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THE GEOGRAPHY OF NUCLEAR PROLIFERATION NETWORKS
The Case of A.Q. Khan

Justin V. Hastings

This article uses a geographic approach to examine one aspect of the nuclear black market: the coordinators who bring buyers and sellers together, and transport goods between them. The most important factor in determining the geographical structure of a proliferation network is the network coordinator’s access (or lack thereof) to unique state resources. Coordinators with access to state resources and prerogatives can avoid embedding themselves in hostile countries or relying on commercial infrastructure, often leading to territorially diffuse logistical networks. Coordinators without such access are forced to rely on commercial infrastructure and favorable local political, economic, and social conditions, often resulting in territorially centralized logistical networks. This is illustrated through case studies of Abdul Qadeer Khan’s supply networks to Pakistan, Libya, and Iran. The article concludes with some observations about the implications of a geographical approach for understanding nuclear proliferation networks.

KEYWORDS: Nuclear proliferation; black market; A.Q. Khan; Pakistan; Libya; Iran

On February 11, 2004, President George W. Bush gave a speech on nuclear proliferation that highlighted not only the traditional US concern with weapons of mass destruction and the states and terrorist groups that might use them, but also new ways in which they might acquire such weapons:

In recent years, another path of proliferation has become clear, as well. America and other nations are learning more about black-market operatives who deal in equipment and expertise related to weapons of mass destruction. These dealers are motivated by greed, or fanaticism, or both. They find eager customers in outlaw regimes, which pay millions for the parts and plans they need to speed up their weapons programs. And with deadly technology and expertise going on the market, there’s the terrible possibility that terrorists [sic] groups could obtain the ultimate weapons they desire most.¹

No longer was nuclear proliferation solely a matter of cooperation between states. Non-state actors who traded nuclear technology and knowledge in a black market were now a genuine proliferation threat, in terms of supplying both states and other non-state actors such as terrorist groups. Bush went on to discuss in detail the network that had just been made public, and that was seen as the greatest exemplar of this new “path of proliferation”—the Abdul Qadeer Khan network.
The revelation of Khan’s global smuggling operations indicated that nuclear proliferation may have entered a new and more dangerous phase, one accelerated by globalizing technologies such as telecommunications and cheap and fast transport, where the knowledge of how to build nuclear weapons has spread to developing countries, and the ability to manufacture components for nuclear facilities (especially uranium enrichment technology) is no longer solely the province of companies in developed, and presumably well-regulated, countries. Many observers marveled at the sheer number of countries and suppliers involved in A.Q. Khan’s network—in Europe, North America, East Asia, the Middle East, and Africa—how much customers, including countries like Libya, were able to get on the black market as a means of furthering their nuclear goals, and that Khan was able to get away with it for so long.

Since then, President Barack Obama has followed in the previous administration’s footsteps. His 2010 Nuclear Posture Review again identified the black market as a proliferation problem, noting that “[a]lthough terrorist groups are currently believed to lack the resources to produce weapons-usable nuclear material themselves, the vulnerability to theft or seizure of vast stocks of such nuclear materials around the world, and the availability of sensitive equipment and technologies in the nuclear black market, create a serious risk that terrorists may acquire what they need to build a nuclear weapon.”

The nuclear black markets referred to by both the Bush and Obama administrations are nuclear proliferation networks comprised of three types of actors: buyers (states like Libya or non-state actors like terrorist groups), sellers (states like Pakistan or non-state actors such as engineering firms in Europe), and the people who actually run the black markets—the coordinators who, through their support networks, knowledge of smuggling routes, and connections with potential buyers and sellers, can complete successful transfers of radioactive sources, nuclear material, and nuclear components. These coordinators are akin to the “brokers” of drug trafficking and terrorist recruitment networks—they have influence largely because they are able to connect, either through social or transportation ties (or both), two distinct groups of people.

This article uses the various proliferation networks built by A.Q. Khan from the 1970s onward to investigate one aspect of this nuclear black market: the coordinators. Using a geographic approach to proliferation networks, it argues that the tools and resources to which the coordinators have access play a large role in determining the geography of proliferation networks—where nodes within the networks are located, how materials are moved around the world, and the logistical challenges proliferation networks face. While the future of the nuclear black market may or may not lie in non-state actors, coordinators without access to state resources are forced to rely on infrastructure they do not necessarily control for both supply and transport, forcing the geographical distribution of their networks into transportation pathways and advantageous locations that provide access to that commercial infrastructure. Coordinators who have access to state resources are able to operate in a way that bypasses commercial infrastructure and locations, which results in geographically more diffuse logistical networks. I close with a discussion of the implications from this research.
The Geography of Nuclear Proliferation Networks

A geographic approach to proliferation networks does not invalidate the traditional approach to proliferation so much as takes it in a different direction, in two respects. First, a geographic approach attacks a different (and prior) element in the causal chains usually associated with network analysis in international relations. Second, a geographic approach uses conceptions of nodes and links based not only on the relationships of nodes to each other, but also on the relationships between nodes and links, and nodes and territory.

Traditional network analysis in international analysis is primarily concerned with how a network affects its external environment or, more relevant here, how the internal structure of the network—the relationships among the nodes—affects the actors within the network and leads to political outcomes. The geographic approach focuses instead on how the nature of the network actors—and the spatial distribution of the technological and transportation infrastructure they use—shape the structure of the proliferation network, and, more specifically, how it is physically arrayed across the world.

This analysis requires a rethinking of nodes and flows. Although there is nothing per se stopping links between nodes from being the physical movement of goods, in practice, most traditional network analysis in international relations assumes nodes are states or organizations (or, in the case of terrorist networks, individuals), and the links between the nodes are social or treaty relationships or some other form of cooperation. In his work on proliferation networks, for instance, Reed College political scientist Alex Montgomery treats entire countries as nodes, between which flow nuclear components and expertise. This approach works well if the proliferators are governments. In traditional proliferation rings, states are simultaneously the suppliers of technology and expertise, the coordinators (through government-to-government agreements) for the logistics networks that move goods between countries, and the buyers of that technology. There is little need to think about the logistics of cooperation because one state’s decision to transfer physical material and machine components directly to another state makes that transfer essentially a fait accompli (as opposed to tacit knowledge transfer, as Montgomery points out).

By contrast, the nodes of political geographers’ illicit transnational networks are people or organizations anchored in a specific piece of territory—a city, region, or country with a specific set of social, political, and economic characteristics. These characteristics shape and constrain the nodes and channel the movement of people, goods, and information. Since the nodes and flows are both anchored in territory, of central importance to a geographic understanding of networks is not only where the nodes are, but how exactly the people, goods, and information are being moved from point to point—over what kind of terrain, using what kind of transportation mechanism. The focus here is thus on the logistical networks by which proliferators move physical technology (and nuclear material) from origin to destination; the links are not social connections but physical flows. This is important because nuclear black markets, however we think of them, are liable to have non-state actors (a direct state-to-state transfer would not require entry into a market) or at least arms-length interaction between states. When a non-state actor such as a terrorist group or a private firm is involved, it is more difficult to
assume that nuclear material and components will be transferred successfully, since these non-state actors may be at the mercy of potentially hostile states. What a geographical approach allows us to do, in essence, is to problematize the logistical challenges that proliferation networks might face. A proliferation network with logistical challenges to overcome is liable to look different, both structurally and how it is arrayed territorially, from one that has fewer logistical challenges.

Actors in a proliferation network—buyers, sellers, and coordinators—collectively face three fundamental logistical problems: how to get the goods out of the origin facility (and then out of the origin country), how to get the goods from the origin country to the destination country, and how to get the goods into the destination country. Buyers and sellers can be either states or non-state actors such as terrorist groups or private firms. Since it is the coordinator who provides the links between buyers and sellers, and thus has the largest territorial “footprint” (within buyer and seller countries, between buyer and seller countries, and within transit countries), I will focus on coordinators in this article.

The key variable in determining the geographical layout of the logistical networks created by coordinators is the access that they have to state resources. Coordinators who have access to state prerogatives and resources can avoid setting up logistical support structures that are embedded in potentially hostile countries, while their control of their own means of transportation allows them to bypass legitimate commercial transportation and economic infrastructure when they move goods. The territorial layout of these networks thus tends to be either direct between two proliferating states (if they are transporting materials themselves directly), thus bypassing commercial infrastructure (and other countries’ ability to interdict them) and unfriendly countries or, if there are multiple suppliers, territorially dispersed routes between suppliers and the buyers.

On the other hand, coordinators without access to state prerogatives and resources lack both of these advantages, and so must set up support structures that depend on advantageous economic, political, and social characteristics of their host countries, and move their goods through economic and transportation infrastructure often controlled by hostile states. The result is that the territorial footprint of these networks hews to the legitimate “commercial” landscape, moving through commercial hubs and countries with favorable political, economic, and social characteristics. In the next few sections, I examine the effect of access to state resources more systematically by looking at different networks that involved A.Q. Khan in the role of coordinator. In the case of the Pakistan supply network, Khan had access to state resources. In the case of the Libya supply network, Khan’s resources were quite different. Finally, in the case of Iran, Khan used state and non-state resources at different points, allowing us to examine the effect that state resources have on logistics even within the same network.

**Coordination with Access to State Resources: Pakistan’s Supply Network**

State actors in nuclear proliferation networks have several characteristics that non-state actors lack, largely due to their sovereign status. First, states control territory and thus the nodes in the transportation infrastructure needed to move goods around the world (even
if the actual containers are owned by private companies). Through rules and regulations, states control the political and economic characteristics that make certain pieces of territory more or less attractive to non-state actors. Second, states control access to this infrastructure through control of their borders, a characteristic that even weak states have an incentive to maintain as the primary symbol of their external sovereignty. Third, and most importantly, states can use the resources and prerogatives associated with external sovereignty—notably the trappings of diplomacy and the presumption of foreign non-interference—to their advantage. With the use of military and state-owned transportation infrastructure, embassies, consulates, and personnel with diplomatic immunity, states can bypass the need to anchor themselves as deeply in the political and economic landscape of other countries as non-state actors do when they engage in illicit activities. With the presumption of foreign non-interference within their borders, states also solve one of the more important problems faced by non-state coordinators. For example, Stanford University’s Chaim Braun and Christopher Chyba define “second-tier” proliferation rings as networks wherein the suppliers, coordinators, and buyers are all (non-nuclear, developing) states, and thus face fewer external logistical barriers to proliferation. Since it is the governments that are proliferating, there is no concern about moving goods or information into the buyer country, or even out of the supplier country. If the goods are moved by government transport (say, military cargo planes), even the task of moving the goods between the two countries is minimized, and the need to geographically centralize the logistical networks is also minimized.

The supply network that Pakistan used to acquire the capacity to build nuclear weapons in the 1970s and 1980s was dependent on state prerogatives. This affected how the network was spread across the world. Pakistan received some nuclear assistance from China, but after France and Canada ceased to provide nuclear reactors to Pakistan due to proliferation concerns, the Pakistani government was forced to use more creative measures to build nuclear weapons. In practice, this meant that even as the plutonium reprocessing route to weapons stalled amidst other governments’ lack of cooperation, Pakistan prioritized the uranium enrichment route, a route that involved the use of foreign companies as suppliers.

Critically, unlike building a reactor, uranium enrichment required little official cooperation from foreign governments, particularly if the Pakistani government had scientists who knew how to build centrifuges (and all of the supporting equipment) and knew where to buy the components on the open market. A.Q. Khan, a Pakistani metallurgist working at URENCO, the main European uranium enrichment facility, not only had the knowledge and the connections, but also the desire to help his country develop nuclear weapons. In December 1975, he left the Netherlands with centrifuge blueprints and offered his services to the Pakistani government, who put him in charge of the uranium enrichment program.

Khan immediately set about establishing a network to supply the parts needed to build a uranium enrichment facility. At the center of the network in Europe was S.A. Butt, a scientist who was accredited to Pakistan’s embassy in Belgium (and later France), as a senior diplomat. Butt set up an acquisition office in 1975 and began approaching companies in Europe for parts, based on lists of URENCO suppliers given to him by A.Q.
Khan. The European suppliers provided a large number of parts, including, in one case, enough maraging steel for 532 centrifuges, sent directly to Pakistan. In 1976, a team of Pakistani scientists went to buy valves (which, as individual components, were not prohibited from export) from Vakuum Apparat Technik in Haag, Switzerland. They then ordered a gasification and solidification unit for converting uranium into uranium hexafluoride and back again from CORA Engineering, also in Switzerland. The shipment was so large it required three Pakistani Air Force C-130s to fly it from Switzerland to Pakistan. Neither of these orders were secret—in fact, both companies sent technicians to provide service to Pakistan afterward. That same year, Pakistan ordered 6,500 steel tubes from Van Doorne Transmissie (VDT) in the Netherlands, which VDT shipped to Pakistan despite Dutch government concern.

Elsewhere, Pakistan’s embassy in West Germany established an office headed by Ikram ul-Haq Khan (no relation to A.Q. Khan) who, like S.A. Butt, was accredited as a diplomat and could buy parts in West Germany. He succeeded in buying vacuum pumps and gasification equipment from Leybold Heraeus and aluminum components from Aluminium Walzwerke. As part of Leybold Heraeus’s contract with Pakistan, a Leybold employee named Gotthard Lerch went to Pakistan and met with A.Q. Khan. Lerch would also later become involved in Khan’s illicit network.

Throughout the 1970s and 1980s, A.Q. Khan’s access to Pakistan’s diplomatic offices, credentials, and military transport shaped the Pakistani supply network’s geographic structure in a number of concrete ways. First, the network was, initially, not really a secret. The Pakistani government made many of the orders publicly, but denied they were for nuclear use. In other cases, it hid sensitive orders among a large shipment of less sensitive goods to throw customs agents off the scent. Because the Pakistani government did not state publicly that it would use the equipment it was buying for the development of nuclear weapons (or more specifically, the enrichment of uranium), in the beginning it was able to buy and import large amounts of equipment, such as when it sent the C-130s to pick up the orders in Switzerland. For as long as it could, Pakistan preferred to use legitimate routes and legitimate methods to obtain what it needed for its nuclear program. When it was forced to become duplicitious, Pakistan was able to do so—there were at least fifty-one organizations designated as false end-users for the nuclear supplies shipped to Pakistan.

Second, as nuclear supplier countries learned to close many of the loopholes in the export control regime and better monitor companies’ activities, the Pakistani government picked up the slack.

Personnel in Pakistani diplomatic outposts were tasked with ordering equipment while front companies were set up as the recipients. The advantages of external sovereignty accrue even to states that have weak or no control over their territory and people, as well as to governments that, in other circumstances, would be considered nothing but warlords or organized crime gangs. These advantages include the ability to place people and resources in the territory of any country in the world with which the state has diplomatic relations and to protect those outposts’ diplomatic correspondence from outside interference. Pakistan is certainly not the only country to take advantage of this “loophole.” Although it is unclear if North Korea has used its embassies to buy components for its nuclear program, Western analysts have long suspected that North
Korean diplomatic personnel have been involved in smuggling drugs, laundering money, and distributing counterfeit money through North Korea’s embassies. Few coordinators without access to state resources have this sort of global reach or the ability to act with legal immunity in countries where they possess few local ties. In contrast to states’ embassies, every terrorist cell must be adapted to dodge the “host” country’s law enforcement agencies, a task that requires a certain amount of anchoring in local political and economic conditions, customs, and languages.

These factors led the A.Q. Khan network to adopt a geographic structure that was noticeably different from networks with non-state coordinators. Because they did not have to embed themselves too deeply into the supplier countries, the purchasing agents were able to operate flexibly, out of any country where Pakistan had diplomatic accreditation. The routes themselves were also territorially diffuse; there were initially no logistical hubs because Pakistan had no need for them. The fact that the centrifuge components could be initially shipped without subterfuge, either on Pakistani government-owned transports or by commercial transport, meant that it was nearly impossible to interdict Pakistan’s shipments once the goods had left their countries of origin.

As European countries became more concerned about Pakistan’s program, the Pakistani government had to resort to greater and greater degrees of subterfuge. In 1975, the Pakistani government had approached a company in the Netherlands about buying power inverters (to convert direct current to alternating current) through its Brussels embassy. When this order fell through, a third-party company ordered the inverters from Emerson Electric in the United Kingdom on behalf of Pakistan’s Special Works Organization. A commissioning agent in West Germany likewise ordered another sixty inverters from Emerson. As Pakistan felt more pressure, even though it continued to take advantage of the prerogatives of the state, it was forced to rely increasingly on commercial purchasing agents and front companies. This had consequences for the logistics of its supply network: whereas before, components could be shipped directly to Pakistan, now they had to go through a third country. In 1980, two Pakistanis accredited to Pakistan’s consulate in Montreal used three Canadians as buying agents to purchase parts for more inverters in Canada and New York state. The parts were shipped through an agent in the United Arab Emirates (UAE), Khalid Jassim General Trading. As Pakistan increased its dependence on non-state infrastructure and middlemen, it also increased its reliance on commercial transportation infrastructure and logistical hubs, thus centralizing the movement of the goods it had ordered from non-state suppliers, and requiring its commercial agents to be embedded in the local politics and economies of other countries. Figure 1 shows the relative lack of hubs for obtaining and shipping nuclear components back to Pakistan. Although countries are listed as nodes (as they are in Figure 2), the actual nodes are technically individuals or companies located within those countries.

Coordination Without Access to State Resources: Libya’s Supply Network

Coordinators without access to the state resources discussed above face logistical constraints because they ultimately must move goods out of—and possibly through—hostile states,
and because they must rely on transportation infrastructure they neither created nor control. Both factors encourage them to move goods along commercial pathways and establish hubs in politically and economically advantageous locations. Coordinators in these networks face a tradeoff between the security of the route (in the sense of avoiding the power of the state), and costs and time. While nuclear traffickers could, in theory, use tunnels underneath borders, or move through the mountains and jungle, in practice, they often try to smuggle their goods through minor land and sea border checkpoints to minimize cost and time, even at the risk of diminished security. That is, they use the roads and ports that are built by governments to facilitate travel and therefore have to deal with the state directly, but try to minimize the chance of being caught by crossing the border at points where state security measures might be minimal, or officials might at least be more easily bribed. It should not be surprising, then, that Georgia, which is adjacent to both Russia and Turkey, has seen a number of nuclear material transshipment cases, or that Kazakhstan has bolstered security at a number of land checkpoints in a bid to stop nuclear trafficking. Turkey itself also may be a transshipment hub, especially for materials being smuggled by ship through the Black Sea.

FIGURE 1
Structure of Pakistan’s official nuclear supply network

Locations of Parts Suppliers

- Switzerland
- Netherlands
- United Kingdom
- Canada
- West Germany

Locations of Purchasing Agents

- Belgium/France
- West Germany
- Dubai

Shipping routes

- Commercial purchasing agents
- Diplomatic purchasing agents
Proliferation networks with non-state coordinators who are moving goods from one supplier to one buyer can often be characterized as fragmented “snake” networks, where some actors acquire small amounts of material and other actors then move it by land or sea through adjacent (or nearby) countries to their destination. In this sense, they are similar to some drug trafficking networks, whose structure allows them to move goods across borders by a limited number of people with no obvious command and control structure, but also renders them slow to recover when one of the links in the chain is severed. This appears to be the structure adopted by many radioactive material smuggling networks. The research of Georgian analyst Alexander Kupatadze, for example, suggests that many radiological smugglers in Georgia are not members of professional crime networks but are experienced smugglers who attempted to take advantage of their (chain-like) smuggling networks to sell radioactive materials.

But this logic of the tradeoff between time, cost, and security applies just as much to larger-scale proliferation networks with non-state coordinators. For coordinators who need to move large quantities of components long distances on a reliable basis from multiple suppliers (almost the exact opposite of Kupatadze’s opportunistic smugglers operating in an unstable market), this reliance results in the territorial centralization of proliferation networks in commercially viable logistical hubs around the world. The coordinators can more efficiently receive and dispense information and goods to the peripheral nodes, but also open the network up to disruption if the coordinator is captured or otherwise compromised.

This is because of the spatial distribution of economic and transportation infrastructure around the world. A legitimate multinational corporation, for example, might manufacture a product in southern China for sale in western Europe. Southern China has political and economic conditions that make it ideal for manufacturing—such as low wages and permissive regulations—while western Europe has conditions that make it attractive as a node for sales: consumers with buying power and a commercial infrastructure adept at distributing and advertising the product. The route and nature of the flow—how the product is moved between China and Europe—is shaped by the physical geography of the area between the two regions and the political and economic conditions of nodes in between. Namely, it is most cost-effective, assuming time is not an issue, to move the product by sea from China, change ships in Hong Kong or Singapore (which are both geographically convenient for transshipment, and have the infrastructure to move cargo from ship to ship quickly and efficiently), and then ship the product to Europe (or to Dubai, another major transshipment port, and thence to Europe). While the nodes on either end may be territorially diffuse, for long distances, then, the logistical pathways tend to go through chokepoints that limit non-state actors’ options for movement.

The economic infrastructure contained within or between these nodes—seaports, airports, and highways, for example—is both encouraged and, in some cases, controlled by governments, which also create the regulatory framework for companies to conduct business within and through their countries. For legitimate companies, this is usually a good thing. For organizations trying to move goods illicitly, this is less than ideal. Since the infrastructure most suitable for transporting goods across great distances in comparatively
short periods of time is also often the infrastructure most suited to state control, illicit organizations are faced with a dilemma of either trying to sneak their goods through these countries, or avoid the countries entirely and move more slowly over smaller distances. Either way, coordinators have to set up support structures—front companies, bribed or otherwise friendly officials in the right places, safe houses—to help them either avoid state-controlled chokepoints or to slide through them. The result of using subterfuge to move through legitimate commercial transportation infrastructure is that, for shipping goods over long distances, the routes tend to move through logistical transshipment hubs, and illicit actors have to put down roots that allow them to operate illicitly in various hubs, roots that are constrained by political and economic conditions.

The network that A.Q. Khan built to supply Libya in the 1990s and early 2000s is a prime example of a large-scale network coordinator without access to state resources and prerogatives. To be sure, this is not an uncontested understanding. Pakistan itself was usually considered as the relevant node in these proliferation networks, either because there is some question as to how much Pakistani government officials knew of Khan’s activities, or because, regardless of what they knew, the presumed policy “solution” to the A.Q. Khan network was to pressure Pakistan to rein in control of its nuclear establishment. If Khan’s network was largely a result of Pakistan’s (perhaps willful) failure to control its scientists and materials, then perhaps it would be a mistake to refer to A.Q. Khan as a non-state actor at all. Some authors even go so far as to describe Pakistan (the government) as proliferating through A.Q. Khan. The workings of the network, in this view, were encouraged to such an extent by Pakistani officials that A.Q. Khan’s activities could not be considered “non-state” in any sense of the word. Yet focusing on the geographical distribution of the links and nodes in Khan’s Libya supply network allows us to sidestep the question of whether Khan was a state or non-state actor. Regardless of whether elements of the Pakistani government knew about Khan’s activities, or even supported him as a matter of policy, they did not provide him with access to the prerogatives and resources of the Pakistani state. This resulted in a proliferation network whose spatial distribution was noticeably different from that of the Pakistani supply networks of the 1970s.

According to International Atomic Energy Agency (IAEA) documents, Khan approached Libya with offers of centrifuge technology in 1984, but Libyan officials decided to pass due to the technical complexity of the project. From 1989 to 1991, Khan again dealt with Libya, this time providing information on P-1 centrifuges. Khan in 1997 then provided twenty old P-1 centrifuges and components for two hundred more, all of which could be shipped from Pakistan to Libya through Dubai without too much trouble. While Libya pursued testing of P-1 centrifuges, it was even more desirous of P-2 centrifuges, an interest it expressed that same year. Khan delivered two complete demonstration models in September 2000. After this, Libya apparently placed an order for 10,000 centrifuges, the supporting equipment for the enrichment facility, and a precision machine workshop to manufacture its own centrifuges.

This was when the major shipments started, not only for uranium enrichment equipment but also for nuclear materials. According to the IAEA, Libya received two uranium hexafluoride shipments from the Khan network. The first consisted of two small
cylinders hidden among seventy-nine crates of components flown from Kahuta to Tripoli aboard a commercial freight flight through Dubai in September 2000. The second was a single large shipment the following February. Together, the shipments totaled 1.8 metric tons. The second shipment, a large cylinder, was transported from Pakistan to Libya via Dubai on a “Pakistani airliner.”

As for the other pieces, the workshop arrived in 2001, and the centrifuge components began arriving in December 2002, according to the IAEA. For the components, there were apparently two supply sub-networks within the larger Khan network. The first network was managed by Khan associate Gotthard Lerch. In 1999, Lerch contracted out the manufacturing of the control system for the centrifuge cascade to his own associate, Gerhard Wisser in South Africa. Wisser in turn brought his own employee, Daniel Geiges, in on the contract, and sub-contracted out the manufacturing of the piping and feed systems to encase the centrifuge cascade to a South African firm, Tradefin Engineering, run by Johan Meyer. The designs for the components were based on those produced by Lerch and Wisser’s firm in the 1980s, and after Wisser met with Khan associate B.S.A. Tahir, Lerch flew down to South Africa and explained them to Geiges in 2001 and 2002. Lerch also ordered vacuum tubes from a company in Liechtenstein, and had them shipped to Tahir in Dubai. Tahir ordered aluminum alloy from Abu Bakr Siddiqui, a middleman in the United Kingdom who had shipped various dual-use and non-nuclear parts to A.Q. Khan and Muhammad Farooq, Khan’s deputy, in the 1990s, but British customs officials in 1999 seized the shipment, which was destined for a front company owned by Tahir in Dubai, and ultimately Pakistan. Siddiqui also shipped parts to Deepsea Freight Services, which forwarded them to Khan Research Laboratory’s (KRL) front companies in Pakistan. In turn, these companies then sent the components (by air) from Pakistan back through Dubai for transshipment to Libya.

The other sub-network contracted with Comercial Nork, a Spanish company, to produce two flow-forming lathes and a number of specialized machines. Comercial Nork subsequently trained Libyan technicians in the use of the machines, and shipped them to a company in Dubai. That company then transferred them to Tahir, who, in November 2000, sent one of the lathes to Tradefin Engineering. Although Meyer successfully built the stainless-steel piping and feed system—which eventually reached three stories high, weighed 200 tons, and took eleven crates to store—he never used the lathe, and sent it back after a few months, after which it ended up in Libya. Other machine and centrifuge components shipped to Dubai allegedly came from companies in Italy, Australia, Switzerland, and Turkey. Friedrich Tinner, another old Khan associate, also supplied parts to Tahir through suppliers in Europe, including his son, Marco Tinner. Marco’s Swiss company, Traco, shipped 5,000 centrifuge components to Dubai.

Originally, the plant to manufacture centrifuge components was supposed to be located in a warehouse in Dubai, and Marco Tinner’s brother, Urs Tinner, ran the technical aspects of the operation. Desert Electrical Equipment Factory, a front company in Dubai, reportedly trained Libyan scientists and manufactured some components, but Tahir had difficulty finding skilled technicians in either Dubai or Turkey, and he and Khan began looking for a suitable alternate location. While the network already had contracts in South Africa, maraging steel was heavily controlled there, so it was not a suitable location for
building centrifuge tubes. Instead, Khan and Tahir decided to move the operation to Malaysia, and Urs Tinner subsequently went there in April 2002 to serve as a consultant. The choice of Malaysia was not random, and illustrates how Khan’s network was constrained by the need for social ties and the political and economic characteristics of the countries in which it operated. Khan needed a country that simultaneously had the technological sophistication to manufacture the components, regulations that were sufficiently lax to facilitate the manufacture and export of those components, and a social network to ensure the operation’s success. The manufacturing company, Scomi Precision Engineering, or SCOPE, was a subsidiary of Scomi Group, for which Tahir was a director between 2000 and 2003. After Scomi signed the contract with Gulf Technical Industries in Dubai in December 2001, SCOPE was set up and produced a number of centrifuge components, notably the centrifuge tubes that were found on the BBC China in October 2003 when it was boarded by US and Italian authorities. Urs Tinner brought the designs for the components with him, and took them when he left, but workers at SCOPE assumed this was due to trade secret concerns rather than nuclear proliferation. The manufacturing company constructed the tubes out of materials using machines it bought from companies in Singapore and Japan. A South Korean company was also involved in supplying the Khan network with balancing machines, which arrived in Libya in June 2002. SCOPE began sending components to the companies in Dubai in December 2002. The shipment that was caught on the BBC China consisted of 25,000 parts in five wooden containers mislabeled as “agricultural machinery,” and had been sent from Malaysia in August 2003.

Figure 2 maps out the movement of components and equipment between countries, and makes clear the centrality of Dubai, to the point that it might be considered a “network broker” in traditional network analysis, since all goods were being funneled from Dubai to Libya. The UAE’s political and economic environment, combined with its role in the infrastructure of global commerce proved to be an ideal hub for the Khan network. As such, Dubai is a good case study for the kind of hub that a coordinator without access to state resources would look for. Dubai has among the highest percentage of foreigners in the world—an estimated 70 percent of the United Arab Emirates’s population are non-citizens; Dubai’s non-citizen percentage is probably higher. The front companies set up by the Khan network were in that respect not particularly unusual. Since the 1970s, Dubai has also had a longstanding policy of encouraging foreign direct investment with low taxes and lax regulations in free trade zones. Prior to 2003, UAE customs officials were reportedly more concerned with drug and cigarette smuggling than nuclear proliferation, so Khan and his associates were not engaged in activities that were of special interest to the authorities.

Khan used shipments to and from Dubai (and to a lesser extent South Africa) to mask the origins and destinations of the components. This use of certain countries to hide the destination of goods masks the larger point. Any other non-state actor shipping a container from Malaysia to the Mediterranean would most likely also have gone through Dubai. In the 1970s, Dubai also began developing its port facilities as a means to offset its declining revenues from oil. While Bahrain, Qatar, and Abu Dhabi also encourage foreign direct investment (particularly banking), only Dubai has such a large port capable of
efficiently transshipping containers. It is, in fact, the only port in the Middle East that is among the world’s ten busiest containerized transshipment ports, the rest being in east and Southeast Asia, and Western Europe. To minimize costs and shipping times, legitimate commercial shipping operates much like airlines’ hub-and-spoke systems. There are few ships that offer point-to-point service. Instead, ships sail to and from transshipment ports, where containers are transferred as quickly as possible to other ships that may go on to the ultimate destination or to another transshipment port.

As such, if Khan wanted to ship components from Pakistan, or even from anywhere in East or Southeast Asia to the Mediterranean while keeping costs down by using legitimate commercial shipping infrastructure, he would likely have had to ship them through a transshipment port in the Middle East—either Dubai or Salalah, Oman (the next busiest Middle East transshipment port). Dubai’s encouragement of foreign companies and expatriates, and its relatively efficient economic infrastructure, made it the most attractive choice for serving as both the logistical and command and control hub for the
network. Arguably it would have been difficult to run such an extensive enterprise without state support out of any other country in the Middle East.

While Khan was indeed quite cunning in how he bypassed export controls and disguised his movements, as he shifted from being dependent on the infrastructure that a state could provide him to being dependent on using illicit support structures and commercial infrastructure, his network's geography changed. The centralization of logistics and certain aspects of command and control in Dubai allowed the Khan network to move goods relatively quickly and efficiently, but made it more vulnerable to choking. Western intelligence services had been following the BBC China for nearly a year, suggesting Tahir had contracted to send parts on the BBC China more than once between Dubai and Libya. This routinization of the smuggling eased transaction costs, but meant that the United States knew what to look for once the components left Dubai in August 2003. The Khan network could have thrown Western intelligence agencies off the scent by avoiding commercial infrastructure entirely, and using only illicit routes that bypassed legitimate state-controlled chokepoints. From the network's perspective, however, this was not feasible. The goods being "smuggled" by A.Q. Khan and his associates had to be bought from legitimate companies, some of whom did care—at least somewhat—about export controls. The goods themselves were also too large and too numerous to smuggle on the back of a truck over some mountain road, to say nothing of the problem that Libya was geographically nowhere near Pakistan. Such an undertaking would have required the Khan network either to purchase its own means of transporting goods by air and sea, or to limit the geographical reach of the network's suppliers, so that it could move goods only short distances.

But Khan did not rely on suppliers that were territorially proximate to Libya, and instead used suppliers all around the world. This has led some analysts to comment that one of the disturbing things about the network is its global reach, particularly the fact that it was able to source components from countries outside of North America and Western Europe (and their supposedly stricter export controls). But both the globalized nature of the network and specific countries to which the work was outsourced show more about the limitations of the network than its ingenuity.

First, outside of the first-tier of developed countries, there remain a limited number of second-tier countries capable of manufacturing precision components for centrifuges. Although Malaysia had clearly reached the point where it could properly manufacture precision components, the contractor companies in South Africa had considerably less success (even though South Africa had by then already built and then dismantled half a dozen nuclear weapons). In both cases, the manufacturing companies were assisted by engineering consultants sent out by the Khan network from Europe. Most of the other components were sourced from developed countries, with the electronics manufacturers in Turkey being the only other middle-income outlier. This is not to say that low-income countries are incapable of building nuclear weapons (or at least building the components for machines used to create the material for nuclear weapons)—clearly Pakistan, India, China, and North Korea have all built nuclear devices. But Khan's use of South Africa, Malaysia, and Turkey suggests that while middle-income countries are on the cusp of being able to manufacture the parts for nuclear facilities indigenously, this is still a
relatively contained subset of the world’s countries. Bangladesh, for all its export of textiles, for instance, was in no position to do what Malaysia did.

Second, while the many personal connections among the principals and middlemen in the network did increase the efficiency and security of operations—Gotthard Lerch could ask Gerhard Wisser to work on his behalf in South Africa, for example—the reliance on those personal ties also limited the geographical scope of the network. The Khan network went to Malaysia, Turkey, the UAE, and other countries in part because they already had built-in support structures for illicit and semi-illicit operations. B.S.A. Tahir chose Malaysia as one of the manufacturing centers not only for its newly advanced technical expertise, but also because he was a Malaysian permanent resident, was a partial owner of the Scomi Group that owned SCOPE, and had connections to the ruling class of the country. A coordinator with state resources would not have needed to do this, and indeed, in the initial iteration of Pakistan’s supply network, Khan did not rely so heavily on personal ties.

This is a problem faced by non-state illicit networks of all types: often the best way to ensure trust within a criminal syndicate is to bring in members who share familial, ethnic, historical, or legitimate work connections. Illicit networks operating across international boundaries often must establish nodes in countries where there are members of the same ethnic group, clan, religion, and so on, or pass on their illicit goods to another criminal network that does have those connections. This is why ethnic crime syndicates such as Chinese triads, for all their vaunted global reach, tend to congregate in Chinatowns in Western Europe, North America, and Southeast Asia, or why drug trafficking syndicates tend to be fragmented into those who produce the drugs, those who transport them, and those who distribute them. The Khan network’s principals involved themselves in every aspect of the process, from design to manufacturing to transportation, rather than handing off some responsibilities to other networks. Tahir and others within the network seem to have contracted on a regular (if discrete) basis for many of the peripheral machines and parts, but the most central aspects of the network—the transit hub in Dubai, and the manufacturing facilities in Malaysia and South Africa—were based on personal relationships, leading to the question of how geographically expansive the network could have gotten without giving up control over at least parts of the process.

From a geographical perspective, the network was in a double bind. The parts that it needed could only be sourced from countries that were not necessarily anywhere near the ultimate buyer country due to the limited number of countries capable of manufacturing them, and it could only source the really sensitive parts from countries where it had personal connections (which, again, were not necessarily anywhere near the buyer countries). Because of these issues, it was forced to become a global network to supply Libya, but without the benefit of the logistical and diplomatic prerogatives of the state, which meant it had to rely on logistical pathways that used commercial infrastructure, and embed itself in locations around the world that provided the greatest access to that commercial infrastructure.
Hybrid Coordination? Iran's Supply Network

Pakistan and Libya were not the only supply networks for which A.Q. Khan served as a coordinator. Iran and North Korea also seem to have received components, materials, and expertise through Khan, although specific information on what Khan supplied is significantly more limited than what is available for either Pakistan or Libya. Iran’s dealings with Khan provide an especially interesting case study to illustrate the effect that a coordinator’s access to state resources and prerogatives has on the geographical structure of a proliferation network. Some of the sections of Iran’s supply network were able to take advantage of state resources thanks to Khan’s position as head of Khan Research Lab (particularly the supply routes that ran to Pakistan), while other sections of the network (such as those running through Dubai to Iran) looked more like the commercial infrastructure-dependent routes seen in the Libya supply network or in radioactive material smuggling networks.

A.Q. Khan started working with Iran as early as 1987 as a Pakistani government trainer for Iranian nuclear engineers; this official start to his future “freelance” work for Iran thus blurs the line on how much was known (and condoned, or even ordered) by Pakistani government officials, and how much was genuinely illicit. According to some sources, it was in fact Gotthard Lerch, the Khan associate who had supplied Pakistan’s official network with vacuum valves in the early 1980s, who began A.Q. Khan’s move toward use of non-state resources in his logistical network. Iranian buyers of conventional weapons parts approached Lerch in 1987, and suggested he could also sell them uranium enrichment equipment. After some negotiation, the Iranians agreed to meet with Lerch and his associates in Dubai. The meeting with the Khan network was apparently a one-off affair in which Khan himself was not present. Instead, Lerch and his colleague, Heinz Mebus, met with Iranian representatives in the apartment of Muhammad Farooq, the uncle of B.S.A. Tahir. Lerch handed over two complete P-1 centrifuges sent by Khan from the junk pile at KRL, as well as technical documents. After transferring $10 million into Farooq’s account, the Iranians took the centrifuges and the documents back on the plane with them to Iran. They then used the documents to buy components on their own.

The network made Iran another offer in 1993; more substantial equipment shipments were apparently the result. In 1994, Iranian representatives again went to Dubai several times. During this series of transactions they met with Tahir, Muhammad Farooq, and Khan himself, and handed over several million dollars in cash, stowed away in suitcases. The Iranians wanted P-2 centrifuges, but Khan was unable to smuggle P-2 components out of Pakistan at this time, so he gave them the components for 500 P-1 centrifuges and documentation with specifications for P-2 centrifuges. There were several shipments made in January, March, and May 1994, and some time in 1995. The logistics of the shipments were similar: Khan shipped the parts from Pakistan to Dubai, where they were stored in a warehouse. Tahir’s company, SMB Computers in Dubai, then arranged for the parts to be shipped as computer parts on an Iranian merchant ship from Dubai to an Iranian computer company in Bandar Abbas, Iran. One shipment also included bellows (flexible joints that break up a centrifuge rotor into several pieces, increasing its
efficiency) sent from Switzerland, and electronic equipment from Turkey. There were apparently a number of meetings between Iran and the Khan network from 1996 to 1999, mostly to deal with the poor quality of the parts Khan had sent to Iran. It is unclear if Iran ever obtained complete P-2 centrifuges, but as a result of Iran’s dissatisfaction with Khan, he supplied them with designs for the P-2 in 1996.

With Iran still not entirely forthcoming about what help Khan provided, it is difficult to map out the full network related to Iran, but we can glean several insights. First, Khan initially solved many of the logistical problems posed by smuggling by not really solving them at all. He was not at the first meeting with the Iranian agents in Dubai, and while he shipped the centrifuges and components to Dubai, the Iranians did the rest. Even what he supplied to Iran was (at first) mostly old equipment he already had in his possession at KRL, which were useless to Pakistan’s nuclear program after it successfully upgraded to the faster but more complicated P-2 centrifuges. For these parts, from a smuggling perspective, he had to solve only the problem of how to get them out of Pakistan and into Dubai—a single route. He did this by shipping small quantities at any given time and hoping they evaded inspection, a method similar to those used by regular smugglers. As Iran demanded more material, Khan was able to use his position at KRL to over-order incoming components and then export them back to Iran (or at least divert them to Iran). This is a fairly common smuggling technique, and requires a minimal support structure—usually either a cooperative customs official or simply poor oversight on the part of the customs service.

Because he was still relying on Pakistan’s state resources, he did not need to set up an extensive network of his own to get components into Pakistan, and thus did not encounter many of the difficulties that his non-state routes would later face.

Second, Iran’s proximity to Pakistan meant that there were fewer potential interdiction points once Khan got the components out of Pakistan. It was possible to transport goods by land from Pakistan to Iran, eliminating interdiction points entirely (with the possible exception of Pakistani customs officials, if the Pakistani government was not in on the operation), and apparently Khan did try to do this on at least one occasion. Outside of Iran, Dubai was the only transshipment point, and the short distance by sea or air from Pakistan to Dubai, and from Dubai to Iran meant that there was limited time and opportunity for other countries to interdict shipments, even had they been willing to at that time. Iran was thus in some respects the ideal customer for Khan: it was physically proximate and initially required little more than what Khan already had laying around or could send overtly.

Third, Khan’s Iran supply network involved the reactivation (or, in some cases, the reappropriation) of individual suppliers from the network he had helped to build with Pakistan, but without some of the prerogatives of the Pakistani state, such as the ability to use diplomatic personnel or (presumably) Pakistani military aircraft. The result was that on some routes, the network needed to rely both on commercial shipping infrastructure and to anchor itself in a country politically, economically, and culturally suited for its operations. The previous use by Pakistan of Dubai as a transshipment hub, and the presence of Khan’s associates in Dubai (already with companies equipped to deal with imports and exports), made Dubai ideally suited for this purpose, even over and above its territorial proximity to the relevant countries.
Conclusion

Analytically, a geographic approach to nuclear proliferation networks offers several advantages. Using a geographical approach, we can see the effect that access to state resources (and the lack thereof) has on nuclear proliferation, which will be useful to know when analyzing future networks that may not exactly match what we have seen in the past. The shifting structure of A.Q. Khan’s networks over time serve as particularly good examples of this, in large part because of Khan’s varying access to state resources over time. Particularly in networks that include non-state actors (or at least coordinators without access to state resources), such an approach highlights that, in addition to knowing who the actors are and how they are related, examining where those actors are, what they are actually trading (be it knowledge, nuclear material, or components), and what resources they have at their disposal gives a more complete picture of nuclear proliferation networks’ structure and behavior. More specifically, a geographical approach allows a focus on the logistical challenges that nuclear proliferation networks face, and helps us to understand the behavior of coordinators in those networks.

There are also policy implications. If there is in fact a black market where states can buy nuclear technology, the states themselves must make a choice as to how to proceed. If they use their own prerogatives and transportation resources, they will likely be able to acquire technology more securely and more quickly, but run the risk of discovery and sanctions from other countries. If they resort to coordinators without access to state resources, they can more easily cover their tracks (due to plausible deniability), but the middlemen will be forced to rely on infrastructure they do not control, and support networks that will be successful only inasmuch as they find countries with the right combination of political and economic conditions and location within the global economy. As nuclear supplies and expertise necessary for proliferation become increasingly difficult for states to obtain openly, or at least directly from other states, states that rely on coordinators without access to state resources will find themselves at the mercy of commercial infrastructure and encounter the same problems that many large-scale smugglers encounter when moving goods across long distances.

Finally, this analysis gives hope to countries seeking to contain proliferation, even proliferation as nebulous as that supplied by private companies and aided and abetted by non-state coordinators. Precisely because they operate without the benefits of state status, nuclear smugglers are dependent on conditions that limit their movements. In particular, the tendency toward logistical centralization in large-scale smuggling networks opens up a third type of country that can be instrumental in nonproliferation efforts: the country that contains logistical chokepoints. Bringing in countries that are likely to play an important role in the logistical networks of non-state coordinators would shore up many of the nonproliferation efforts that are otherwise concentrated on supplier and buyer countries.

NOTES


16. Much of the information for this section can be found in Weissman and Krosney, *The Islamic Bomb*, pp. 178–89.


24. Ibid., p. 119.
27. This is particularly true of terrorist networks. Al Qaeda, for instance, seems to have failed in its ability to establish a network in Somalia in the early 1990s precisely because it had neither state prerogatives such as embassies nor a deep understanding of the local culture. See Watts, Shapiro, and Brown, “Al-Qaeda’s (Mis)Adventures in the Horn of Africa.”
37. Kenney, “Turning to The ‘Dark Side,’” pp. 79–102, discusses this in the context of Colombian drug cartels.
44. Ibid., pp. 108–09.
45. IAEA Director General, “Implementation of the NPT Safeguards Agreement in the Socialist People’s Libyan Arab Jamahiriya,” p. 4.
47. IAEA Director General, “Implementation of the NPT Safeguards Agreement in the Socialist People’s Libyan Arab Jamahiriya,” pp. 5–6.
This is notably true of the Taiwanese criminal organizations operating in China, which tend to prey on
Frantz and Collins,
Bill Keller,
68. This is not unheard of among particularly wealthy smuggling networks. Colombian drug traf
67. Armstrong and Trento,
66. Armstrong and Trento,
65. Armstrong and Trento,
64. Corera,
63. United Nations,
61. Frantz and Collins,
59. Corera,
58. Corera,
57. Frantz and Collins,
56. Armstrong and Trento,
55. Frantz and Collins,
54. Armstrong and Trento,
53. Armstrong and Trento,
52. Frantz and Collins,
51. Armstrong and Trento,
50. Frantz and Collins,
44. Armstrong and Trento,
43. Armstrong and Trento,
42. Armstrong and Trento,
40. This is not unheard of among particularly wealthy smuggling networks. Colombian drug traffickers are known to have their own fleets of planes and cargo ships to move drugs into the United States and Europe from transshipment hubs in the Caribbean and West Africa. See Kenney, *From Pablo to Osama*, pp. 38–40, 67–69, and Vivienne Walt, “Cocaine Country,” *Time*, June 27, 2007, <www.time.com/time/magazine/article/0,9171,1637719,00.html>.

75. See Frantz and Collins, The Nuclear Jihadist, p. 156.

76. Ibid., p. 158.

77. Corera, Shopping for Bombs, pp. 65–66.

78. Frantz and Collins, The Nuclear Jihadist, pp. 159–161. See also Armstrong and Trento, America and the Islamic Bomb, p. 158.


80. See Armstrong and Trento, America and the Islamic Bomb, p. 167.

81. Ibid., p. 168.


83. Corera, Shopping for Bombs, pp. 69–70.


85. Armstrong and Trento, America and the Islamic Bomb: The Deadly Compromise, p. 168 See also IAEA Director General, “Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions 1737 (2006) and 1747 (2007) in the Islamic Republic of Iran,” p. 4. It is unclear if the documents handed over at the 1994 meeting between Khan and Iran were complete designs for the P-2.


87. Richard N. Cooper, “Tariffs and Smuggling in Indonesia,” (New Haven, CT: Economic Growth Center, Yale University, 1974).