, 411 874 artillery guns of all types and calibers, 231 099 airplanes of all types, and 74 896 vessels of all types. The cost of one B-17 heavy bomber fully equipped was \$292 000 whereas for the B-24 it was almost \$237 000. The cost of one medium B-25 bomber was \$153 396 and for a B-26 it was \$239 655.⁵¹

This comparative perspective shows that German production could not match the allied production in terms of quantity. It is also observable, even from the limited economic data, that the allies achieved economies of scale and scope faster than the Germans. This seems to be true for the Soviets and the British but more data, which is not presently available, would be required in order to strengthen this argument.

3b. The irrational exploitation of occupied Europe and the failure of defence production maximization

The second essential error of the German armaments planning strategy is the failure to integrate the industries of occupied Europe to the defence production of the Reich. Occupied Europe provided immense amounts of supply of raw materials, minerals, semi-finished goods and labour force, as Table 9 indicates.

The data of Table 9 shows that the victories of the period 1939-1941 period provided Germany with immense economic potential. To this one has to add the colossal materials of the occupied USSR. Between June to December 1941 the German armies conquered a 978 000 square km territory of 62.4 million inhabitants, with 31 850 factories, 239 000 electrical machines, 175 000 machine tools, and 65 000 km of railways.⁵² In spite of these tremendous reserves and raw materials the actual contribution of occupied Europe to the German armaments production was small. In 1943 the industries of occupied Europe supplied to the German armed forces the 4,8 percent of light arms, 6,4 percent of ammunition, 16,2 percent of vehicles, 35,7 percent of ship construction, 8,9 percent of aeroplanes production, 28,6 percent of telecommunications equipment, and the 8,1 percent of optical equipment.⁵³

Turning to the aerospace industry we point out that the French industry during the period summer 1940-1944 produced only 4 142 aeroplanes. From those the 3 606 were delivered to Germany (87 percent) and with the addition of 11 219 aeroplane engines.⁵⁴ Furthermore throughout the period 1938-1945 the German armed forces looted from occupied countries more than 90 494 armour vehicles out of a grand total production of more than 111 866 items.⁵⁵ It goes without saying that the actual contribution of the industries of occupied Europe to hardware equipment was extremely low.

4. The German armaments production under the broader context of German strategic / operational planning

The second essential dimension is the armaments production *vis a vis* the operational (tactical) and strategic requirements of the armed forces. Here the question is associated with the short and long term requirements of the armed forces during the war as the character of the war changed. Thus during the period September 1939 to December 1941 the German armed forces (Heer, Kriegsmarine, Luftwaffe) were anticipating short term blitzkrieg-style wars, mainly with the countries of continental Europe. The only exemption to this strategic doctrine was Britain where long term planning was made. This planning changed by December 1941, as Operation

Barbarossa failed and the USA entered the war. Germany faced a two front war with the Anglo-Saxon powers and with USSR. The problem after this development was dual. The first problem was that no-one could predict accurately the time-duration of the conflict. But the greater challenge was that this dual war imposed different priorities. The war against the USSR was mainly a land based conflict and thus the emphasis had to be given to the Heer (Army). The war against the Anglo-Saxon powers was mainly one of naval and air character thus priority had to be given to the Navy (Kriegsmarine) and to the Air-Force (Luftwaffe).

Resources	Germany & Austria	European Axis Allies (*)	Occupied countries (**)	General total
Territory (square km)	554 000	801 000	1 922 000	3 277 000
Population (m.)	76	78	129	283
Electro-energy (kwh million)	52	15	43	110
Coal (m. tons)	185	2	161	348
Iron ore (m. tons)	3.4	0.5	22.4	26.3
Copper (thousand tons)	31	1	67	99
Bauxite (thousand tons)	93	848	1 176	2 117
Petroleum (m. tons)	0.5	8.7	0.8	10
Iron (m. tons)	16.3	1.4	20.2	37.9
Steel (m. tons)	20	3.2	20.4	43.6
Aluminum (thousand tons)	131	23	64	218
Grain (thousand tons)	136	148	264	548
Wool (thousand tons)	19.6	59.7	59.4	138.7
Cattle (million)	22.9	15.3	45.4	83.6
Pigs (million)	26.7	9.9	27.8	64.4
Vehicles (thousand)	333	75	268	676

Table 9: Resources of Germany and Occupied Europe⁵⁶ (*) Italy, Hungary, Romania, Bulgaria. (**) France, Belgium, Netherlands, Luxemburg, Denmark, Norway, Poland, Greece, Albania, Czechoslovakia. The table is incomplete since it does not include Finland and occupied USSR territories.

4a. Assessment of the defence industry supply and the Army (Heer)

The Army (Heer) requirements were massive. To illustrate, the average daily expenditure of ammunition increased from 1 557 tons in 1942 to 2 453 tons in 1943 and to the astonishing figure of 2 941 tons in 1944.⁵⁷ In the Eastern front in 1941 the daily consumption of supplies by a panzer division was 30,4 tons when it was inactive; but in case of heavy combat the consumption of supplies increased to the staggering level of 711,2 tons. In the case of an infantry division the numbers were 81,2 tons and 1 117,6 tons respectively. An infantry soldier when inactive was consuming 4,5 kg of supplies daily; but under heavy fighting the daily consumption increased to 22,6 kg.⁵⁸ In the Eastern Front (20 June 1941), the Army group North was supplied with 68 000 tons of ammunition, Army Group Centre was supplied with 127 000 tons, and Army Group South with 84 000 tons. By June 25th 1941 the available quantities for the three Army Groups were as follows: 74 000 tons (North), 135 000 (Centre) and 90 000 tons (South). By December 1941, the available quantities were reduced.⁵⁹ During the summer attack of 1942 the situation was improved. During the seizure of Sevastopol, according to Giovanditto (1984) in the period May 7th to June 7th 1942 the town was hit with 13 000 tons of bombs by Stuka bombers - in total the German artillery used 46 000 tons of shells with a rate of 324 shells per second.⁶⁰ In the battle of Kursk in July 5th 1943, during the early morning hours, around 10 000 German guns and mortars consumed more shells than the combined number of the German consumption during the campaigns against Poland and France put together. In December 1944, during the German attack in the Ardennes the Second Army had just 15 099 tons of ammunition, and had to provide to the 15th Army the 5 353 tons.⁶¹ During the period September 9th to December 15th the 7th Army received 1 502 personnel trains and almost 500 ammunition trains. An additional amount of 144 735 tons of supplies were also used. Throughout the Ardennes offensive the German side consumed 1 200 tons of ammunition per day.⁶²

Turning to the front in Africa, during 1941-1943 the German Africa Corps was constantly under supplied. To illustrate, in 1941 50 000 tons of supplies were needed per month but in July they only received 32 000 tons, in August 28 400 tons, and in November just 30 000 tons.⁶³ According to Italian sources, the Axis forces in Africa during 1941 received 853 193 tons of supplies out of a total amount of 1 016 442 tons (or 83,9 percent).⁶⁴ The supply situation in Africa deteriorated in 1942. German and the Italian forces between February and May 1942 requested 100 000 of supplies per month, but received only 60 000 tons. In July the supply was just 26 000 tons. In his diary entry (8-9-1942) Rommel, the German supreme commander in Africa, noted: "in the past eight months we have received on average 120 000 tons of supplies per month which covered only the 40 percent of our needs". In November the Axis forces received only 4 879 tons of oil and 2 331 tons of ammunition. In December the daily needs were for 400 tons of oil and 50 tons of ammunition but

the available amounts were just 152 tons and 16 tons respectively.⁶⁵ In January 1943 the Africa armies were supplied with 46 000 tons, 50 tanks, 214 artillery guns and 2 000 vehicles. On February 10th 1943 the forces in Africa were having a deficit strength of 257 tanks, 177 reconnaissance vehicles, 565 anti-tank guns, 106 guns and mortars, 5 794 vehicles, 938 motorcycles, 2 386 machine guns.⁶⁶ By May 1943 when the German and Italian armies in Africa surrendered to the allies they had available only 0,1percent to 0,4 percent of necessary fuels, 0,8 percent of infantry requested ammunition, 0,5 percent to 0,9 percent of requested anti-tank ammunition, and artillery shell supplies covered only the 1,2 percent of total needs.⁶⁷ In the Italian front in 1944 the German forces did not have a supply problem. To illustrate, in March 1944 the German armies in Italy had a surplus of 16 891 tons of ammunition, increasing to 18 102 tons in May.⁶⁸ In general the German land armies in all fronts, with the African front as the only exemption, were well supplied.

4b. Assessment of the defence industry supply and the Navy (Kriegsmarine)

The picture is different naval warfare. In the navy the main weapon against the allies was the submarine but both the supply of submarines and the logistical support was problematic. The construction of other types of vessels was very limited throughout the war period (Table 10).

YEAR	39	40	41	42	43	44	45	Total
Pocket battleships	3	-	-	-	-	-	-	3
Cruiser battleships	2	-	-	-	-	-	-	2
Battleships	-	1	1	-	-	-	-	2
Cruisers	8	1	-	-	-	-	-	9
Destroyers	22	2	5	5	2	1	-	37
Torpedo-boats	20	9	4	4	6	5	1	49
Submarines	58	68	129	282	207	258	139	1 141
Fast attack	20	26	34	44	46	52	11	233
Minesweepers	44	14	25	31	38	29	8	189

Table 10: Construction of Vessels 1939-1945⁶⁹

In 1938 the construction of an aircraft carrier had started under the name Graf Zeppelin. By 1943 the 95 percent of the vessel was completed however the construction was abandoned in 1944 and the semi-finished ship was transported to Kiel and was dismantled by April 25th 1945. The absence of aircraft carriers had tremendous strategic and tactical limitations for the naval warfare. Furthermore, the decision to dismantle a 95 percent complete vessel demonstrates the irrationality of the procurement system.

The Naval priorities are demonstrated in Tables 10 and 11. Naval armaments shifted to submarines and neglected the surface ships. When the war erupted the Navy asked for 300 submarines as the required level of strength in order to destroy allied convoy systems. However, the number of operational vessels was never so high (Table 11). The maximum operational U-Boat strength of 240 vessels was achieved in May 1943, well below the 300 optimum target. It is worth pointing out that because of the limitations of the means of naval warfare, in June 7th 1943 Hitler requested the build-up of the largest naval program in German history. According to that 11 134 ships were expected to be constructed until 1948. From those, 2 400 were expected to be submarines. That was the fantasy of a lunatic.⁷⁰

Moreover the limitations of naval warfare were also associated with raw materials availability and logistical support. To illustrate, in the first quarter of 1940 submarine construction was reduced as the navy had only 140,000 tons of iron at its disposal; whereas the minimum requirements were for 170 000 tons. Further, the available fuel quantities were inadequate as well. On March 16th 1940 navy fuel was just 870 800 tons; whereas in October 1st 1940 it was 807 500 tons. In November 1941 the German Navy reported that total available fuel was 380 000 tons. To this another 30 000 tons could be added as the Italian navy reserve. The total Axis reserve of 410 000 tons was inadequate as the monthly requirements of the German Navy were 90 000 tons. There were also 106 000 diesel fuel tons available. However German surface vessels needed 40 000 tons of diesel during the two month period November-December 1941 and the submarines needed other 28 000 tons. Thus the Kriegsmarine was facing immobilization just at the time the US entered the war.

The oil supply problem became worse. On April 1st 1942 total naval oil reserves were 150,000 tons. The total monthly allotment for both German and Italian navies was just 61 000 tons! The shortage of other raw materials was also critical. To illustrate, for the first quarter of 1943 the Navy was granted only 127 000 tons of steel. That was just the 5 percent of total steel production. However there was also a man-power problem since there was a major deficit of 200 000 men in June 1943 and until September 1944 the man power problem became greater with a deficit of 334 838 men.⁷¹

	Total U-boat strength	U-Boats under repair	Training U-Boats	Operational / front line U-Boats	Monthly production*	Total monthly losses
Sep. 1939	57	6	12	39	1+1	2
Nov. 1939	52	6	13	33	2	1
Jan 1940	55	6	14	35	2	2
May 1940	49	3	15	31	3	1
Jun 1940	51	4	20	27	3	-
Nov 1940	68	11	33	24	6+3	2
Dec 1940	73	13	33	27	9	-
Mar 1941	99	29	43	27	11	5
Jun 1941	138	52	48	38	14+1	4
Aug 1941	168	59	45	64	19	3
Sep 1941	186	65	48	73	24	3 (1)
Dec 1941	236	99	49	88	22	10
Feb 1942	257	99	57	101	16	2
Apr 1942	283	107	57	119	17	3
Jun 1942	309	124	59	126	21	3
Sep 1942	356	122	62	172	18	11 (1)
Nov 1942	372	103	62	207	23+1	13 (1)
Dec 1942	381	115	62	204	23	5
Jan 1943	400	125	62	213	22	6
Mar 1943	417	125	63	229	27	16 (2)
May 1943	432	124	68	240	26	41
Jun 1943	415	131	70	214	25	17
Sep 1943	399	156	79	164	21	10 (2)
Oct 1943	419	165	79	175	25+3	27
Nov 1943	422	175	85	162	25	19 (9)
Dec 1943	424	168	97	159	28	8

Table 11: German submarine fleet 1939-1943 (selected months)⁷² (*) =war loot appear with + in monthly production. In the last column the numbers in brackets refer to accidents, or losses, in the Baltic.

The German armaments industry failed to supply to the Navy the necessary weapon systems as well as the logistics required for an effective maritime war. The navy was constantly undersupplied in surface ships and even the submarine arm was denied the required numbers of vessels. The additional limitations of raw materials, fuel, man power, made the situation worse. Under the circumstances the German defeat in the battle of the Atlantic was the expected outcome for an under-supplied navy. With the command of the oceans the Anglo-Saxon naval powers were allowed to transport to Europe millions of men and material first for the liberation of North Africa and later for the liberation of Europe (Italy-France).

4c. Assessment of the defence industry supply and the Air-Force (Luftwaffe)

As already demonstrated the overall air armaments production during the war was estimated between 113 000-125 000 airplanes. The production of the most used types is demonstrated in Table 12.

Most sources point out that total production covered the overall losses. To illustrate, according to Ellis (1995) the overall losses were 116 584 airplanes. Sitaras (2006) provides the estimate of 100 000 airplanes; whereas Overy (2005) estimates the losses of fighters, bombers and night fighters to 70 611 airplanes.⁷³ Although total production surpassed the losses when this is compared and contrasted with the allied aircraft production (UK, USA, USSR) the numbers are overwhelmingly against the German effort. To illustrate, Ranki (1993) provides the estimate of 87 221 British airplanes, 231 099 US airplanes and 84 800 Soviet planes during 1942-1944, providing a total allied production of 403 120 airplanes.⁷⁴ Ellis (1995) provides the figure of 121 754 airplanes only for the UK. The estimate for the US is 324 750 airplanes and for the USSR it is 157 261 airplanes, thus providing an amazing total of 603 765 airplanes.⁷⁵ The figures provided by Overy (1995, 2005) are: 105 286 British planes, 324 840 US planes and 158 218 Soviet planes; thus an overall figure of 588 344 airplanes.⁷⁶ Harrison (1998) provides the following figures: 94 600 British planes, 192 000 US fighter planes and 112 100 Soviet planes; thus providing an allied total of 398 700 planes⁷⁷

In spite of the variations it is clear that the combined allied airplane production at least triple that of Germany, but it was not just the numbers but also the quality since the allies produced super heavy bombers which the German Luftwaffe could not dream of a similar design. Allied fighters were in many cases equal if not better to those of the Luftwaffe. Thus, in spite of the efforts the German aircraft production could not secure a victory against the allied air bombing offensive.

Type	Quantity produced	Role
Ar 196	435	Hydroplane
Ar 234	214	Bomber
BV 138	276	Hydroplane
BV 222	4	Hydroplane
Do 17	506	Bomber
Do 217	1 730	Bomber
Do 215	101	Bomber
Do 18	71	Hydroplane
Do 24	135	Hydroplane
Do 335	11	Fighter
Fi 156	2 549	Telecommunications
FW 190	20 001 (7 647)	Fighter
FW 200	263	Long range reconnaissance
FW 189	846	Reconnaissance
Go 244	43	Transport
He 111	5 656 (5 678)	Bomber / Transport
He 115	128	Hydroplane
He 177	1 446	Bomber
He 219	268	Night fighter
Hs 126	510	Reconnaissance
Hs 129	841	Ground support
Ju 52	2 804	Transport
Ju 87	4 881 (4 890)	Dive bomber
Ju 88	15 000 (16 911)	Bomber, reconnaissance, Night fighter
Ju 188	1 036	Bomber
Ju 290	41	Long range reconnaissance
Ju 352	31	Transport
Ju 388	103	Bomber
Me 109	30.480 (31.887)	Fighter
Me 110	5 762 (6 257) (6 050-6 170)	Night Fighter
Me 262	1 294 (1 433)	Fighter & Fighter-bomber
Me 323	201	Transport
Me 410	1 013 (1.160)	Bomber
Ta 154	8	Fighter
Ta 152	67	Fighter
Total	98 755	

Table 12: Production of Main Types of Airplanes 1939-1945⁷⁸

5. Concluding remarks: An opportunity cost analysis

The conventional analysis of the German armaments production is associated with the so-called Speer-miracle; the tripling of armaments production from 1942 to 1944 under the bombardment of allied air-forces. Although this static analysis is correct from the analysis of the above data the following conclusions can be deducted:

5.1. The German defence industry had to supply the armed forces during the period September 1939-December 1941 for short war type campaigns under the blitzkrieg operational/ tactical doctrine. During this period the priority of armaments production was given to the Air-Force (Luftwaffe) and the Heer (Army). However after December 1941, when the German assault in front of Moscow was checked and the US entered the war the German industry had to plan for a long war with both the USSR and the Anglo-Saxon powers (UK and USA). However it was not just the time duration of the war but the fact that the war against the USSR was mainly a land warfare struggle; whereas the war against the USA and Britain was a naval and air-warfare struggle. To this strategic challenge the German industry failed completely. The German side did rather well in the land warfare struggle against the USSR by producing adequate quantities of material and weapons; however it did very poorly in the naval and aerial warfare against the Anglo-Saxons. Thus at the strategic level the so-called Speer miracle was not a miracle at all. Under the Speer administration the Germans did quite well against one opponent but not against the other.

5.2. The strategic failure is not just the only aspect which has to be reconsidered. At the tactical and economic level important errors have been made. Thus during WWII the Germans (and Hitler himself) tried to do everything. The attempt was to produce tanks, guns, all types of airplanes, submarines, missile systems, built fortresses (Atlantic Wall), produce small arms etc. To make things more complex the idea was to procure many different types and models of weaponry thus instead of standardization the German side produced multi type weapon systems. This policy had immense harmful ramifications, and these are briefly illustrated below:

5.3. Starting with the Army (Heer) the German industry had to maximize the production of low cost and high efficiency tanks like the Panzer III, Panzer IV and Panther types. Thus the development and production of the expensive Tiger I, Tiger II, and Maus systems was a classic case of waste of resources (both financial and raw materials).⁷⁹ In the artillery similar examples can be given. Again production should have been focused on the Nebelwerfer systems the 88mm the 75mm and the 120 mm guns. The super heavy guns and the railway guns were a waste of resources. The logistical support of numerous artillery and tank systems was difficult. To illustrate according to a memorandum of January 1st 1945-

- the Rheinmetall-Borsig company had under development 31 different types of ammunition and gun tubes;
- the Fastrstoff und Spinnerei company had five new models under development;
- the Wittkowitz Bergbau company, had six models under development;

- the Skoda company had 24 models;
- the Brunner Waffenwerke had six models;
- the Bradenburger Eisenwerke had 13 models;
- the Hugo Steiner had five models;
- the Hessische Industrierwerke had five models;
- the Krupp Industry had 24 models;
- the Dynamit AG had nine models;
- the Jungker had 2 models;
- the Schrammberg had 18;
- the Deutsche Sprengchemie had four models;
- the Deutsche Waffen und Munitionfabrik had 31 models;
- the Th. Bergmann had 11;
- the Zeiss had four models,;
- the Siemens & Halske had two;
- the Güstloffwerke had four;
- the AEG had six;
- the Deutsche Edelstahlwerke had four;
- the Sachenwerke had two;
- the Stock & Co (Stolberg) had two;
- the SGW Döhlen had three; and
- the Niedersachen AG had 29 different models.⁸⁰

The various types of vehicles used 29 types of telescopes, 26 types of periscopes, 4 types of observation periscopes, two additional types for the driver. There were 20 different telecommunication systems and 40 different types of machines for the armored vehicles.⁸¹

5.4. In the Navy (Kriegsmarine) the policy of priority to submarine construction versus that of surface vessels was correct, since submarines were cheaper and needed less time, however at the tactical level the construction of 660 VII-type submarines was a waste of resources since they were technologically inferior and had only 14 torpedoes when the submarines of IX-type (version C) had 22 torpedoes, they were faster and had a bigger range. Thus production should have been focused in the second type rather than the first.

5.5. In the case of the Air-Force (Luftwaffe) the production of Me-109 fighters against the FW-190 was an error. Already from the Battle of Britain it was clear that the Me-109 was marginalized by the British Spitfire. When the US P-47 and P-38 appeared the Me-109 had no chance of success. The fighter policy of the Luftwaffe was catastrophic. The German side had to focus in 3 types of fighters only.

These were the FW-190 for day missions, the Me-110 for night missions, and the Me-262, turbine jet fighter which had to be operational at least 18 months earlier. Thus the production of 12 807 Me-109 fighters in 1944 was a classic example of failure at tactical and strategic level.⁸² In the bombers case, the He-111 although reliable was inefficient, since it was a medium range design. The production of the Ju-87 Stuka, was a gross error. Another error was the case of the Me-210 fighter. This particular design was originally made in 1938, but mass production started in April 1941. The plane had technical problems and by April 14th 1942 the program was terminated, after the overall development of 158 airplanes (with other 26 in the production line). The overall, Me-210 project cost, to the Luftwaffe in terms of capital, raw materials and productivity, was equal to the amount of 600-1 000 planes.⁸³

5.6. The decision to establish an immense Anti-aircraft (A/A) arm was strategically correct but the implementation of the decision was a tactical error. The most important argument in favor of the A/A umbrella was that the cost is smaller compared to the increase of the air-fleet. To illustrate, the increase of fighter strength is associated with the following additional costs:

- Training of pilots in the new fighters,
- The re-training of pilots and the land based personnel for the technical support of the airplanes (more advanced models may have different technical specifications),
- Additional requirements and expenditure in fuel,
- Construction and expansion of new or existing aerodromes which require additional A/A protection,
- Expansion of Search and Rescue capabilities,
- Built of new telecommunication facilities, radar systems, ammunition and spare parts for planes, lubricants etc.
- In addition the time production of A/A guns and the time of operational entry is smaller compared to that of airplane design, mass production, entry to service, logistical support etc.

The A/A umbrella was not wrong; however the mass production of A/A guns should have been focused, to the best type that of 128mm gun with a range of 35 000 feet and an average consumption of 3 000 shells per 1 shoot down. Contrary to this the well-known 88mm gun (Model 36-37) needed 15,000 shells / 1 shoot. By the end of 1944 only 5 percent of A/A guns was of 128mm calibre and the majority of A/A guns was of 88mm calibre.⁸⁴ The correct decision to establish an A/A umbrella was

undermined by focusing the production to the 88mm A/A gun which had smaller caliber and consumed more shells.

5.7. The development of strategic missiles (V-1 and V-2) was also an error. The V-1 systems had an average production cost of just 5 000 RM or £150.⁸⁵ The production of one V-1 demanded 900 working-hours.⁸⁶ The total R&D cost for the development of the V-2 system was at the staggering level of 2 billion RM, amount equal to the 25 percent of the cost of the US Manhattan Project (for the construction of the atom bomb). In addition to this the cost for the production of 12 000 V-2 systems was 750 m. RM.⁸⁷ According to a different source, the production cost of one V-2 was £6,000, excluding the initial R&D cost.⁸⁸ These sums could have been invested for the procurement of conventional weapons with more destructive power. The real contribution of V-1 and V-2 systems to the war effort was marginal; thus in terms of cost benefit analysis their production was catastrophic.

5.8. The construction of the Atlantic Wall was also an error. Static defence fortresses could easily be destroyed, bypassed or captured. This was the lesson actually from the successful German operations of 1940 against the French Maginot line and the Belgian fortress of Eben-Emael. However the Germans failed to understand these lessons and by investing in the Atlantic Wall immense sums and raw materials deprived other more essential armament priorities.

5.9. During the war years the German labour force in the economy was reduced considerably from 39 114 000 workers in 1939 to 29 800 000 in 1944 and the size of forced labour (prisoners of war, Jews and other nationalities from occupied Europe) increased from 301 000 workers to 7 126 000 in the same period.⁸⁹ Thus total labour force in the economy decreased from 39 415 000 workers in 1939 to 36 926 000 in 1944. The mass murder in concentration camps of more than 6 000 000 Jews was not only an immense humanitarian atrocity it was the biggest error in German war effort since these people could have been used as additional labour force.

5.10. The German planners failed to realize that all efforts after 1942 were doomed to fail, since Germany could not balance the joint armaments production of the Big-Three (Britain, US, USSR). When in March 1944 the German Armaments Minister Dr. Speer announced the so called "Victory Program" which aimed to increase arms production by 98 percent, tank production by 73 percent, vehicle production by 26 percent, airplane engine and frames production by 74 percent and ammunition production by 20 percent, was a futile plan. Even after the Normandy landings the German Minister was stating that the war would last for five more years.⁹⁰ The strategic error of the German side is obvious. Hitler and his planners failed to realize that the German armaments effort was futile especially since in many

sub-categories was below the production volumes of the Hindenburg Program of 1917-1918. Furthermore even with the addition of Japanese and other Axis allies strength the Allies enjoyed overwhelming superiority. If the German armaments production was maximized in 1942, rather than 1944, a window of opportunity was open for a German victory in the East. When this did not achieve for tactical and strategic reasons the probability of victory became more and more marginalized. It goes without saying that the “Speer miracle” has been a strategic and operational failure.

Endnotes

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