

THE FIRST SCIENTIFIC DISPUTE OVER *EFFECTS*

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The *Effects-Based Approach* (EBA) has stimulated a lot of writing in recent years. Various examples have been claimed of historical campaigns which can be considered, in retrospect, to have been conducted in accordance with EBA and it would not be useful to argue over which was the earliest such campaign. In contrast, the *assessment*, on scientific principles, of the effects being achieved in such a campaign is relatively recent, scientists not having been in a position to conduct such an assessment until the Second World War. Almost certainly, the earliest operation planned in this way and subject to scientific assessment was what is sometimes known as the Transportation Campaign – the attempt to cripple the transport network in occupied Europe in 1944. This campaign was also controversial, so it generated a great deal of argument, much of which can be reconstructed from the surviving papers. Combat assessment ought, one might suppose, to have been relatively easy in this case: no social effects were intended; there was no attempt to sap the will of the populace or its leaders; the aim was merely to prevent the railways being used to bring troops up to the beachhead to oppose amphibious landings. Nevertheless, bitter disputes arose. I believe that the nature of those disputes still has much to teach us about assessing what is going on in EBA.

The great protagonist for the Transportation Plan was Professor Solly Zuckermann, who, as the history of OA goes, was something of an oddball. He was never a civil servant but remained throughout the war an Oxford University lecturer loaned to the government for war work. He was *Professor* Zuckermann on the basis of a chair at Birmingham whose duties he had not yet taken up and which in 1945 he would try very hard to avoid taking up. He did not regard himself as doing operational research, which he regarded somewhat condescendingly as a bit basic.² Whereas the operational researchers generally tailored their reports to the needs of their military readership, keeping them fairly short by modern standards, Zuckerman's reports were massive affairs. Yet for a while at least he commanded more attention than any operational researcher has before or since: a telegram survives from Portal (as Chief of the Air Staff) to Tedder in North Africa asking when Zuckerman's report on the campaign against the railways in Southern Italy would be ready.³ I cannot think of any other OR report that has been anticipated quite so eagerly.

Zuckerman's expertise was actually in the physiological effects of bombs and shells. He was sent out to North Africa by Combined Operations to gather such weapon effects data as might be of use in the forthcoming landings in Northern Europe. He went out as the junior partner to J D Bernal, who was to handle the physics side, but Bernal was ordered to America to support Combined Ops' scheme for an aircraft carrier made of ice, and Zuckerman found himself responsible for the physics side as well. Tedder, the Air commander for North Africa, then asked him to assess the

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² Solly Zuckerman, *From Apes to Warlords*, 1978, 174.

³ National Archives (formerly Public Record Office) (henceforth TNA), AIR 2/5523, enclosure 46A of 23 Nov 43.

bomb tonnage required to suppress the Italian fortifications on Pantelleria. Fortunately, Bernal and Zuckerman had already tackled a similar question in drawing up plans for an assault on Alderney. In the course of this work they had established two key principles: statistical modelling of bomb impact points, and a level of physical destruction at which the defence was deemed to collapse. Applying these to Pantelleria, Zuckerman produced a detailed specification of what aim points should be used in what phases, with he himself responsible for assessing when one phase was complete and the attack could progress to the next phase. Zuckerman insisted on going with the landing force and, as the first boats reached the beach, had the pleasure of seeing the garrison run up a white flag and surrender.

Zuckerman's own analysis subsequently showed that an error of a factor of 2 in bombing accuracy had been almost exactly counteracted by greater than expected vulnerability of the Italian gun direction systems.⁴ The cynic might also suggest that Italian will to fight had sunk to such a level by this date that, had only one-tenth of the effort been employed, the garrison might still have run up the white flag at exactly the same moment. Nevertheless, Zuckerman was regarded as something of an oracle. In particular, he and Tedder forged a relationship which would last to the end of the war and beyond.

Planning for the Sicily landings threw up a requirement to impede the movement of enemy forces by rail to attack the beachheads. The intention was to prevent this by bombing key bridges. This was an issue which had received attention back in the UK, both within Combined Operations and by the Directorate of Air Tactics at the Air Ministry. Between them, they had formulated the idea of the *strategic* (we might now say *systemic*) approach to disabling a railway network based on attacking a range of feasible targets that would impede and ultimately cripple *all* railway functions, rather than cutting lines, which was termed the *tactical* approach.⁵ Zuckerman proposed that the Sicily plan should be revised to attacking "nodal points" on the railway systems of Sicily and Southern Italy.⁶ His proposals were accepted by Tedder and, after the invasion, Zuckerman led a team to assess how the approach had worked. They collected traffic data from Battipaglia, south of Naples (where the local railway officials were thoroughly helpful) and crawled over the locomotive shed at Naples plotting bomb impact points and the damage caused.⁷ Zuckerman's report⁸ concluded that a principal factor in crippling the railway system had been the destruction and damage of rolling stock and repair facilities. A far more costly air effort would have been needed to achieve tactical blockage compared to this strategic approach. Finally, he noted with regret that damage to the railway system would be felt by the civil population long after hostilities had ceased.

The most articulate opposition to Zuckerman's approach came from the economists, notably Oliver Lawrence at the Ministry of Economic Warfare, and C P Kindleberger, Head of the Enemy Objectives Unit, Economic Warfare Division, at the US Embassy

⁴ TNA AIR 23/8710 – Report on Operation CORKSCREW, dated 20 Jul 43.

⁵ COSSEC/RAF/346 dated 21 Aug 43 was a key stage in the development of these ideas. It was issued about the time that Zuckerman was addressing these problems in North Africa, but it is evident from TNA AIR 2/5523 that the ideas had a long gestation.

⁶ Zuckerman (1978), 198.

⁷ A railway expert provided an assessment of how long it would take to repair each locomotive; unfortunately there is no indication as to whether the damage was caused by blast or by fragments.

⁸ TNA AIR 23/1516 Air Attacks on Rail and Road Communications. The report was issued 28 Dec 43.

in London. Their concern at the long-term damage that would be inflicted on the Italian railway system went well beyond Zuckerman's mere regret. They noted that military traffic only amounted to about 10% of the traffic handled by the railways; this would evidently be given priority; so, unless complete and total breakdown was achieved, Zuckerman's plan would cause long-term economic damage without having any direct military effect. They also noted, from the figures in Zuckerman's own report, that the fall in traffic across the Messina Straits preceded and exceeded the fall in the train-miles statistics for Battipaglia.⁹ Arguably the statistics were falling because of the attacks on the ferries to Sicily rather than because of the attack on key railway nodes that Zuckerman had advocated.

The two approaches can be usefully contrasted by an influence diagram (Figure 1). Causing breaks in the network would undoubtedly achieve the desired end, but Zuckerman's weaponeering calculations showed that it was unachievable without inordinate effort. In contrast, attacks on strategic centres were certainly feasible from a weaponeering viewpoint, but they would only achieve the desired end if they resulted in a near-total cessation of rail traffic. It was this link from the destruction of strategic centres to the near-complete cessation of traffic where Zuckerman's argument was weakest.

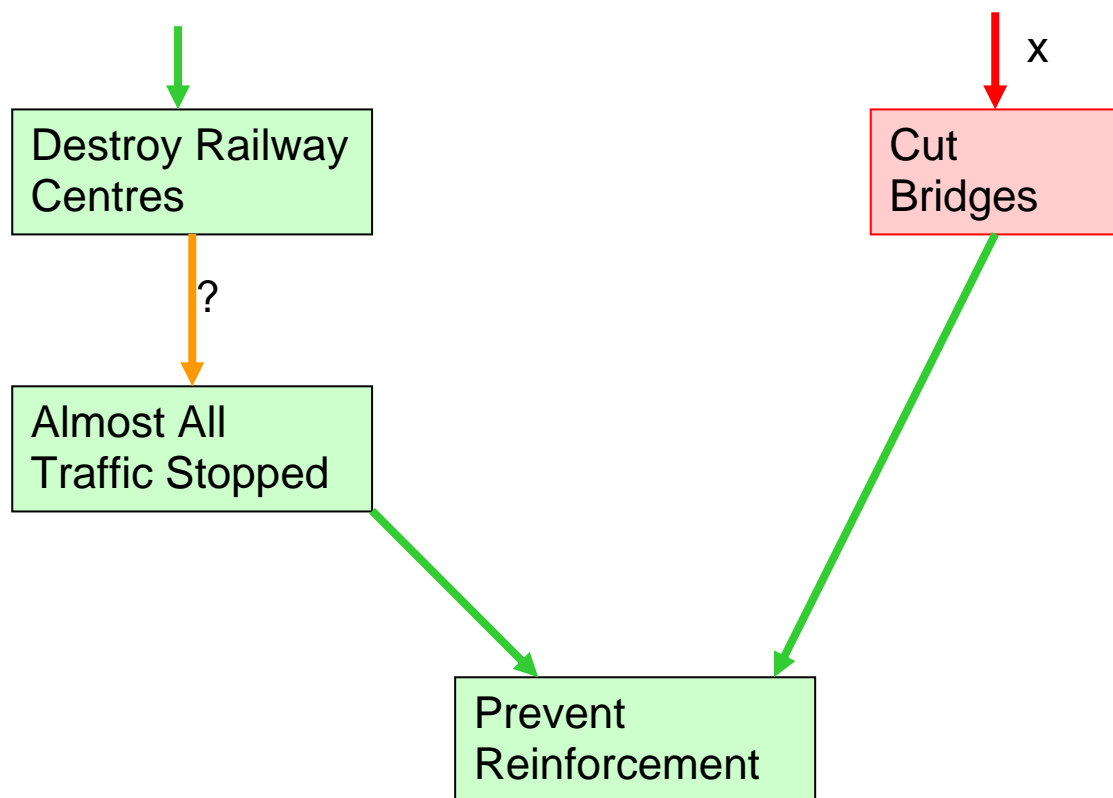


Figure 1: Alternative methods of preventing reinforcement.

Zuckerman continued to fudge this issue, arguing that a rail system was like a biological organism and that complete destruction was not required to knock it out. If that failed he was liable to fall back on the line 'I've been there and seen it', but of

⁹ TNA AIR 23/1517

course a single instance does not demonstrate a reliable effect unless one can demonstrate a causal mechanism.

In fact, the complete absence of attempts to rectify the damage which he describes at Naples should have given Zuckerman himself cause for concern. To fill in craters only requires unskilled labour. Re-railing derailed locomotives and rolling stock would typically be done with shear-legs – basically long poles and pulleys. Why had none of this been done? One suspects that the attitude of the railway workers played a part in this: they had a vested interest in avoiding further long-term damage to the railways; and (I presume) they were suffering mental and physical exhaustion brought about by malnutrition. How much easier to declare that nothing could be done: it would need a steam-crane! And they were right: our intelligence branches were monitoring activity; no activity meant no further attacks.

Now Zuckerman was a very politically-aware scientist, somewhat left-wing in his views. But I cannot think of any instance of his acknowledging that the labouring classes might themselves hold political views which might affect their actions. The matter was of some significance, because Zuckerman was using the results from Southern Italy to argue that a similar campaign would be effective in Northern Europe and indeed in Germany, where the reactions of railway workers might well be different.

The economists had some US intelligence derived from an Italian General. One of the railway lines north of Rome had been cut; their source could not understand why the other had not been attacked, as that would have cut supplies completely. Furthermore, the Germans had been removing overhead wire and switch-gear from the (electrified) Italian railways in order to ship them off to Germany. One of the two tracks from one of the main lines out of Rome had been taken similarly. Despite all the bombing, a military supply train had been leaving Rome each evening for Cassino, aiming to get back before dawn.

One might choose to disregard the General's views on how the railways ought to have been attacked as mere opinion, but the reports of equipment being shipped back to Germany suggest that the railway network was by no means in the chaotic state that Zuckerman supposed: the Germans were getting what they needed from it and indeed it had spare capacity so far as their military needs were concerned. That suggests that our influence diagram needs two extra arrows, representing behaviour of the workers and actions by the occupying forces. In this case, of course, the Germans were shipping equipment *out* but one could envisage circumstances where they might have shipped locomotives (say) *in*, in order to keep military trains running in the face of an offensive against locomotives and repair centres.

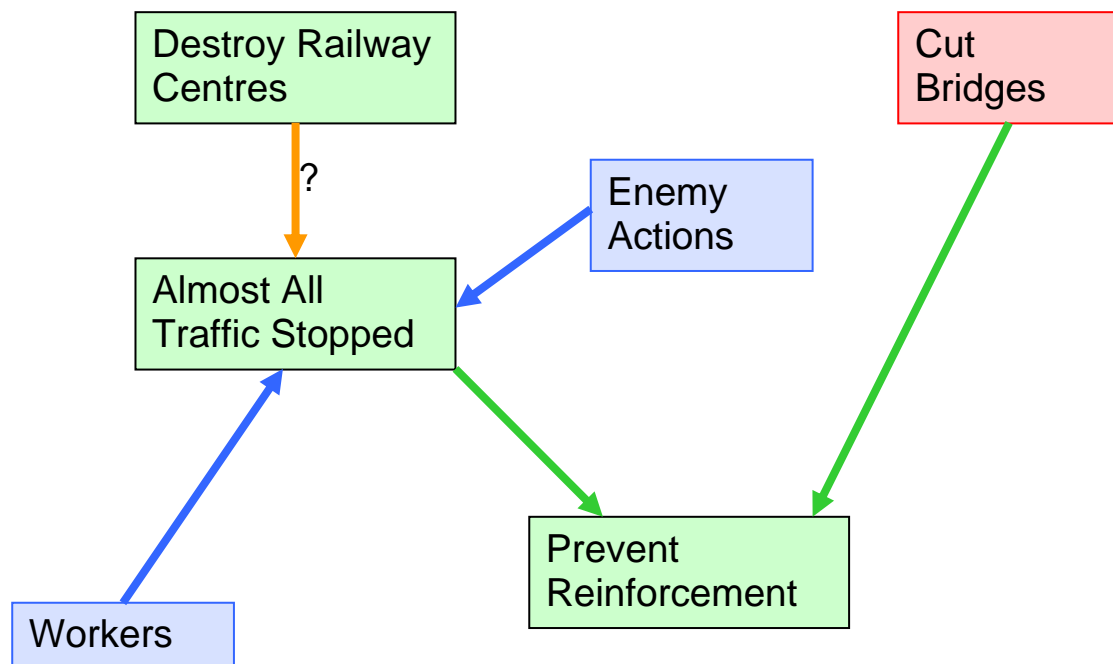


Figure 2: Bringing in further actors

How then did this argument develop? So far as I am aware, there was no meeting of minds. Zuckerman had Tedder's ear; Tedder was the air commander for the invasion, so the views of a bunch of economists who knew nothing about weapon effects were utterly irrelevant. However, in this case, Tedder's authority was limited. Harris at Bomber Command considered railways yet another 'panacea target'. Bufton, as Director of Bomber Ops at the Air Ministry, was also opposed.¹⁰ More seriously, the US 8th Air Force planners, advised by their intelligence staffs, took the view that 'Axis European transportation ... was too extensive and would require too long to destroy.'¹¹ They realised that they needed to offer a constructive alternative, and so the Oil Plan (in its 1944 form) was born. In the end, Eisenhower resolved the dispute by asking of each option whether it would have any effect by the time of D-Day. The transportation plan, it was conceded, might well have some effect; the oil plan would not have any effect until later. Accordingly, the transportation plan went ahead, with coordinated attacks starting in March. The SHAEF G-2 staffs remained bitterly opposed. As late as D-7, they assessed that the Germans had 3 times the rail capacity needed for military trains, 4 times the rolling stock, 8 times the locomotives, and 10 times the servicing facilities.

Meanwhile, there had been tactical developments intended to explore whether destroying a bridge really was as difficult as Zuckerman had calculated.¹² A few experimental attacks were made from the end of April and a coordinated programme

¹⁰ Air Cdre Sydney Bufton had been aware of the 1943 papers on how best to attack railways. He chaired the meeting of 25 Feb 44 which attempted to bring Zuckerman, the economists and the railway experts to a common view. He subsequently argued for the attack of oil-related targets.

¹¹ Gordon A Harrison, *US Army in WW2: European Theater of Operations: Cross-Channel Attack*, Washington DC, 1951, 217*et seq.*

¹² This can be traced back to attacks in Northern Italy, largely by B-26s, on 19-28 March 1944. Most of these attacks were against the Palazzone viaduct. Harrison states that the French attacks on bridges took place at the urging of 21st Army Group. I have not established whether developments in France drew on lessons from Italy or were independent.

of attacks against bridges went ahead from 7 May.¹³ It was an outstanding success: by 26 May¹⁴, all railways across the Seine north of Paris were closed to traffic, and they remained closed for the following 30 days. A further development was the use of fighter-bombers from 20 May¹⁵ against open sections of track and small stations. The strafing of trains appears to have had a strong impact on morale. The combined effect of these measures was that, when the D-Day landings took place on 6 June, the movement of defending forces by rail was hugely impeded. The campaign had undoubtedly succeeded in meeting the commander's intent.

That was not the end of the story. Railways were evidently a profitable target, and there was a strong case for extending the campaign to the railway system of Germany itself. But was Zuckerman's prescription of attacks on rail centres the best way, or should the focus be on cutting bridges. It was clearly necessary to establish how and why the campaign against the French railway system had succeeded. A Bombing Analysis Unit was set up in Paris, with Zuckerman as Scientific Director, and it managed to obtain a set of German graphs of traffic in the region centred on Brussels. These showed a precipitous fall in traffic (all trains) in April, which flattened out after the attacks started on bridges and then fell again at the end of May. Military traffic fell less dramatically: by the end of May it had reached about 50% of its level in February. So far as Zuckerman was concerned, the strong correlation between falls in traffic and bombs dropped on railway centres, and the absence of any correlation with the closing of bridges, was decisive. In fact, for one brief moment he thought he had been accused of forging the graphs.¹⁶ Without doubt, the Bombing Analysis Unit had proved that, if one wished to knock out an entire railway system, then systemic attack was best. But the commander's intent had been all along to prevent the use of the railways for bringing up forces to oppose the landings. Overall traffic statistics for the Brussels region, even statistics of *military* traffic for this region, do not address this issue.

Perhaps the most relevant evidence on bringing up troops came from a French account of a move (KASTAINE 'A') of troops from Amiens to Paris.¹⁷ 12 trains set off; only 1 reached Paris. But the most telling points are the way the railwaymen viewed it. First of all, at a time when serviceable locomotives were the greatest constraint on their operations, they were ordered to provide a couple of locomotives here, a couple there, more at a third station, merely to act as *reliefs* for these military trains, just in case their own locomotives suffered unserviceabilities. Then the slow progress of these trains is recorded 'in spite of the fact that 2/3 of the haul was to be with German equipment'. That casual remark conjures up a picture of a system on which maintenance has been so chronically deferred that every journey is plagued by a succession of hot axle-boxes, failed injectors, and a dozen other critical faults. Finally, the account noted that no further progress was made after 10 June when an order went out that, because attacks on moving trains had become so prevalent, no further movement was to take place by day. Here was evidence for the effectiveness

¹³ TNA AIR 40/1669. Bombing Analysis Unit Report No 1, *The Effects of the OVERLORD plan to Disrupt Rail Communications*, dated 4 Nov 44.

¹⁴ Harrison (1951)

¹⁵ Harrison (1951) notes that the US forces called this 'Chatanooga Day'.

¹⁶ Zuckerman, 1978, 300.

¹⁷ BAU Report No 1, para 62.

both of attacks on maintenance centres and of the strafing of trains. Unfortunately, no attempt seems to have been made to follow up these points in a systematic way.

There is an interesting contrast between the rather partisan way in which Zuckerman's Bombing Analysis Unit in France set about proving that Zuckerman had been right all along and the Bombing Survey Unit in Italy established by the HQ RAF Mediterranean / Middle East Operational Research Section.¹⁸ Italy too had seen a shift in bombing policy, with marshalling yards receiving the greatest weight of bombs in January-March 1944, followed by a massive switch to bridges from April. In Italy too, traffic statistics were located, but here the analysis was focused on military trains. The numbers of these fell from an average of 16 trains/day to 3 trains/day by the end of January, and to zero by the end of February. The report made no attempt to declare whether attacks on marshalling yards or on bridges were inherently superior, being more interested in relating inputs to outputs. For the most profitable type of bridge, an average weight of bombs of 37 tons was required to close a bridge; repair took an average of 4.3 days. In contrast, marshalling yards had received 1189 tons of bombs in January (bridges having received 584 tons in that month), 509 tons in February (bridges receiving 151 tons). In fairness, disentangling strategic causes of disruption from the tactical effect of cuts would have required a depth of evidence that simply could not be obtained.

What lessons can we draw from these events? First, I suggest, that discussion of effects requires clarity of argument. This is assisted by an influence diagram. Analogies, biological or otherwise, may stimulate thought but they do not convince.

Secondly, it really is necessary to persuade by rational argument all the relevant parties. Unless subordinate commanders understand why the campaign has been shaped the way it has and are happy with the reasoning, their actions are unlikely to accord with the overall intent, even if they do not consciously try to flout it.

And thirdly, analysts should not lose sight of the commander's intent – as the Bombing Analysis Unit seems to have done.

¹⁸ TNA AIR 20/7890. *A Study of the Bombing of the Central Italian Railway Lines during Operation STRANGLE*, dated Aug 45.