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PROBABLE ECONOMIC TARGETS

FOR

TERRORISM BY RADIOLOGICAL ATTACK

by

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Biography

Timothy W. McBride has served within the Department of Defense in Washington, DC in a variety of analytic, staff and leadership positions since 1984 when he was hired as an associate computer scientist. He has completed three overseas tours in the Pacific theater, one in Japan and two in Australia. Prior to attending the Air War College, he served as a division chief and senior operations officer at a joint U.S.-Australian defense facility from 2002-06.

An Alabama native, Mr. McBride attended the University of Alabama as an Alumni Honors Scholar and graduated in 1983 with a Bachelor of Science degree in Computer Science. He also earned a Master of Science degree in Space Studies from the University of North Dakota in 1999. In addition, Mr. McBride has attended numerous other courses, including advanced topical seminars, specialized technical courses, and various managerial and senior leadership programs. He is a member of the adjunct faculty for the National Cryptologic School, has been an instructor with the Astronomy Department of the University of Maryland's Asian Division, and has been a guest lecturer at the Joint Military Intelligence College at Bolling Air Force Base.

Introduction

Although there have been no successful terrorist attacks within the United States since 11 September 2001, many terrorism experts believe that another is likely to occur in the near future. There have been a number of foiled attacks in the intervening years, some large in scale and others small, including plans to attack airport fuel pipelines[1], detonate a radiological dispersal device[2], and explode as many as 12 airliners over five U.S. cities.[3] Whether originating within the U.S. or abroad, terrorists continue to seek opportunities to strike targets in America. They also show a trend of increasing sophistication to defeat security practices already implemented since 9/11. The binary liquid explosive plot originating in Britain and plans by Al Qaeda-associated terrorist Jose Padilla to use a "dirty bomb" illustrate this trend. This latter example is the most frightening, as Al Qaeda has expressed the intent to acquire and use nuclear devices within the United States.[4] Osama bin Laden stated unequivocally in a December 1998 interview that "there is a duty on Muslims to acquire them.[5]" The acquisition by terrorists of components for a nuclear bomb, or a complete weapon, is obviously a grave security concern. Terrorists may encounter difficulties in obtaining, fashioning, transporting and detonating a nuclear bomb. Some have suggested that if Al Qaeda possessed a nuclear bomb then it would have already have been used against the U.S.; others believe that the terrorists may be waiting patiently for a date of significance to them or their movement to use such a device.[6] However, there are other methods

[1] Kathleen Koch, Kelli Arena and Jason Carroll, "Four Charged with Terror Plot at JFK Airport," *CNN.com*, 4 June 2007, http://www.cnn.com/2007/US/06/02/jfk.terror.plot/index.html.
[2] Dan Eggen and Susan Schmidt, "'Dirty Bomb' Plot Uncovered, U.S. Says," *The Washington Post*, 11 June 2002, http://www.washingtonpost.com/ac2/wp-dyn?pagename=article&contentId=A28493-2002Jun10.
[3] Sandra Laville, Richard Norton Taylor, and Vikram Dodd, "A Plot to Commit Murder on an Unimaginable Scale," *The Guardian*, 11 August 2006, http://www.guardian.co.uk/terrorism/story/0,,1842272,00.html.
[4] Charles D. Ferguson et al., *The Four Faces of Nuclear Terrorism* (Monterey, CA: Center for Nonproliferation Studies, 2004), 116.
[5] Bruce Lawrence, ed., Messages to the World: The Statements of Osama bin Laden (London: Verso, 2005), 72.
[6] Paul L. Williams, The Day of Islam: The Annihilation of America and the Western World (Amherst, NY: Prometheus Books, 2007), 33-34.

of nuclear attack which are simpler, less expensive and almost as psychologically effective as detonating a nuclear bomb. The use of radioactive materials against various soft targets offers these advantages to terrorists, making a radiological attack the most likely major terrorism strike against the U.S. in the near future.

Radiological Dispersal Devices

The common misconception about nuclear terrorism is that it invariably will involve the explosion of a stolen or crudely-fashioned nuclear bomb. While it is possible that Al Qaeda or some other terrorist group has obtained an intact nuclear warhead or the fissile material to make their own Hiroshima-type weapon, it is far easier to obtain the materials for a radiological dispersal device. Often called a 'dirty bomb', a radiological dispersal device (RDD) is designed to spread radioactive material over a wide area, rendering it unsafe for human use. An RDD may employ explosives to spread the material, but the blast damage is incidental to the radioactive dispersal.

The target population can be exposed to the radioactive material using simple, unobtrusive techniques that are likely to go unnoticed for some time, ensuring a high dosage of radiation.[7] If in solid form such as plates, discs or pellets, the radioactive material can be concealed in furniture, fixtures and other décor where it will not raise suspicion. Material in powdered form can be distributed over wide areas by mechanisms to spread it as dust, in home-made fireworks or even dumped over an area from a model airplane. Powdered materials represent the most dangerous form of RDD material as the fine particles are easily ingested and spread by person-to-person contact. These materials are also very difficult to clean up during

[7] Ferguson et al., The Four Faces of Nuclear Terrorism, 259.

decontamination; the tiny particles can lodge in small crevices or mix with other loose materials such as soil and plant materials. Demolition of contaminated structures and removal of contaminated soil is often the only method to ensure complete removal of the radioactive source materials.

Unlike the uranium and plutonium isotopes used in nuclear weapons, the radioactive material in an RDD has a relatively short half-life. Defined as the time for one-half of the radioactive atoms in a mass to undergo decay, a shorter half-life indicates that the isotope is giving off more radioactive decay products per unit time than an isotope with a longer half-life. This higher production of radioactive decay products – alpha and beta particles and gamma rays – makes the shorter half-life isotopes more effective in causing long-term damage to humans. The alpha and beta particles pose little danger to humans as long as they are not inhaled or ingested on contaminated food or water. Outside the body, alpha particles are stopped by a few inches of air; beta particles can be stopped by the skin, although direct contact with a source of beta radiation can cause serious burns. Gamma rays, however, can penetrate several centimeters of lead shielding. Human tissue can be injured by the ionizing effect of gamma rays, which can also produce irreparable damage to DNA and cause cancer.

Isotope	Half-Life
Cesium-137	30 years
Cobalt-60	5.26 years
Iridium-192	74.2 days
Iodine-125	60.2 days

Table 1. RDD-suitable isotopes

Table 1 shows a list of short half-life isotopes suitable for use in an RDD. Compare these with the half-lives of uranium-235 and plutonium-239, 710 million and 24,000 years respectively. A terrorist may use more than one isotope in an RDD; for example, he may include iridium-192 or iodine-125 to ensure an initial high dose of radiation, along with cobalt-60 or cesium-137 isotopes to contaminate the area for many years.

Compared to fissile materials, the isotopes for an RDD can be obtained quite easily within the United States. Cobalt and cesium are used extensively in medical radiotherapy devices, industrial gauges and measuring devices, and in commercial food sanitizers. The wide range of applications for radioactive materials makes it very difficult to regulate their use or secure them adequately.[8] The Government Accounting Office (GAO) reported in 2003 that between 1998 and 2002 there over 1,300 radioactive sources in the US were lost, stolen or abandoned.[9] The report detailed how a powerful cesium-137 source in an industrial gauge from a defunct Maryland chemical company was discovered in a load of scrap metal. The source had traveled unsecured for an unknown period of time before ending up at a North Carolina steel mill.[10] A terrorist could obtain these materials through theft, by locating orphaned sources in abandoned factories, or even from legitimate suppliers by setting up a front company and obtaining the appropriate licenses from the Nuclear Regulatory Commission (NRC). Similar lost or abandoned sources can be readily found in areas where the political situation and the rule of law have broken down, such as Russia or the Balkans. The International Atomic Energy Commission reported that 27 cesium-137 sources were lost in Croatia in the late 1990s.[11] However, obtaining radioactive source materials within the U.S. would sidestep the possibility of detection by radiation sensors should a terrorist attempt to bring these materials across the border or through major ports.

A panel of experts estimates the probability of an RDD attack as 25% in the 2005-2010 timeframe and 40% in the years 2005-2015.[12] The GAO recently illustrated that acquiring the necessary radioactive materials was a rather simple matter. Senator Norm Coleman (R-Minn)

[8] Peter Zimmerman and Cheryl Loeb, "Dirty Bombs: The Threat Revisited," *Defense Horizons*, no. 38, January 2004: 2.
[9] Ibid.
[10] Ibid.
[11] Ibid, 3.
[12] Richard G. Lugar, The Lugar Survey of Proliferation Threats and Responses, Senate Foreign Relations Committee (Washington, DC: United States Senate, June 2005), 22-23.

requested GAO investigate lax regulation policies at the NRC. In a sting conducted July 2007, GAO investigators posed as West Virginian businessmen to obtain in under 28 days a federal license that would allow them to purchase low-level radioactive materials. The investigators were then able to easily modify the license to permit the purchase of a large number of more powerful sources. The radioactive material potentially would have been enough to build an RDD.[13] Although the NRC has pledged to fix its procedures, the patchwork of federal and state regulations that govern the purchase of radioactive materials no doubt has other undiscovered loopholes.

Psychological Impacts

The psychological impact of an RDD attack would be very nearly the same as one employing a nuclear weapon. While the explosive damage and widespread fallout effects can not be replicated with an RDD, the negative connotations of radiation and its effects are still present. These connotations are a result of the aftermath of the nuclear weapons used against Japan in World War II, the prolonged obsession with nuclear weapons during the Cold War, and industrial incidents such as Chernobyl and Three Mile Island. Popular media have further heightened the fear of exposure to nuclear materials through movies such as *Silkwood* and *The China Syndrome*. Panic, anxiety and a demand for medical treatment, not only among those actually exposed to radiation but also those who believe they were exposed or fear exposure, would ripple through society. Hospitals and clinics would be saturated, and first responders would be at great risk to exposure.

[13] Kathleen Day, "Sting Reveals Gap at Nuclear Agency," *The Washington Post*, 12 July 2007.

The demand for medical and psychiatric services would continue for months, if not years after an attack. Post-traumatic stress disorder may be experienced by 10-35% of those directly involved in a terrorist event. Survivors exhibit four categories of reaction following a traumatic event:

1. **Emotional reactions** – temporary feelings of fear, shock, denial, grief, anger, resentment, guilt, shame, helplessness, and detachment from others.
2. **Cognitive reactions** – confusion, indecisiveness, worry, disorientation, memory difficulties, shortened attention span, self-blame and unwanted memories.
3. **Physical reactions** – tension, nausea, bodily aches and pains, change in libido, nervousness, sleepiness, insomnia, rapid breathing, sweating, being easily startled, and panic attacks.
4. **Interpersonal reactions** – distrust, irritability, withdrawal, isolation, feelings of abandonment or rejection, being judgmental, over-controlling or distant.[14]

Victims will require the support of family, friends, support groups and religious organizations in addition to professional help. Resiliency to psychological stress can be increased with pre-event educational outreach, prompt and accurate information during an event, and well-publicized restoration of normalcy and events providing closure such as honoring the dead and the heroes.

An Economic Awakening

Terrorism is first and foremost a type of coercion. The attack itself may occur at a police station, a marketplace or a military installation, but in each case there is a specific intent to influence the opinions and actions of the general populace. Terrorism places psychological

[14] Judith J. Mathewson, "The Psychological Impact of Terrorist Attacks: Lessons Learned for Future Threats," in *The Homeland Security Papers: Stemming the Tide of Terror*, Michael W. Ritz et al., (Maxwell AFB, AL: USAF Counterproliferation Center, February 2004), 200-201.

pressure on citizens who in turn pressure their leaders to accede to the terrorist's demands. Warden's five-ring model of coercion[15] (see Figure 1) notes that the more protected inner rings (the leadership) can be influenced by attacking the less protected outer rings (the population). This model was originally developed as an aid to strategic warfare but is adaptable to counter-terrorism planning. Warden notes that attacks on the population achieve little strategic effect and is morally reprehensible to Westerners;[16] however, terrorists have shown no compunction against civilian attacks. The dispersed nature of a population increases the psychological impact of terrorism as the geographic separation dilutes security resources to counter an attack. The attacks appear more random than they are, further increasing the psychological pressure through fear, anxiety and dread.

Since an RDD attack has reduced destructive and psychological impacts relative to a nuclear attack, terrorists are likely to stage an RDD attack where it will have the greatest mass effect. Key economic sectors are obvious targets for such an attack. Terrorists have come to realize the importance of economic targets. Speaking of the 9/11 attacks in a December 2001 interview, Osama bin Laden stated that "[h]ere we have clear proof that this destructive, usurious global economy that America uses, together with its military force, to impose unbelief and humiliation on poor peoples, can easily collapse.[17]" He further recognized that military effects could be achieved indirectly: "it is possible to strike the economic base that is the foundation of the military base, so when their economy is depleted they will be far too busy with each other to be able to enslave poor peoples.[18]" The Al Qaeda leader displayed a firm grasp of the economic impacts of terrorism in an interview the month after the 9/11 attacks:

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[15] John A. Warden III, "The Enemy as a System," Airpower Journal, Spring 1995, http://www.airpower.maxwell.af.mil/airchronicles/apj/apj95/spr95_files/warden.htm.
[16] Ibid.
[17] Bruce Lawrence, ed., *Messages to the World: The Statements of Osama bin Laden* (London: Verso, 2005), 150.
[18] Ibid., 151.

“I say that the events that happened on Tuesday September 11 in New York and Washington are truly great events by any measure, and their repercussions are not yet over. And if the fall of the twin towers was a huge event, then consider the events that followed it … let us talk about the economic effects, which are still occurring. According to their own admission, the share of the losses on the Wall Street Market reached 16 per cent. They said that this number is a record, which has never happened since the market opened more than 230 years ago. A collapse of this scale has never happened before. The gross amount that is traded in that market reaches $4 trillion. So if we multiply 16 per cent by $4 trillion to find out the loss that affected the stocks, it reaches $640 billion of losses from stocks, with God’s grace, and amount that is equivalent to the budget of Sudan for 640 years. They have lost this through an attack that happened with the permission of God, lasting one hour only. The daily income of the American nation is $20 billion. The first week [after the attack] they didn’t work at all as a result of the psychological shock of the attack, and even today some don’t come to work because of it. So if you multiply $20 billion by 1 week, it becomes $140 billion – and the actual amount is even bigger than this. If you were to add it to the $640 billion, we’ve reached how much? Approximately $800 billion. The cost of the building and construction losses? Let us say more than $30 billion. So far, they have fired or liquidated more than 170,000 employees from airline companies, including airfreight companies and commercial airlines. American studies have mentioned that 70 per cent of the American people are still suffering from depression and psychological trauma as a result of the incident of the two towers,

> and the attack on the Defense Ministry, the Pentagon. One of the well-known hotel companies, Intercontinental, has fired 20,000 employees, thanks to God's grace. These repercussions, cannot be calculated by anyone, due to their large – and increasing – scale, multitude, and complexity, so watch as amount reaches no less than $1 trillion by the lowest estimate, due to these successful and blessed attacks.[19]"

Clearly he is aware of the far-reaching and continuing impacts of an attack on economic target, as well as the psychological influences that accompany them. Only time will whether Al Qaeda uses such knowledge in an operational manner.

Economic targets for an RDD attack

Since terrorism is a coercive strategy to influence a population, terrorists are likely to attack those elements of Western civilization that affect large numbers of people. Direct attacks on people, even large-scale attacks, can induce the desired reaction through fear and panic, but such attacks affect too small a fraction of the population to have widespread, long-term negative effects. Achieving these effects require a different strategy beyond brute force attacks.

Microeconomics describes the decision-making behavior of small units of the economy, specifically individual persons and businesses.[20] Looking at the economy from this perspective, a consumer-based model comprised of people, products and processes can be postulated.[21] It is clear that the people are the key component of the model. Not only are they as consumers a primary part of the economy, they also are necessary for the full operation of the production and

[19] Ibid., 111-112.
[20] Gary E. Clayton, *Economics: Principles & Practices* (Columbus, OH: Glencoe/McGraw-Hill, 2005), 89.
[21] Julian M. Chestnut, "Defeating the United States with Radiological Weapons in Fourth Generation Warfare," Research report: Air Command and Staff College, April 2003, https://www.afresearch.org/skins/rims/home.aspx.

processes components. The radiation from an RDD can cause illness and even death (depending on the level of exposure) and can prevent people from occupying an area to perform economic activity for a long period of time.

A very simplified version of the consumer-based model is presented in Figure 2, where each person requires three necessities: food, shelter and comfort. A fourth pseudo-necessity, an income source, is also represented as payment for these necessities is expected in a capitalist economy. The successive levels of dependence for each necessity are also displayed. The commodity path from farm to the food retailer is illustrated with sub-paths through food preparation activities and wholesalers. Shelter is obtained directly from the home-builder or a landlord acting as an intermediary. Comfort is obtained in the fuels and electricity that heat our homes, cook our food and provide energy to run all the modern conveniences to which we have become accustomed. Inspection of this model will lead to the identification of a possible primary target for terrorist disruption of our economy with an RDD attack.

The following sections of this paper will identify five possible targets that are vulnerable to an RDD attack, and a specific example of a target within this class and its economic impacts are given. One can not rule out near-simultaneous attacks on more than one target class or multiple targets within each class. Recent terrorist attacks have employed multiple attacks against more than one target: 9/11 involved four aircraft against at least three separate buildings; the 2004 Madrid train bombings involved 13 bombs on four separate trains, 10 of which exploded in a three-minute span; the 2005 London subway bombings involved 3 separate bombs on different trains exploding within one minute of each other, with a fourth bombing of a bus an hour later; and the “Bojinka” plan that was disrupted reportedly involved coordinated attacks on 11 planes traveling over the Pacific Ocean towards the U.S. Multiple attacks derive from the

implementation of separate cells of terrorists performing the simultaneous missions against similar targets. This operational tactic minimizes the risk of exposing the plot by limiting the number of people involved in any one segment of the attack, and increases the likelihood that at least one target will be hit should one or more segments fail.

Target class #1 – Petroleum refinery

The energy commodity path in Figure 2 points to a key vulnerability in our economic system. Figure 3 shows a reduced version of the economic model, illustrating those commodity pathways that require transportation powered by petroleum products and those pathways for transportation of petroleum products themselves. The transportation sector of our economy depends upon petroleum products for 96% of its energy needs, 98% when natural gas is included.[22] A reduction in petroleum product availability would have a dramatic effect on the price of transporting commodities, reducing their availability and increasing prices to the consumer. Additional impacts would be felt in the manufacturing, residential and electrical generation sectors which also depend upon petroleum products. These impacts would be similar to those of the oil crises in the 1970s which had severe effects on all sectors of the economy, resulting in high inflation rates and increased unemployment. Investment speculation in petroleum futures would keep prices high even after the effects of an attack had been nullified, extending the duration of the economic impacts.

A cursory inspection of Figure 3 would lead one to believe that the fuel distribution node is the key target to bring on such a collapse. However, the large number of distributors nationwide negates its apparent importance in the diagram; likewise, the oil fields themselves are too numerous and geographically separated to be practical RDD targets.

[22] Energy Information Administration, "Energy Basics 101," U.S. Department of Energy, October 2006, http://www.eia.doe.gov/basics/energybasics101.html.

The actual key node is the refinery complex. The smaller number of refineries, their complexity and construction expense make their singular function difficult to replace in timely manner. The prices of gasoline and other petroleum products increased following Hurricane Katrina and have not returned to previous levels. The storm's short-term interruption to a handful of refineries is an indicator of their economic importance. One can only imagine the impacts should one or more refineries be rendered unusable for years following an RDD attack.

The U.S. has 145 refineries operational, 55 of which are in the southern arc of states from Alabama, Mississippi, and Louisiana to Arkansas, Texas and New Mexico. These refineries process 47% of the crude oil refined every day in the U.S., with the 25 Texas refineries shouldering more than half of that load[23]. Of these 25 refineries, the British Petroleum Products North America plant in Texas City has the highest processing rates. Its daily production includes: 4,620,000 gallons of gasoline; 4,111,600 gallons of diesel fuel; 1,680,000 gallons of kerosene and jet fuel; and 4,410,000 gallons of heavy fuel oil.[24]

An RDD attack against this refinery would most likely involve a large explosive detonation to disperse the radiological materials. The detonation point would be chosen away from the security at the entrances, but near the edge of the facility such that prevailing winds will disperse the radiological materials over as much of the refinery as possible. See Figure 4 for an aerial view of the complex.[25] Attacks on multiple refineries could also be easily coordinated to occur almost simultaneously.

The refinery is likely to suspend operations temporarily while the explosion is investigated, and operations will be halted indefinitely once the radioactivity is discovered.

[23] Energy Information Administration, "Annual Refinery Report," U.S. Department of Energy, January 2007, http://www.eia.doe.gov/, Table 1, 1.
[24] *Ibid.*, Table 3, 22.
[25] Google Maps, DigitalGlobe (imagery) and Houston-Galveston Area Council (map data), 2007, http://maps.google.com.

Because of the large, open network of pipelines, machinery and controls, decontamination of the refinery would be a time-consuming and expensive effort – if it is even attempted. Automation of certain aspects of the plant may keep it in minimal operation for a while, but without humans to operate some machines manually and to maintain the refinery all production will slowly grind to a halt. The expense and complexity of the refinery will preclude any possibility of dismantling the affected portions of the complex, and will make building a new refinery to replace the production capacity a cost-prohibitive effort.

Target class #2 – Port facility

The simplified economic model in Figure 2 does not represent activity outside the basic necessities of the individual consumer; there are a wide range of activities that occur in commercial and industrial activities necessary for our economy to function at its current levels, but ultimately affecting the consumer. One key aspect of this broader range of activity is the import of raw materials and finished goods, most of which arrive in the U.S. by cargo container ships at one of several port facilities.

The most active port in the U.S. is the facility at Los Angeles, handling 8.5 million cargo containers annually. With other non-containerized goods, almost 190 million metric tons of cargo worth $225.8 billion transit the port each year. Almost $175 billion of that activity comes from trade with China, Japan, Taiwan, South Korea and Thailand.[26] The facility employs over 4% of the labor force of southern California with 259,100 full- and part-time positions. The wages and salaries paid to these employees put $8.6 billion annually into the regional economy, and the port pays $1.4 billion in state and local taxes on its $26.8 billion annual earnings as

[26] City of Los Angeles, "Frequently Asked Questions," Harbor Department, Port of Los Angeles, September 2006, http://www.portoflosangeles.org/about_faq.htm.

well.[27] Obviously, a disruption of this facility's operation would have a large national and regional economic impact. An estimate of the economic impact from 15- and 120-day closures of the Los Angeles port facility was conducted in 2005. The estimate predicted that a 15-day closure would result in a $99.5 million loss in the gross regional product and 962 man-years of labor losses. The 120-day closure effects were even more dire: $796.5 million of impacts and 7,692 man-years of labor losses.[28] National-level impacts are more difficult to quantify but are expected to result in shortages of consumer goods, manufacturing delays, rising prices and increased unemployment.

The RDD attack itself could be conducted in a similar manner to the refinery attack, with an explosive RDD detonation at a suitable point along the perimeter. However, another scenario offers a better probability of impacting the port facility operations. The RDD could be placed inside a small shipping container, driven through the gates of the facility and detonated once inside. Since inbound containers are of greater security interest than outbound ones, the RDD is likely to proceed into the facility unchallenged. Even if the truck delivering the container is stopped at the gate for some reason, detonating the RDD at that point would distribute the radioactive materials over key areas of the port. The map in Figure 5 shows an overview of the Los Angeles Port facility.[29] Such a scenario is a strong argument for enhanced inspection of outbound containers at a location separate from the port facility.

[27] City of Los Angeles, "Economic Impact," Harbor Department, Port of Los Angeles, September 2006, http://www.portoflosangeles.org/about_economicimpact.htm.

[28] Peter Gordon et al., "The Economic Impact of a Terrorist Attack on the Twin Ports of Los Angeles-Long Beach," in *The Economic Impacts of Terrorist Attack,* ed. Harry W. Richardson et al. (Northampton, MA: Edward Elgar Publishing, 2005), 272-273.

[29] City of Los Angeles, "Map/Directions to the Los Angeles Port Facility," Harbor Department, Port of Los Angeles, September 2006, http://www.portoflosangeles.org/about_map.htm.

Target class #3 – Major airport

As noted earlier, terrorists seem to have a preoccupation with using airplanes to accomplish their goals. An RDD attack aboard an airliner is unlikely as the contained environment would not allow the radioactive materials to spread, a key factor in creating fear and panic. This limitation, however, does not rule out an effective RDD attack at some other point within the aviation industry. A major airport terminal teeming with passengers who are bound for a large number of domestic and international destinations would provide an excellent venue for an attack. Like the port facility, air transportation is a supporting function that enables other sectors of the economy which affect the consumer, such as business and leisure travel or air cargo services.

Here surreptitious methods rather than an explosive device would prove the most advantageous for spreading the radioactive material. Releasing it as a fine powder on the floor of the terminal or in the ventilation system would ensure widespread contamination throughout the terminal. The ventilation system would be the preferred delivery method as complete decontamination of the system would be problematic, almost ensuring long-term or even permanent abandonment of the terminal.

The Hartsfield-Jackson terminal at Atlanta, Georgia is the most heavily traveled airport for the past two consecutive years. In the 12 months ending in May 2007, there were 37,182,000 passengers emplaned on 435,675 departing flights from this airport. Table 2 shows the departing passenger and flight statistics for the top 10 U.S. airports during this timeframe.[30] Figure 6 shows a map of the main terminal building.[31] While disruptions in service at any of these airports would

[30] Bureau of Transportation Statistics, "Airport Fact Sheet", U.S. Department of Transportation, September 2007, http://www.transtats.bts.gov/airports.asp.

[31] Hartsfield-Jackson Atlanta International Airport, "Main terminal", City of Atlanta, excerpted from http://www.atlanta-airport.com/sublevels/terminal/pdf/mt.pdf

have significant psychological and economic impacts, an RDD attack at the more heavily traveled airports will have proportionally larger effects. These effects will extend beyond the affected terminal to the entire commercial aviation industry as worried travelers avoid air travel, placing an enormous strain on the airlines' ability to operate profitably.

Rank	Airport	Departing Passengers	Departing Flights
1	Atlanta	37,182,000	435,675
2	Chicago-O'Hare	30,840,000	402,959
3	Dallas-Ft. Worth	25,761,000	306,812
4	Denver	22,045,000	272,793
5	Los Angeles	21,401,000	242,196
6	Las Vegas	20,795,000	195,411
7	Phoenix	19,817,000	224,364
8	Houston	16,403,000	229,295
9	Orlando	15,829,000	151,882
10	Minneapolis-St. Paul	15,794,000	196,736

Table 2. Top 10 U.S. Airports, June 2006-May 2007

The Atlanta airport is also the largest single place workplace in the state of Georgia. More than 56,000 employees from airlines, local and federal government, and numerous tenant organizations receive $2.4 billion annually in payroll earnings, with a further $5.6 billion of direct and indirect impacts to the local economy. Total regional impact of the airport is estimated to be $23.5 billion each year.[32]

Target class #4 – Food storage

Another key economic target is the nation's food supply. While there are far too many farms and types of crop for a small number of RDD attacks to produce a significant economic

[32] Hartsfield-Jackson Atlanta International Airport, "Fact Sheet", City of Atlanta, http://www.atlanta-airport.com/Default.asp?url=sublevels/business_info/contracts.htm.

impact, there are places not illustrated in Figure 2 in the distribution path where foodstuffs are concentrated in large enough amounts to make an attack viable. These concentrations occur specifically for grain products such as corn, wheat, barley, and oats. Grain products are transported from individual farms to large storage areas near rail or waterway shipping points, although some grains are shipped to and stored temporarily in community or regional storage areas before being sent to the shipping point. It is in these large storage areas where these foodstuffs are most susceptible to radiological attack. Spreading and mixing radioactive materials with the grain would make it unusable, necessitating its destruction. The facility would have to be decontaminated if possible, and even then may lose the confidence of grain farmers and buyers and be forced out of business. Other large-scale grain storage facilities would require time-consuming checks to ensure their inventories were uncontaminated, and buyers would likely demand expensive detection equipment be installed to guard against future contamination attempts.

Corn in particular is an attractive target due to its consumption by both humans and livestock, the potential for corn-derived ethanol as an alternate fuel source, as well as the thousands of products such as drugs, cosmetics and cleansers that are made with and from corn components.[33] The U.S. exported 2.1 billion bushels of corn in 2006, with the bulk of that going to Japan, Mexico, Taiwan, South Korea, Egypt, Colombia, Algeria, Canada, Israel and the Dominican Republic.[34] An RDD attack against one or more major corn storage facilities would have international as well as domestic price impacts. Since Iowa leads the U.S. in corn production,[35] one or more of the major storage areas in this state would be prime targets.

[33] Iowa Corn Promotion Board and Iowa Corn Growers Association, "Iowa Corn," http://www.iowacorn.org/cornuse/cornuse_3.html (accessed on 10 November 2007).
[34] Ibid.
[35] Iowa Department of Agriculture and Land Stewardship, "Iowa Quick Facts," http://www.agriculture.state.ia.us/quickFacts.htm (accessed 14 November 2007).

Figure 7 serves as an example of the size of grain storage areas. The DeBruce grain elevator in Wichita, Kansas is reportedly the largest grain storage facility in the world. Its half-mile long row of 310 interconnected grain silos stands 120-feet high and can hold 20.7 million bushels of several different grains.[36] This facility was the site of the last major explosion of grain dust in the U.S., with seven men killed and another 10 injured in the blast.

Target class #5 – Retail sector

As with the agricultural sector, commonsense indicates that the retail sector of the economy is too diverse and geographically separated to provide viable targets for RDD attack. However, an RDD has a strong psychological impact, and the confluence of large retail facilities with American spending patterns could overcome the more obvious detriments of this target class.

The day after Thanksgiving initiates the Christmas buying season in the United States. Most stores offer big discounts and operate extended hours on this day, often referred to in the retail industry as Black Friday, to draw in large crowds of shoppers. It is the largest single-day purchasing event of the year with an estimated 147 million Black Friday shoppers in stores this year.[37] Retailers have come to depend on Black Friday sales to put them "in the black" on their ledger sheets. Approximately 10% of the projected $474.5 billion in 2007 Christmas shopping was conducted on Black Friday.[38] An RDD attack against one or more major shopping centers early on Black Friday could cause a serious reduction in sales nationwide as fear of additional

[36] U.S. Department of Labor, Occupational Safety and Health Administration, "OSHA Special Report: Explosion of the DeBruce Grain Elevator, Wichita, Kansas, 8 June 1988," http://www.osha.gov/as/opa/foia/hot_6.html (accessed on 14 November 2007).
[37] National Retail Federation, "Black Friday Weekend Traffic up 4.8 Percent As Consumers Shop for Smaller Items," http://nationalretailfederation.com/modules.php?name=News&op=viewlive&sp_id=420 (accessed 30 November 2007).
[38] Ibid.

attacks kept potential shoppers at home. The Mall of America near Minneapolis, Minnesota, shown in Figure 8, would be a suitable target for such an attack.

The Mall of America is a 4.2 million square-foot facility hosting 520 individual retail shops, including 50 restaurants, a 14-screen multiplex theater, a 1.2-million gallon walk-through aquarium, a dinosaur museum and an indoor amusement park complete with roller coaster. Its regular complement of 11,000 employees is augmented by another 2,000 seasonal employees during the Christmas season. The Mall of America contributes over $1.8 billion annually to the local economy.[39] An RDD attack here on Black Friday would create a media frenzy, and the resulting panic could potentially short-circuit the Christmas buying season. The psychological and economic impacts of such an event would continue to be felt for several years.

Consequences of an RDD Attack

When considering the consequences of an RDD attack, it is important to remember the likely scale of contamination. Erroneous comparisons are often drawn to the nuclear accident at Chernobyl in 1986. In that incident, reactor design flaws and bad operational procedures were responsible for a core meltdown and subsequent explosion of the reactor vessel by superheated steam. Uranium-235, plutonium-239 and their radioactive decay products were released into the atmosphere. The reactor building was engulfed in flames from the heat in the reactor vessel, greatly contributing to the spread of the radioactive material.

An RDD attack obviously is not of similar magnitude to Chernobyl. While there have been no RDD attacks to use as a baseline, there are similar radiation exposure incidents. The one

[39] Mall of America Corporation, "Mall of America Facts," http://www.mallofamerica.com/about_moa_mall_facts.aspx (accessed on 2 December 2007).

in Goiânia, Brazil may prove most insightful.[40] Two men scavenging for scrap metal in September 1987 entered an abandoned medical facility that had used radiation to treat cancers. The radiotherapy machine had been left behind and its powerful cesium-137 source was still inside. The scavengers took the source capsule from the machine, and took it and other recovered material home. At some point the capsule was punctured, allowing radioactive material to escape. The men began to experience vomiting and diarrhea, symptoms of radiation exposure, but they dismissed their illness as food poisoning. They sold the capsule to a junkyard owner, who noticed the powder leaking from the capsule glowed blue in the dark. He took it home to show to family and friends. The powdered radioactive material was divided between family members, several of whom rubbed it on their bodies like the glitter used during the Carnival festival.

The occurrence of radiation sickness increased as more people were in close contact with the radioactive material. Other family members from neighboring villages came to Goiânia to assist their sick relatives, only to take radioactive contamination back home with them. One person was hospitalized and later transferred to a facility specializing in tropical diseases when his symptoms did not respond to treatment. Radiation exposure was never considered as a diagnosis until two weeks after the source capsule was scavenged.

Five people, including a six-year old girl, died from exposure related to ingesting the cesium-137 particles. More than 112,000 people were checked by Brazilian and international experts, finding 249 that were externally contaminated with the radioactive material. Of those 249, 151 exhibited signs of internal contamination as well. Only 49 of the 151 were hospitalized, 20 with serious to life-threatening levels of exposure. Their level of contamination made

[40] Peter Zimmerman and Cheryl Loeb, "Dirty Bombs: The Threat Revisited," *Defense Horizons*, no. 38, January 2004: 4.

treatment difficult. Medical personnel could only approach them if adequately shielded in lead-lined aprons used by X-ray technicians; some hospital staff refused to administer treatment.[41]

Clean up and containment of the radioactive material in Goiânia involved 85 buildings, seven of which were demolished due to high levels of contamination. Another 41 buildings were evacuated, displacing 200 residents. A total of 3,500 cubic meters of radioactive waste was sent to a disposal site. At least one city bus was contaminated when the radiation source was carried in a bag to the clinic for examination. Radiation even spread as far away as Rio de Janeiro when some Goiânia victims was airlifted there and no one thought for several days to decontaminate the ambulances that met them at the airport.[42]

Consequence Management

Presidential Decision Directive 39, signed in June 1995, divided post-attack responsibilities into law enforcement activities (crisis management) and emergency response activities (consequence management). This division introduced ambiguities on authorities and responsibilities that could potentially impede both activities. Successive policy directives in the aftermath of 9/11 such as Executive Order 13228, National Security Presidential Directive 8, and the establishment of Northern Command did little to resolve the uncertainty. This situation would continue until February 2003 when the formation of the Department of Homeland Security (DHS) and the signing of Homeland Security Presidential Directive 5 (HSPD-5) overhauled the federal response to terrorist attacks. HSPD-5 designates DHS as the lead agency,

[41] Ibid.
[42] Ibid.

institutes the National Incident Management System, and implements the National Response Plan to replace the Federal Response Plan and numerous specialized plans.[43]

Consequence management is now considered to include the emergency management functions of protecting public health and safety, restoring essential government services, and assisting governments, businesses and individuals in addition to the emergency response for an event.[44] These activities must be linked to and driven by pre-event planning and preparation. While it is logical to separate pre- and post-attack activities, it is imperative to remember that successful consequence management is not performed *ad hoc* – it requires as much effort as the procedures and tactics designed to prevent terrorist attacks. The federal government must provide tools and resources for pre-event training and familiarization. These include tools for situational awareness, hazard assessment, command and control, and damage assessment, as well as specialized medical resources, psychological services and financial assistance.

While consequence management necessarily will be lead by the federal government, both by policy decision and due to resource requirements, local entities will perform the emergency response role unassisted for several hours or even days. For this reason it is imperative that local police, fire and rescue personnel be trained and equipped to deal with an RDD attack. Cooperation with emergency response units in neighboring cities, counties and states is essential so that local units are not overwhelmed. This cooperation requires interoperable equipment, standardized procedures and established agreements to ensure optimal response to the event.

Communications are a key element of cooperation. The rapid exchange of information between responding units promotes improved reaction to the situation, and the smooth flow of

[43] Richard Falkenrath, "Homeland Security and Consequence Management," in *The Challenge of Proliferation* (reprint of article available online at http://www.brookings.edu/~/media/Files/rc/articles/2005/summer_terrorism_falkenrath/2005_aspen.pdf), 131-132.

[44] USAF Counterproliferation Center, "Consequence Management," http://cpc.au.af.mil/consequence.htm (accessed on17 Jan 2007).

accurate to the coordinating authority aids timely dissemination to the public, which in turn reduces panic, encourages cooperation, and rebuilds confidence in personal safety.[45] The capability to communicate classified information on secure telephone and computer links is essential to operating the emergency command center. Information collected at or near the scene could provide vital clues to uncovering and preventing additional RDD events in a multi-attack scenario, and this information must be communicated without delay to the appropriate agencies. Innovations such a modular command centers have been tested before with some success, but never widely adapted. DHS funding should be allocated for a comprehensive effort to design, acquire and locate sections of a modular command center at many communities, beginning with those nearest to potential terrorist targets. A longer-term goal would be to have at least one modular command center in each county across the United States. This would allow them to be useful for natural disaster relief and other emergency situations. The deployed modules should contain a standard suite of equipment for radio, cellular and satellite communications, computers to run assessment tools, an area for meetings and press briefings, portable radiation detection equipment, a decontamination station, detailed maps of the local area, and a self-contained electrical generation capability. In the event of an RDD attack, the local command center module would be joined by additional federally maintained modules with additional communications equipment for secure telephone and computer networks, analytic equipment to determine the exact nature and extent of the radiologic threat, more workspace and additional decontamination facilities. Ideally, there would be several sets of the federal modules to accommodate multiple

[45] Shawn D. Smith, "The Need for a Consequence Management Solution Focused on Local Governments," http://riskinstitute.org/NR/rdonlyres/7A3A68F0-8527-48FE-AB1E-3A9530DA0BFC/0/NEMNWhitePaper020107LONG.pdf (accessed on 17 Jan 2007), 3.

attack/disaster scenarios. Individual modules should also be small enough to be transported by C-130 cargo aircraft for delivery to even small airstrips closest to attack site.

Another key element is frequent, integrated exercise of the response plan by federal and local assets. Similar to the military practice of "train like you fight," integrated exercises bring all the responsible parties together to build relationships, trust and confidence in the procedures for dealing with a protracted disaster scenarios. The exercises should be held as frequently as possible, with a minimum requirement of annual participation by all parties. Frequent rehearsals ensure familiarity with procedures and indoctrinate new personnel into the training partnership.

Template response plans can be drafted to deal the two general types of RDD employment and can then be tailored to meet the current situation based on the dispersal method. An explosive RDD is unlikely to produce large numbers of victims suffering radiation effects from external exposure; most people will evacuate the area of the explosion. It is the first responders that are most likely to experience external and internal effects. They are unlikely to be immediately aware of the radioactive contamination in the area unless they are equipped with and routinely employ detection equipment such as Geiger counters on a regular basis, underscoring the need for proper equipment and training. Their exposure will vary, based on time spent in the contaminated area investigating the scene, extinguishing any fires and assisting victims of the blast. If personnel are unaware of the threat, symptoms of radiation sickness may not begin for several days and may not be correctly diagnosed if the symptoms are severe enough to warrant medical assistance.

A non-explosive RDD attack offers a more insidious threat. People in the area will be unaware of the presence of radioactive materials, increasing their external exposure as well as the risk of inhaling or ingesting particles that would lead to internal exposure. Decontamination

of external exposure can be readily accomplished with thorough washing; special attention must be paid to the hair, which can easily trap the small radioactive particles. The waste water must be gathered and stored so that radiation does not enter the local water treatment system. Handling internal contamination cases is more difficult but straightforward. External contamination must first be removed and then the body purged with the dye Prussian Blue.[46] All blood and human waste from the patient must be treated as radioactive, and medical personnel must take precautions to limit their time in the vicinity of the patient and to shield themselves from radiation while administering care. A further complication is the need to isolate the patient. Isolation rooms are a scarce commodity in most hospitals. A large number of patients would certainly overwhelm any given hospital, requiring the movement and care of most patients to other hospitals. This in turn exponentially increases the exposure of medical personnel.

Determining the extent of the contaminated area following an RDD attack will no doubt require several days, a period that could stretch to weeks or months depending on the amount of radioactive material in the RDD. All streets and buildings in the affected area would require decontamination. External surfaces will be certainly exposed, and open windows and ventilation intakes could allow contamination to spread to internal surfaces. Large areas will have to be evacuated until clean-up operations are complete, effectively bringing all economic activity in the affected areas – and the surrounding areas, as well – to an immediate halt. As there are no established procedures for decontamination of urban and suburban areas,[47] the suspension of economic activity is likely to continue for an undetermined period of time. Small business owners and individuals with little to no cash reserves will feel the impact first. State and federal agencies would be wise to create programs and procedures to deal with the economic hardship

[46] Peter Zimmerman and Cheryl Loeb, "Dirty Bombs: The Threat Revisited," *Defense Horizons*, no. 38, January 2004: 6.
[47] Ibid.

that will quickly follow an RDD attack. Further government support for economic recovery will be necessary as almost all insurance policies underwritten in the U.S. explicitly exclude radiation-related claims,[48] a hold-over from Cold War fears of a nuclear attack.

Likewise, prior identification and preparation of disposal sites will speed decontamination efforts. Some buildings may too contaminated for continued habitation or may prove too difficult to be cleaned of even minimal contamination. These buildings will have to be demolished with construction equipment appropriately shielded to protect workers during the process, and the debris transported in such a way as to limit the spread of contamination during removal to the disposal site. Large amounts of soil and plant debris will require similar removal, transport and disposal. A site for long-term will have to be identified and prepared to receive contaminated materials, possibly in chambers similar to those at the Yucca Mountain nuclear waste storage complex in southern Nevada.

Preventing the Five Scenarios

Preventing an RDD attack involves a layered effort of counterproliferation, regulatory and security measures. These general efforts are reinforced by additional security measures to protect economically sensitive targets. Some of these measures will be unobtrusive while others will require a great deal of cooperation from the occupants of adjoining real estate in what are already congested areas. None of these measures can be accomplished at zero cost, but the one-time expenditure for many of these efforts is far outweighed by the potential cost of an attack.

Attack prevention begins with stopping unauthorized acquisition and theft of radioactive sources. To this end, current counterproliferation efforts must be expanded and reinforced. These

[48] Ibid., 9.

efforts will require closer cooperation and increased information sharing between international law enforcement and intelligence agencies regarding nuclear material smuggling by organized crime and terrorist organizations. Analysts must investigate any reference to radioactive materials or its effects found in intelligence information, and governments must take steps to remove barriers to communication between law enforcement and intelligence agencies.

Securing new and existing radioactive sources is the next step in prevention. Regulatory regimes between the federal and state governments need an overhaul to close gaps and loopholes that would allow unauthorized parties to obtain radioactive materials under false pretenses. Background checks on parties applying for a license should be mandatory, as well as *in situ* checks of the facility where the source will be located to ensure adequate security for the material. Sources already in place should be subject to positive accounting and reporting to the NRC on an annual or semi-annual basis. This accountability would reduce the occurrence of orphaned sources; a failure to report would trigger a site inspect to validate the source's status and recover it for safekeeping should it be abandoned. Theft of sources from medical and industrial equipment could reduced by mandating additional physical security measures and alarms activated on source removal from its enclosure.

These measures will tighten control of domestically produced sources. Acquisition of materials from abroad can be prevented by performing 100% inspection of all items entering the United States by mail, air freight, containerized cargo, rail cars and airline passengers. Radiation detectors will suffice for some inspection needs; in others, detection efforts can be accomplished in conjunction with x-ray and neutron scanning of items for an improvised nuclear device (IND). Radioactive sources will require substantial shielding, as would an IND, which would be an indicator for closer inspection.

The final part in the prevention triad is detection. Radiation detectors can be placed in concealed locations and monitored remotely to provide warning of a possible threat presence. All five potential targets discussed above could benefit from incorporating radiation detectors on or near their operating locations. A refinery poses the most difficult problem in attack prevention just by its sheer size. Creation of a buffer zone around the refinery would greatly enhance security efforts to thwart an attack. Unfortunately, refineries tend to be located in heavy industrial areas or, in some cases, near to residential areas. Acquiring the real estate to create a security zone around the refinery would be expensive in all cases if not impractical in many others. Port facilities would experience fewer problems, as only a smaller area located a short distance from the port is needed to perform checks on outgoing containers arriving by truck. Inspection of incoming containers arriving by ship will remain a risk until international cooperation achieves 100% inspection of all departing cargo. Airport facilities already incorporate security screening at the check-in area. Moving this screening to just outside the terminal area, and adding radiation detection capabilities, will prevent radioactive contamination of the heavily trafficked interior spaces. Inspection of employee and delivery personnel is also required to deter insider operations. Food storage and retail operations benefit from having few entrances to their sensitive areas, easing the burden of equipment costs and increasing the likelihood of threat detection.

Conclusion

Terrorists have the knowledge and the will to carry out a radiological attack against one or more key economic targets. The radioactive component of the device can be obtained cheaply and with minimal risk of exposing their plans. They are aware of the potential large-scale

damage to the U.S. and global economies, and the potent psychological forces that can be unleashed by a radiological attack. Preparations for such an attack may be in progress even now. It is paramount that the U.S. and other countries around the world take steps to tighten regulatory and security regimes to eliminate theft, loss and abandonment of radioactive sources. It is also incumbent on the U.S. to better equip and train its corps of first-responders and medical personnel to meet the challenges of handling an RDD attack. Prevention is our strongest weapon, but we can not ignore even the slight probability of a successful attack. We must not make the mistake of underestimating the intelligence of our adversary.

Some critics have expressed the concern that papers such as this one benefit terrorists more than our own counter-terrorism efforts by providing information on our vulnerabilities and lack of preparation. The criticism is highly speculative and difficult to defend as terrorists rarely publish their targeting rationale in specific terms, and all the information cited herein is publicly available. Predicting the targets of terrorist attacks is by no means an exact science. Much depends on their intentions, which we can only hope to glimpse through their open statements, recovered documents and interrogation of captured terrorists. Their capabilities can be estimated and weighed against their perceived intentions, but our successful counter-terrorism efforts complicate these efforts by introducing changes in their plans and resources. Despite the potential hazard, estimates of potential targets are not with merit. At the very least these estimates provoke debate on possible counter-measures and initiate consideration of appropriate consequence management regimes.

Mark Twain once remarked that “prophecy is a great business, but it is full of risks.” Given the far-reaching impacts of a radiological attack, perhaps a small measure of prophecy is worth the risk.

Illustrations

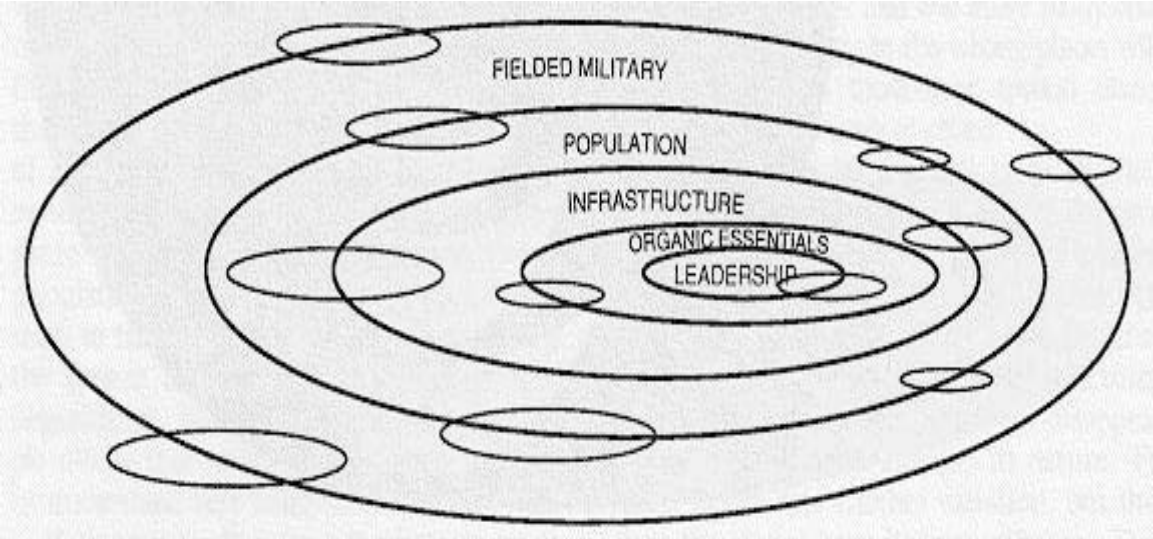

Figure 1. Warden's Ring Model

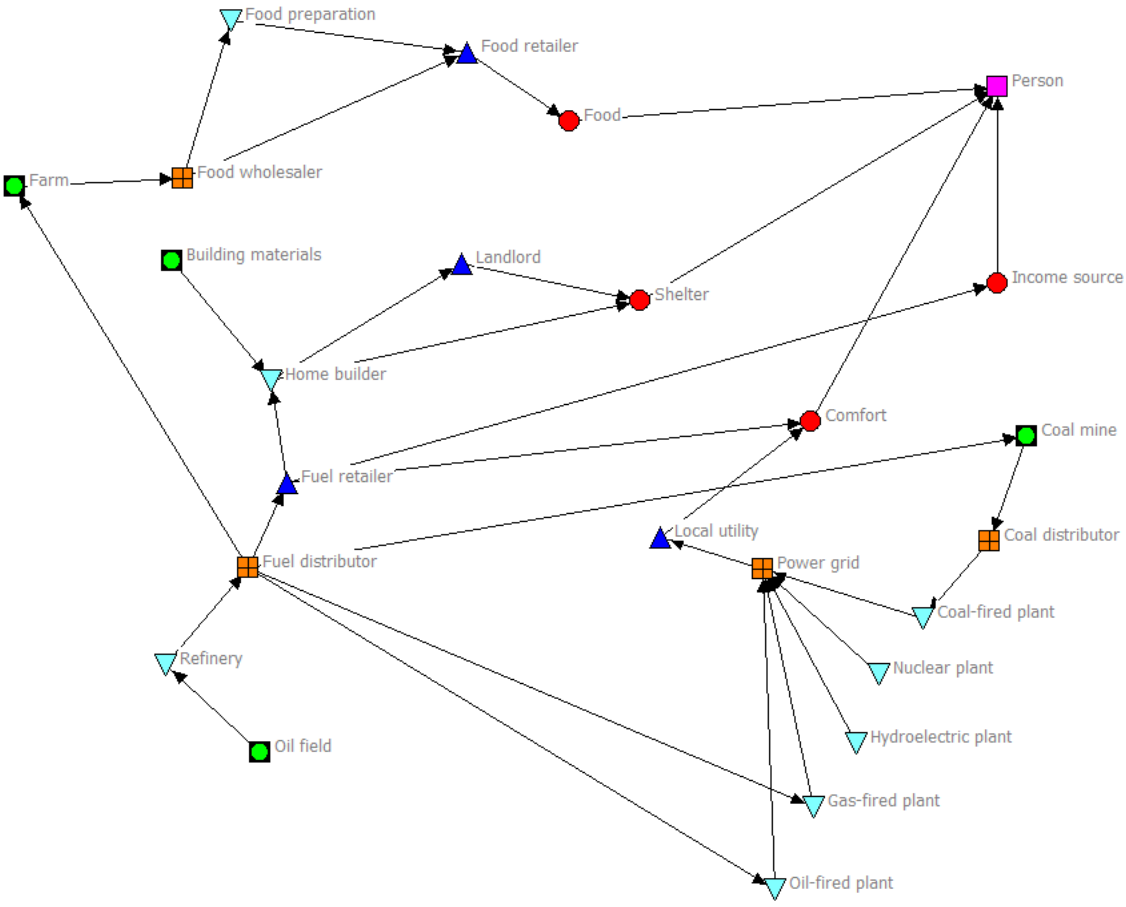

Figure 2. Simplified economic model

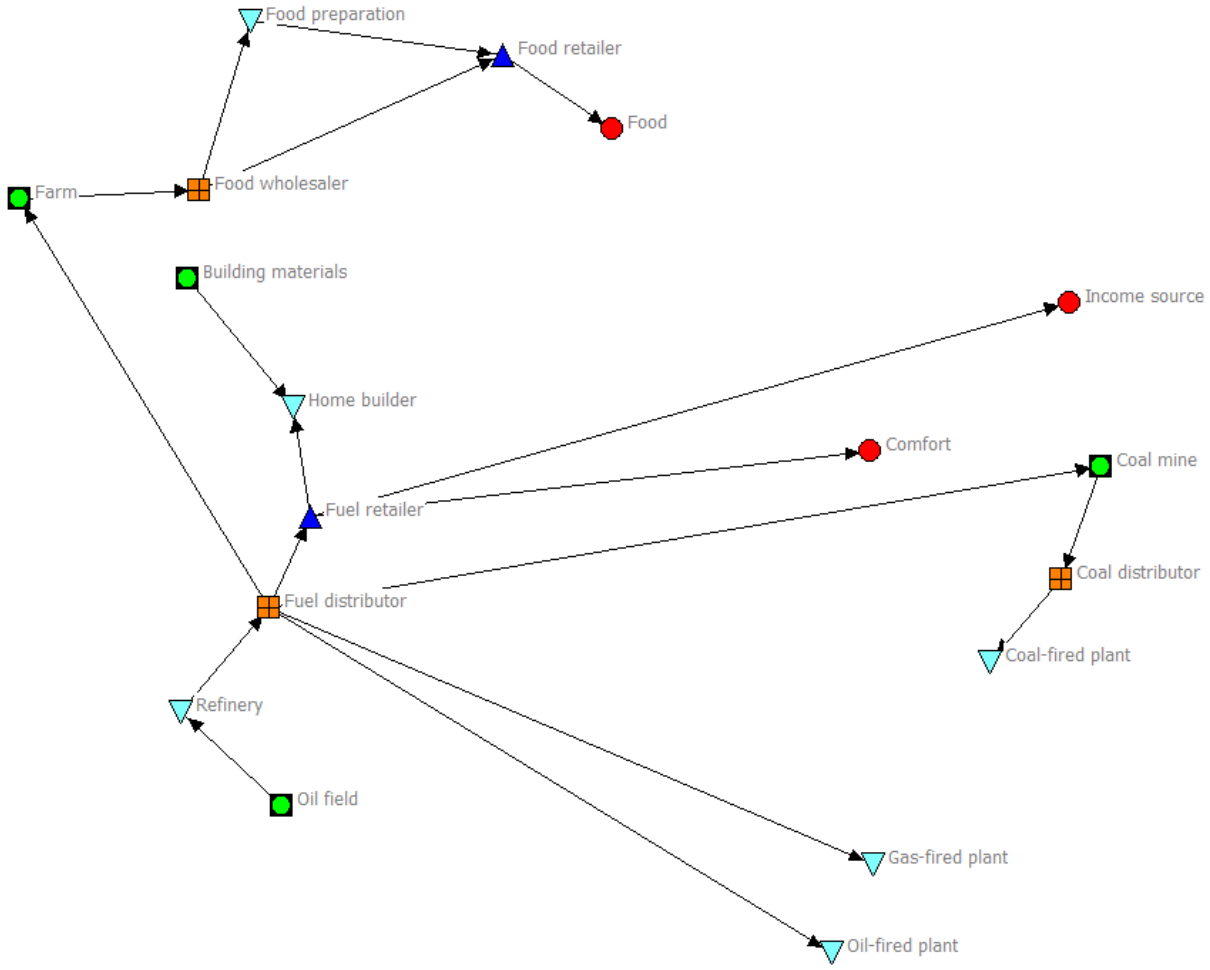

Figure 3. Economic nodes requiring transportation

Figure 4. BP Texas City refinery complex

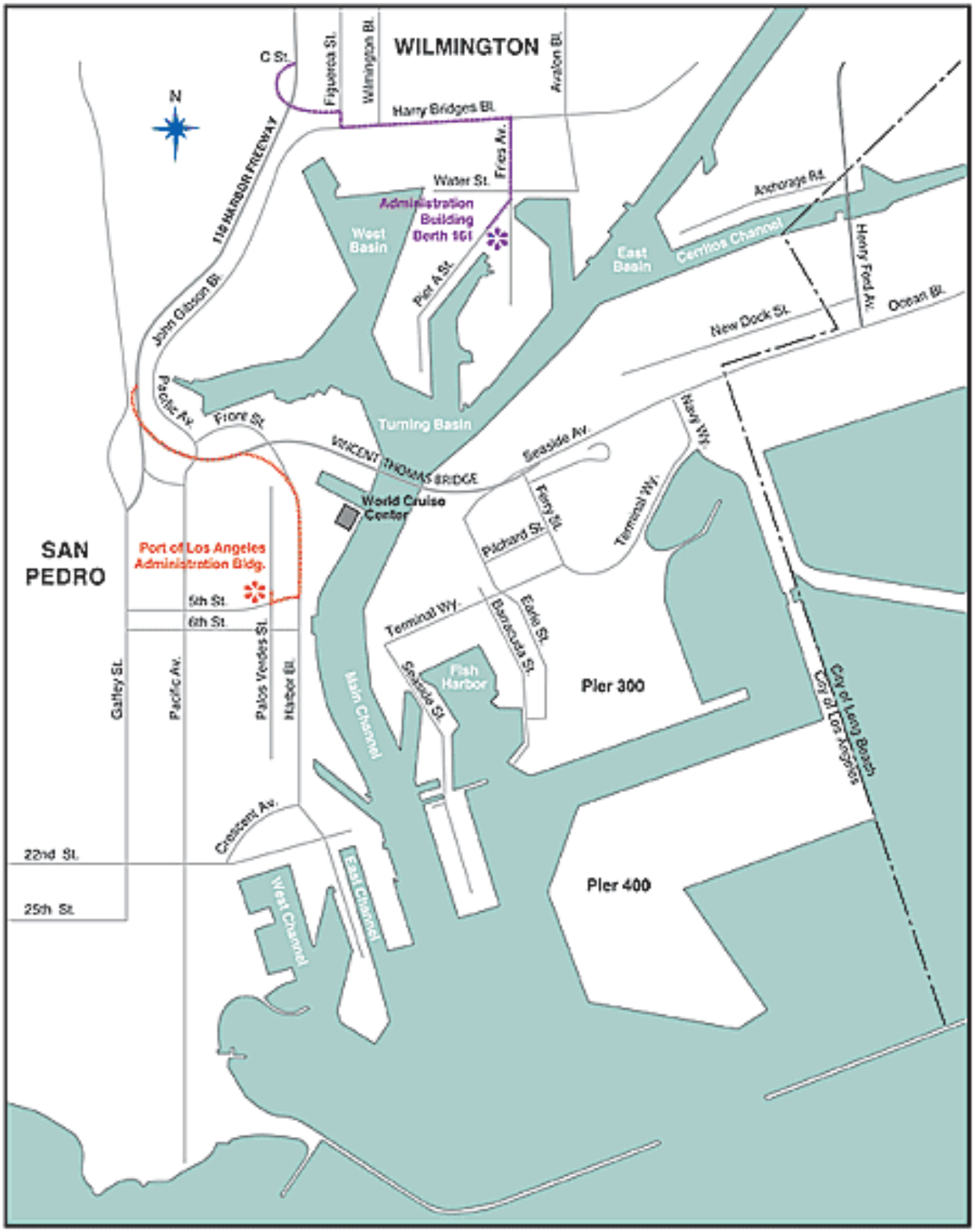

Figure 5. Map of Los Angeles Port facility

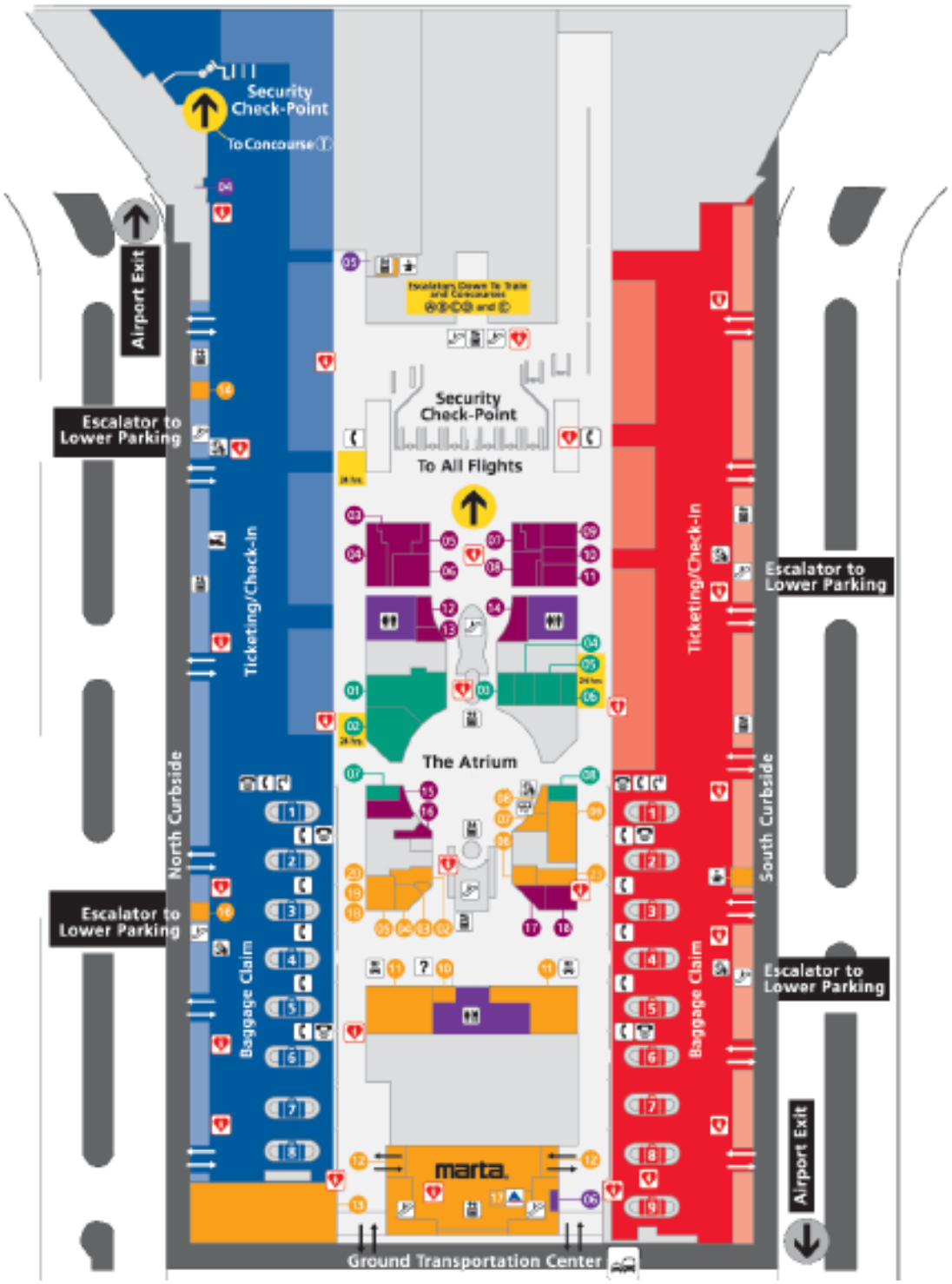

Figure 6. Main terminal, Atlanta Hartsfield-Jackson International Airport

Figure 7. DeBruce Grain Elevator, Wichita, Kansas

Figure 8. Mall of America, Minneapolis, Minnesota

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