# From Cars to People

## Advancing Installation Design

Louis J. Zib III
Christopher M. Chini

While the US Air Force stresses reducing facility life-cycle costs in its design of air bases, supporting infrastructure including roads and utility lines is not figured into cost calculations. As such, the Air Force's current base design maximizes passive protections against outmoded attacks, often to the detriment of supporting infrastructure cost. By exploring how air base design will be altered when supporting infrastructure considerations are paired with updated adversarial attack scenarios, this study proposes a modernized base design that is more cost efficient and more effective at mitigating adversary attacks.

Currently, US Air Force bases are designed to prioritize cars and their use, which is intended to mitigate invasive and noninvasive near-strength adversary attacks. The car-centric use of space between facilities, redundant infrastructure, and low-density buildings is meant to play a role in reducing the effect of such attacks. Yet such a design is based on attack strategies from the World War II and Cold War eras, and the relevance of such strategies to today's environment remains dubious.[1]

Technologies and advancements in homeland defense systems—such as radar-based tracking and intercepting capabilities—reduce the likelihood of such adversarial attacks, limiting the passive effectiveness of car-centric base design in decreasing disruption to operational throughput. In addition, the life-cycle costs of supporting infrastructure inherent to such a car-centric design have not been analyzed. These life-cycle costs are the construction, operation, maintenance, and demolition costs associated with assets that need to be built and maintained for a facility to function for its intended usage over its lifespan; these assets include roads and electrical, waste, water, gas, and communication lines. Today's Air Force faces the challenge of maintaining aging and outdated supporting infrastructure with increasing maintenance costs.[2]

*Captain Louis Zib, USAF, serves as a civil engineer officer and contingency support program manager for the Headquarters, United States Air Forces in Europe - Air Forces Africa Civil Engineer Division, Contingency Support Branch. He holds a master of science in engineering management from the Air Force Institute of Technology.*

*Dr. Christopher Chini is a research scientist with the Earth Systems Predictability & Resiliency Group at the Pacific Northwest National Laboratory in Richland, Washington.*

1. Tod D. Wolters et al., *U.S. Air Force Infrastructure Investment Strategy (I2S)* (Washington, DC: Headquarters, US Air Force, 2019), https://www.af.mil/.
2. Joel A. Sloan et al., "Infrastructure Truths for Air, Space, and Cyberspace," *Air & Space Power Journal* 35, no. 1 (2021), https://www.airuniversity.af.edu/.

Considerable research and effort have been focused on reducing maintenance costs following consolidation guidance set forth in the US government-based Whole Building Design Guide, corresponding installation facilities standards, and other such principles for government and industry professionals.[3] Yet few studies have explored the underlying design criteria the Air Force should utilize when developing the installation of the future and the supporting infrastructure costs and needs. Given the technological advancements of the war machine coupled with the decreasing probability—and usage—of conventional warfare doctrine projected by US near-strength adversaries, the Air Force must adapt a sustainable base model most suited to current and future threats.

Air Force base design centers on four key principles: (1) incrementally increase barriers of access to critical assets, (2) provide resilient protection of the base against adversarial attacks, (3) consolidate the land requirements for the operational and support areas, and (4) reduce the life-cycle costs of facilities.

While the last principle stresses reducing the life-cycle costs for facilities and their individual utility input, support infrastructure is not included in life-cycle cost calculations. In fact, the current car-centric design maximizes the key principles for facilities to the detriment of supporting infrastructure cost, placing the facility at the focal point for operational effort and neglecting the importance of supporting infrastructure. Including life-cycle costs for this infrastructure within the fourth key principle would change the optics that drive base design, allowing planners to make more informed strategic, economic, and holistic decisions regarding base design and to determine more effective alternatives to a car-centric design.

In examining the strengths and costs of the current Air Force base design, this article offers an alternative design that includes life-cycle cost analysis for the supporting infrastructure and sustainable benefits of a redesign. While there are challenges associated with a redesign, the Air Force must move forward with such efforts to meet today's and tomorrow's base attack scenarios while maximizing holistic base sustainability gains.

## Maintaining Supporting Infrastructure

Air Force infrastructure—facilities and supporting infrastructure—is an integral component of base operations.[4] The life-cycle costs of supporting infrastructure are measured by the cost per linear unit.[5] The funding requirements to maintain, repair, and modernize the existing infrastructure are largely based on a percentage amount set aside

3. "Whole Building Design Guide," WBDG (website), October 8, 2021, https://wbdg.org/.

4. Sloan et al., "Infrastructure Truths"; and Wolters et al., *Infrastructure Investment Strategy*.

5. "Whole Building Design Guide"; Rajkumar Roy, "Cost Engineering: Why, What and How?," in *Decision Engineering Report Series,* ed. Rajkumar Roy and Clive Kerr (Cranfield, UK: Cranfield University, 2003), https://dspace.lib.cranfield.ac.uk/; Anghel Patrascu, *Construction Cost Engineering Handbook* (Boca Raton, FL: CRC Press, 1988); and "Materials Prices," ARTBA [American Road & Transportation Builders Association], October 8, 2021, https://www.artba.org/.

for maintenance.[6] Each base then competes centrally to fund infrastructure most in need of repairs. A metric and associated formula are utilized to rank the projects against one another. They both normalize the projects for direct competition but do not account for life-cycle costs of attached supporting infrastructure.

Historically, organizations spend approximately 3 to 9 percent of a facility's total replacement value on its maintenance, with world-class businesses settling on the 2.5 to 3.5 percent value range, using an optimized facility management plan.[7] Based on these statistics, the Air Force should spend at least $7.89 billion on base maintenance for its infrastructure and facilities. Yet the Air Force has committed to just $5.26 billion to maintain its existing infrastructure.[8] It should also be noted that the Air Force has been below the 2 to 9 percent maintenance amount in prior years.[9] In short, the Air Force currently attempts to maintain its vast infrastructure with an inadequate budget, which results in infrastructure that continues to degrade over time. Furthermore, the Air Force has a $33-billion backlog of deferred maintenance and recapitalization, which is projected to triple in the next 30 years. The Air Force will continue to see a deficit unless maintenance spending levels increase or costs significantly decrease.[10]

The Air Force has made progress in including these costs within new construction and major renovations, using sustainability programs such as Leadership in Energy and Environmental Design, the Building Research Establishment Environmental Assessment Method, and Green Globe.[11] While these certifications focus on increasing the efficiency gained from the use of the existing supporting infrastructure supply, they do not address the placement—holistic integration to the supporting infrastructure—or trade-offs for site location to the existing supporting infrastructure.

From the Air Force Comprehensive Asset Management Plan for fiscal year 2021–25 onward, supporting infrastructure projects have no formulaic incentives or positive considerations tied to reducing its footprint. Generally, supporting infrastructure projects are at a funding disadvantage since the metric and associated formulas used to normalize projects were originally designed to compete facility projects.[12]

---

6. Wolters et al., *Infrastructure Investment Strategy*; and Sloan et al., "Infrastructure Truths."

7. John S. Mitchell, *Physical Asset Management Handbook* (Houston, TX: Clarion Technical Publishers, 2002); and Brian Atkin and Adrian Brooks, *Total Facility Management* (Hoboken, NJ: John Wiley & Sons, 2021).

8. Wolters et al., *Infrastructure Investment Strategy*.

9. Brendan Maestas et al., "Defining Success in Air Force Infrastructure Asset Management through Use of the Delphi Technique," in *Engineering Assets and Public Infrastructures in the Age of Digitalization, Proceedings of the 13th World Congress on Engineering Asset Management*, ed. Jayantha P. Liyanage, Joe Amadi-Echendu, and Joseph Mathew (Cham, Switzerland: Springer Nature, 2020).

10. Wolters et al., *Infrastructure Investment Strategy*.

11. "LEED Rating System," USGBC [US Green Building Council], accessed May 28, 2024, https://www.usgbc.org/; "An Introduction to How BREEAM Works," BREEAM [Building Research Establishment Environmental Assessment Method], accessed May 28, 2024, https://breeam.com/; and "The Global Leader in Sustainable Tourism Certification," Green Globe, accessed May 25, 2024, https://www.greenglobe.com/.

12. "Civil Engineeering Playbooks: AFCAMP Business Rules," Air Force Civil Engineer Center.

Although reductions in life-cycle costs continue for facilities by increasing utility efficiencies such as upgrading lighting systems, such costs are not calculated for the supporting infrastructure. By factoring in such infrastructure life-cycle costs in the fourth key base design principle, designers would consider cost interactions between the capacities of the existing supporting infrastructure and the proposed facility, prioritizing sustainable integration. Consolidation of operational and support areas would include the supporting infrastructure system. This inclusion of life-cycle costs would allow base designers to determine alternatives to a car-centric design, such as a people-centric design.

## Car-Centric Design

Car-centric design was first introduced at the 1939 World's Fair in New York as an ideal that shifted the primary mode of transportation within a city from walking and public transit to privately owned vehicles (POVs).[13] Since that time, car-centric design continues to be the primary default for North American cities, but it is widely criticized today for its limits in terms of sustainability.[14] The hallmarks of car-centric design are roads and interactions with the urban environment centered on efficient car travel, with walking and public transit as secondary priorities. Car-centric design allowed planners to develop suburbs outside the urban center of a city.[15]

Such a design also results in long runs of roads and electrical, gas, and water utility lines to accommodate the distances between the city's urban centers and its surrounding suburbs. Applied to a military installation, from a defensive standpoint, car-centric design limits the potential efficacy of any adversary attack since the targeted area grows as the infrastructure lines between facilities increase in length. This design also comes at a cost, limiting the efficiency and sustainment—or the operation and maintenance—of the support infrastructure connecting the facilities within that area.

Without analyzing supporting infrastructure life-cycle costs, the Air Force adopted car-centric design as the key design for bases. While the Air Force's fourth principle of building design stresses reducing life-cycle costs for facilities and their individual utility input, as previously mentioned, support infrastructure is not included in life-cycle cost calculations.

The car-centric design maximizes the key principles for facilities to the detriment of supporting infrastructure cost, placing the facility as the focal point for operations. For example, maximizing the distance between facilities—one characteristic of the car-centric design—provides increasing passive barriers of access and minimizes adversarial damage to facilities, but at the cost of longer supporting infrastructure lines. As of 2021, bases

13. Paul Mason Fotsch, *Watching the Traffic Go By: Transportation and Isolation in Urban America* (Austin: University of Texas Press, 2007).

14. Charles L. Marohn Jr., *Strong Towns: A Bottom-Up Revolution to Rebuild American Prosperity* (Hoboken, NJ: John Wiley & Sons, 2019); and Fotsch.

15. Marohn; and Fotsch.

consolidated individual operational and support facilities while leaving the broader supporting infrastructure system largely the same.[16]

## Car-Centric Installations

Air Force bases have historically been built on existing airports and air fields away from city centers and highly populated areas.[17] Since World War II, the four guiding principles to Air Force base creation centered on the conservation of funds, materials, and national effort; efficiency of operation; maximum use of available facilities; and elimination of nonessentials.[18] By the Cold War, these principles involved force structure, operations, deployments, available facilities, reactivation of existing bases prior to new construction, and a life-cycle of 25 years, a time frame that all have exceeded.[19]

During World War II, an Air Force base location was selected in accordance with these principles, with the main concern being its ability to generate sorties if the base came under attack. This concern stemmed from strategies observed during that time: mass bombing runs backed by fighter escorts. The intent of such tactics was to cause the most destruction possible within an area to disrupt base operations. As such, Air Force bases were designed primarily in low population areas away from city centers to reduce damage to civilian populations.[20]

Additionally, they were designed with space in mind—for example, with the cantonment area and support areas located miles away from the operational flight lines. While dormitories were no more than two or three stories high, operational facilities were often single-story and constructed with large interior footprints.[21] Such a design advantage reduced the ability of a single bomb to halt the facility's operational effort during the war.

Facilities were also designed to be set apart from each other whenever possible. Additional space between facilities assisted in reducing the effective damage a single bomb could produce. To ensure facility operations were available even during an attack, designers planned for redundant support infrastructure for each facility. Electrical infrastructure typically followed a loop system to provide electricity from either junction to a facility if the grid was damaged. Similarly, roads were placed to access each facility from multiple approaches to maintain its logistical throughput. This redundancy assured that bombing runs would yield less efficiency against the facility and that further investments into bombers and corresponding bombs would be needed to destroy its operations.

---

16. "AFCAMP Playbook."

17. Frederick J. Shaw, ed., *Locating Air Force Base Sites History's Legacy* (Washington, DC: Air Force History and Museums Program, 2004), https://www.amc.af.mil/.

18. Robert Frank Futrell, *Development of AAF Base Facilities in the United States, 1939-1945* (Manhattan, KS: Sunflower University Press, 1947).

19. Shaw, *History's Legacy*.

20. Robert Mueller, *Air Force Bases: Active Air Force Bases within the United States of America on 17 September 1982*, vol. 1 (Washington, DC: Office of Air Force History, 1989).

21. "Whole Building Design Guide"; and *Unaccompanied Housing Design Guide* (Washington, DC: Headquarters, USAF, January 2006), https://www.wbdg.org/.

Lastly, Air Force bases were developed with additional distances between the operational areas and its personnel housing and support areas to mitigate the damages from strategies, as discussed above.[22] As a result, air bases feature the airfield in the middle, surrounded by its infrastructure, reducing the effects of a bombing run on the airfield's operations.

Positioned away from the airfield, the housing area comprises low-density housing units, which provide their own security against bombing runs to the population living there. Additional off-base housing is intended to deter adversaries that have the requisite capabilities from finding any gain in bombing housing areas. For unaccompanied Airmen, dormitories are no taller than three stories, and they are often grouped in individual islands throughout the housing area. Support structures such as schools, child development centers, and other base amenities are placed in locations away from housing and the airfield. All these measures are supported by the miles of roads and electrical, gas, and water lines. An example of the current car-centric base design can be seen in figure 1.

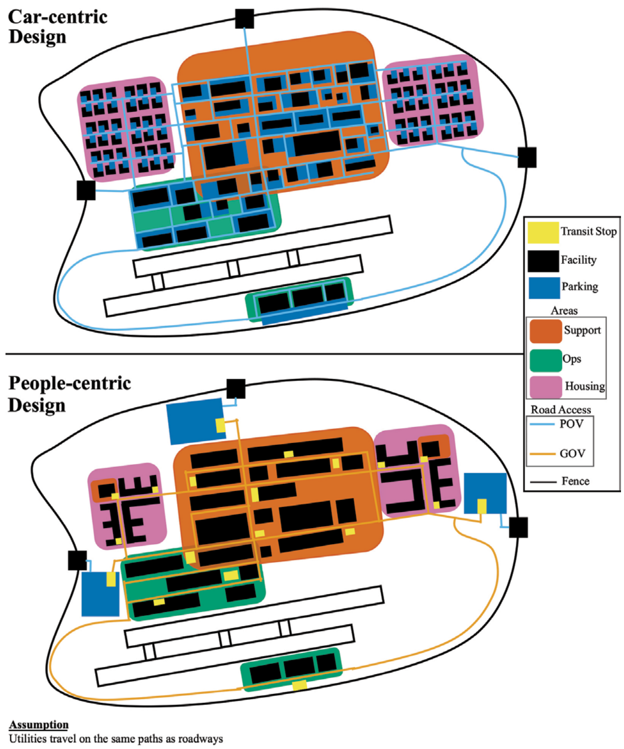


**Figure 1. An example base design created using current car-centric design and a proposed people-centric design**

22. S. Nelson Drew and Paul H. Nitze, *NSC-68 Forging the Strategy of Containment* (Darby, PA: Diane Publishing, 1994); and LeRoy A. Brothers, "Operations Analysis in the United States Air Force," *Journal of the Operations Research Society of America* 2, no. 1 (1954), https://www.jstor.org/.

With a car-centric design, the Air Force is paying for a design whose core premise is to deter effective noninvasive attacks from near-strength World War II- and Cold War-era adversary tactics. Yet since that time, the Air Force has developed homeland defense technologies and systems to counter such attacks. Base design should therefore instead focus on reducing current and future attacks while minimizing support infrastructure costs. Such a design should be driven by the inclusion of the support infrastructure sustainment costs and estimated repair costs from today's likely attack scenarios.

## Criteria for a Modernized Base Design

Today's Air Force faces threats that could not be foreseen in the 1940s, when car-centric bases were designed. The current threats to air base physical infrastructure, augmented by rapid technological advancement, differ considerably from that period.[23] The United States' defense strategy emphasizes the need to protect the homeland from state, nonstate, and transboundary threats, such as climate change and the COVID-19 pandemic.[24] The increased reliance on computer and electronic technologies has become a vulnerability that can be targeted by near-strength adversaries.[25] US reliance on electronics to send messages, monitor infrastructure, and use transportation systems can all be disrupted by an electromagnetic pulse blast. Nonstate actors have a lower barrier to access capabilities that can cause mass disruptions to defense, government, and economic infrastructure.[26] These actors can interfere with operational efforts without the limitations, consequences, or costs associated with state adversaries using conventional means of attack.

Likely threats to an Air Force base center on unconventional warfare and technologically advanced noninvasive attack strategies aimed against current operational capabilities and infrastructure.[27] These threats could impact operational capabilities by disrupting supporting infrastructure to a facility as well as target the facility directly.

Figure 2 details the likelihood of disruptive events for expeditionary base design and homeland base design. At an expeditionary base, the most likely scenario involves conventional and unconventional noninvasive attacks. Yet, the most likely disruptive events for a homeland base is unconventional noninvasive attacks and maintenance/repair of aging infrastructure. As such, the design for the two bases should give the greatest considerations to these most likely threats, respectively.

---

23. James N. Mattis, *Summary of the 2018 National Defense Strategy of the United States of America: Sharpening the American Military's Competitive Edge* (Washington, DC: Department of Defense [DoD], January 2018).

24. Lloyd J. Austin III, *2022 National Defense Strategy of the United States of America* (Washington, DC: DoD, October 2022), https://media.defense.gov/.

25. Mattis, *Summary*; Michale Chipley, "Cybersecurity," WBDG, last updated February 21, 2020, https://www.wbdg.org/; and Austin, *National Defense Strategy*.

26. Mattis; and Austin.

27. Mattis; Sloan et al., "Infrastructure Truths"; and Austin.

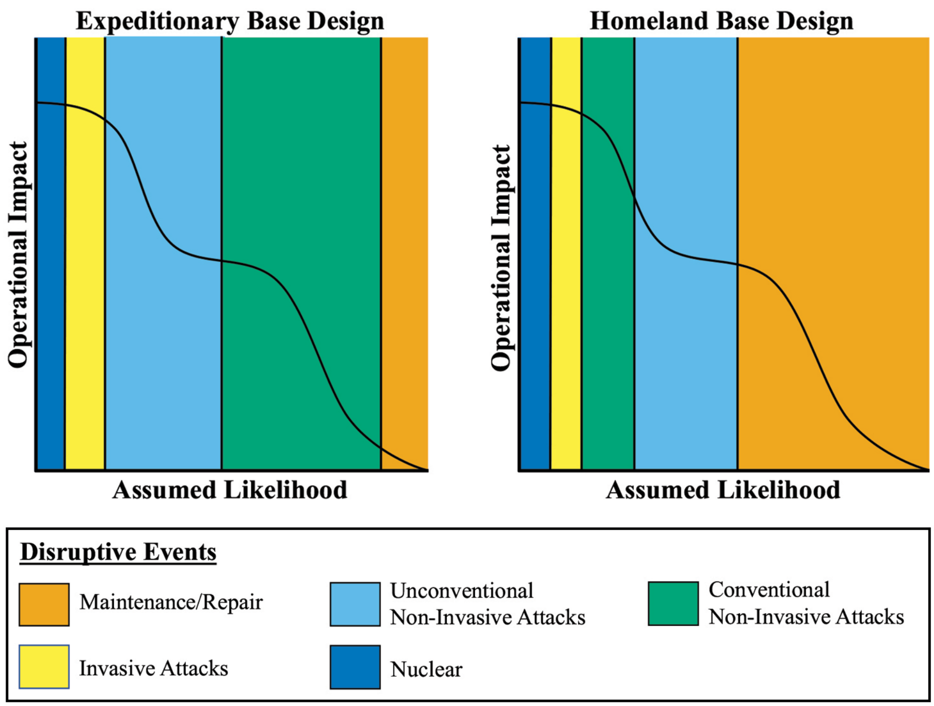


**Figure 2. Differences in assumed likelihood of disruptive events toward operational output between the expeditionary and homeland base designs**

Researchers have analyzed the resilient protection of infrastructure and have proposed several solutions to better protect facilities against conventional, nuclear, and unconventional threats.[28] For example, electromagnetic pulse shielding can be introduced to telecommunication lines and industrial control systems to protect the supporting infrastructure from unconventional warfare. Guidance and teams have been created to respond to and prevent future cyberattacks on these systems.[29]

Additional mechanical restrictions, such as locks and fencing coupled with restricted badging, can deter and delay a small insertion team from disrupting the supporting infrastructure. First responders can counter such incursions more rapidly since they can bypass the same security measure.

Consolidating land requirements would involve constructing multi-use/multilevel facilities, which can support a wide range of operational efforts. With POVs prohibited from

28. Chipley; Mattis, *Summary*; Austin, *National Defense Strategy*; and S. M. Anas and Mehtab Alam, "Comparison of Existing Empirical Equations for Blast Peak Positive Overpressure from Spherical Free Air and Hemispherical Surface Bursts," *Iranian Journal of Science and Technology, Transactions of Civil Engineering* 46, no. 2 (2022), https://doi.org/.

29. Chipley.

operational and support areas, it is possible to reduce the standoff distance between facilities.[30] Taller facilities—which could be designed to resist progressive collapse or air blasts in the event of an attack—would allow for higher density for a given square footage.[31] Coupling such facilities with reduced standoff distances between facilities would create more walkable areas, encourage mass-transit options, and promote their cross-organizational efforts.

With large standoff distances between groupings of facilities, the use of mass transit would also be able to maintain connection to all facilities while providing the benefit of the modernized base design. Government-owned vehicles (GOVs) may still be required, and a base designer should ensure that contingencies are in place should the mass transit system fail or if and when adversarial attacks hinder transportation infrastructure.

Finally, the reduction of infrastructure life-cycle costs would need to be considered during the development of modernized base design. Researchers have explored multiple methods to reduce such costs for the electric grid, water and wastewater lines, and transportation systems.[32] Collocating utility infrastructure into multi-utility tunnels allows for reduced projected labor hours necessary to access, observe, and repair utility runs.[33] Consolidating support infrastructure can also reduce its sustainment cost, restrict access, and protect the infrastructure from adversarial attacks.

Maintenance costs for support infrastructure are inherently tied to the linear amount required to support each tied-in facility. Along with increased cross-organizational communication opportunities, condensing multi-use/multilevel facilities into a smaller land area would reduce overall maintenance costs with only a marginal decrease in protection. While initial construction costs would be higher compared to current design standards, reduced sustainment costs over the life cycle of the support infrastructure will result in a lower support infrastructure life-cycle cost. This modernized base design would account for the threats of today while increasing the resiliency and robustness of the base infrastructure.

---

30. Larry D. McCallister et al., *Minimum Antiterrorism Standards for Buildings*, UFC 4-010-01 (Washington, DC: DoD, December 12, 2018, Change 2, July 30, 2022), https://wbdg.org/.

31. David Stevens et al., "DoD Research and Criteria for the Design of Buildings to Resist Progressive Collapse," *Journal of Structural Engineering* 137, no. 9 (2011), https://doi.org/; Huda Helmy, Hamed Salem, and Sherif Mourad, "Progressive Collapse Assessment of Framed Reinforced Concrete Structures according to UFC Guidelines for Alternative Path Method," *Engineering Structures* 42 (2012), https://doi.org/; Robert Smilowitz, "Designing Buildings to Resist Explosive Threats," WBDG, updated September 14, 2016, https://wbdg.org/; Uwe Starossek, *Progressive Collapse of Structures*, vol. 153 (London: Thomas Telford, 2009); and Jose M. Adam et al., "Research and Practice on Progressive Collapse and Robustness of Building Structures in the 21st Century," *Engineering Structures* 173 (2018), https://doi.org/.

32. Luis Hernández-Callejo, "A Comprehensive Review of Operation and Control, Maintenance and Lifespan Management, Grid Planning and Design, and Metering in Smart Girds," *Energies* 12, no. 9 (2019): 1630, https://doi.org/; Jawwad Latif et al., "Review on Condition Monitoring Techniques for Water Pipelines," *Measurement* 193 (2022): 110895, https://doi.org/; and Shouzheng Pan et al., "Vulnerability and Resilience of Transportation Systems: A Recent Literature Review," *Physica A: Statistical Mechanics and its Applications* 581 (2021): 126235, https://doi.org/.

33. D. V. L. Hunt, D. Nash, and C. D. F. Rogers, "Sustainable Utility Placement via Multi-utility Tunnels," *Tunnelling and Underground Space Technology* 39 (2014), https://doi.org/.

## People-Centric Design

Based on the established criteria, a people-centric design would adequately satisfy the revised criteria for the modernized base design. Figure 1 exemplifies the strengths of the people-centric design.

### *Closed-Road System*

The closed-road system—eliminating POVs within the operational and support areas—permits only GOV access throughout the base, limiting individual transit to restricted locations and thus curtailing the need to have large antiterrorism standoff distances between facilities.[34] To mitigate mobility challenges for base users, policymakers could set funding guidelines and methods to allow for a government transit system—such as rapid bus transit or light rail—that could provide services in a timely and predictable manner.[35]

Base leadership could establish additional restrictions to personnel access at specific transit stops if necessary. The transit loop could also collocate the infrastructure necessary to support the operational effort of the airfield. Redundant legs to the transit loop and support infrastructure would allow for maintenance and repair of damaged infrastructure without impacting the base's operational effort. Lastly, the centralized utility backbone would inherently limit excessive runs of infrastructure and be more sustainable than the car-centric base design. Policymakers can make the funding available in the form of competitive funds solely for sustainment of support infrastructure projects. Separating out such projects, which historically are noncompetitive against facilities for sustainment funds, would benefit overall base sustainment.

While there are benefits to eliminating POVs from the base road systems, it is more difficult to determine the benefits of the people-centric design compared to the car-centric design with regard to active shooter scenarios. Methods—such as using virtual reality—to analyze the human-building interactions during active shooter scenarios are available but are outside the scope of this article.[36]

34. McCallister, *Minimum Antiterrorism Standards*.

35. David A. Hensher and Thomas F. Golob, "Bus Rapid Transit Systems; a Comparative Assessment," *Transportation* 35, no. 4 (2008), https://doi.org/; Vukan R. Vuchic, *Urban Transit Systems and Technology* (Hoboken, NJ: John Wiley & Sons, 2007); Peter A. Duerr, "Dynamic Right-Of-Way for Transit Vehicles: Integrated Modeling Approach for Optimizing Signal Control on Mixed Traffic Arterials," *Transportation Research Record* 1731, no. 1 (2000), https://doi.org/; and Lloyd Wright and Karl Fjellstrom, *Mass Transit Options, Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities*, vol. 3, 3a (Eschborn, Germany: Deutsche Gesellschaft für Technische Zusammenarbeit, 2003).

36. Runhe Zhu et al., "Infrastructure Requirements for Virtual Environments to Study Human-Building Interactions during Active Shooter Incidents," in *Computing in Civil Engineering: Proceedings of the ASCE International Conference on Computing in Civil Engineering 2019*, ed. Yong K. Cho et al. (Reston, VA: ASCE Press, 2019), https://doi.org/.

## *Closer Proximity and Consolidated Facilities*

With the inclusion of a properly designed closed-road system, facility proximity can be reduced. This reduction encourages walkability, discussed above. In addition to myriad health benefits from nonmotorized personal transit, incorporating mass transit stops encourages support agencies to consolidate around these transit nodes. Supporting agencies could better plan the most accessible locations to place grocers, retail, and restaurant amenities as walkability increases.

In a people-centric base, residents and employees could participate in base operations without needing a POV—and also avoid the associated financial strain. This would provide more morale-building opportunities, enable easier access to supporting facilities, and build community relations. Moreover, supporting facilities could be included within the housing areas, allowing for each neighborhood to develop its own unique culture.

Lastly, facility consolidation would reduce the individual strain of security systems and restricted access to facilities as multiple entities benefit from the shared use of such systems. While design and construction of multifunctional facilities are overall more expensive, sustainment costs—which account for the largest cost that a facility experiences throughout its life cycle—would be reduced.[37] The more functions that a facility can support, the more efficient the operation and sustainment costs per function.

## *Resiliency against Disruptive Events*

The envisioned people-centric design incorporates new technologies and designs that retain attack protection. Planners would consider the most likely adversarial attacks associated with a specific base—in-garrison or contingent—and employ available systems or platforms to reduce the likelihood of a successful disruptive event.

If a conventional attack does occur, the base commander would still be able to generate sorties due to GOV traffic being a viable option for the operational area—with larger spacing between grouped facilities reducing the effective operational disruption associated with conventional bombing strategies. Additionally, damage to the utility infrastructure backbone would have less of an impact due to the lines collocated with the redundant legs to the transit loop.

Air-blast resistant and progressive collapse structures would allow personnel the time needed to evacuate a targeted facility. As a last resort, contingent supporting infrastructure could be utilized until the backbone is repaired and operational. Walkability would allow base operations to continue if the road infrastructure is disrupted by craters or damaged roadways, for example. Couriers could be established if all other communication lines are rendered inoperable.

---

37. Mitchell, *Physical Asset*; and D. S. Haviland, *Life Cycle Cost Analysis: A Guide for Architects* (New York: American Institute of Architects, 1977).

### *More Affordable Maintenance*

Another benefit of the people-centric base design is in decreased maintenance costs to overall base infrastructure while ensuring sustained operations. Infrastructure repair and maintenance would be minimized as the linear distance becomes shorter. For roads, different materials can be used to distinguish between vehicle roads and pedestrian streets. For example, for low-vehicle density roads and bicycle paths, cobblestone as a road material has been found to be less costly throughout its lifespan compared to asphalt or concrete.[38] The use of cobblestone or even brick for locations designed to be walkable can also offer a passive traffic calming measure for GOVs.

Furthermore, consolidating areas into distinct and clustered groupings minimizes the utility runs needed for each facility and maximizes the multichannel runs of infrastructure. Walkable areas connecting the facilities within the groupings would further reduce the operational and maintenance costs of the roads. Restricting transportation of the roadways to GOVs or base-provided transit vehicles would also reduce stress loading.

## Sustainable Benefits of Redesign

While sustainability goals for an Air Force base may differ from such goals for cities, the underlying life-cycle cost savings associated with facility sustainability are shared between the two environments. Minimizing outer surface area while maximizing interior space results in reduced construction and life-cycle energy costs and has been adopted in current Air Force dormitory design.[39] Expanding these potential savings to all housing units on base as well as a consolidated support area would lower the yearly infrastructure life-cycle cost.

Consolidating housing from single-family detached units into attached units or apartments increases the density of the useful square footage while decreasing the support infrastructure needed to accommodate each family. The design of such consolidated housing must consider accessibility concerns for dependent family members. These same benefits can also be shared when designing the support hub for the people-centric base.

While the average Air Force base will not see tremendous fluctuations in personnel housed or operating within the base, additions to the housing, supporting, and operational areas remain viable. Furthermore, multi-utility tunnels within the dense people-centric areas are less likely to be damaged by adversarial attacks and can be cheaper and faster to repair, compared to existing utility designs.

38. Damien Triguax et al., "Life Cycle Assessment and Life Cycle Costing of Road Infrastructure in Residential Neighbourhoods," *International Journal of Life Cycle Assessment* 22, no. 6 (2017), https://doi.org/.

39. *Unaccompanied Housing*.

Sustainable urban design is obtainable through constant and consistent feedback from the occupants of the urban environment.[40] Base designers must interact iteratively and persistently with the urban environment as well as with base personnel to identify current problems to better plan for a modernized Air Force base.[41]

Designers should consider what change would have the greatest impact for their base. Creating a closed-road mass transit system may not be financially feasible in the near term, yet base designers may find implementing a bus system or passenger walking routes on the open-road system more feasible until funding is available. Similarly, designers may find that relocating personnel into existing facility groupings may be more plausible until funding can assist with the construction of permanent grouped facilities. Lastly, they should consider how existing infrastructure runs can become more efficient to support the base.

While policy can be drafted in broad enough terms to affect the necessary organizations and changes to base designs, a separate budget may need to be implemented with its own criteria to compete such projects correctly and competitively. Policymakers could incentivize DoD partnerships with government agencies as well as nongovernment agencies such as the Federal Emergency Management Agency, Department of Energy, Department of Transportation, Department of Housing and Urban Development, National Science Foundation, and National Institute of Building Sciences to assist in converting bases to a modernized base design. Policies should focus on the inherent relationship between the supporting infrastructure and the facilities. A team of designers could experiment with an existing base as a test to determine the feasibility, costs, and problems associated with modernizing current bases.

## Challenges

Historically, adequately funding DoD installation maintenance has been difficult to achieve.[42] The primary challenge of the design overhaul presented in this article is justifying the enormous budget needed to reconstruct bases at an accelerated pace over the current projected pace. A separate fund may need to be established to accommodate the shift in base design principles. This new fund could be utilized to supplement existing funding sources or be the sole fund for modernizing such projects.

Still, even if the funds are made available, the Air Force is deficient in manpower and the necessary skills to implement the changes.[43] Such an overture would require multiple teams of urban designers, architects, and engineers to study and improve on the modernized base

40. Massimo Tadi, Sharooz Manesh Vahabzadeh, and Fabrizio Zanni, "Integrated Sustainable Urban Design: Neighbourhood Design Proceeded by Sustainable Urban Morphology Emergence," *WIT Transactions on Ecology and the Environment* 155 (2012); Reeman Mohammed Rehan, "Sustainable Streetscape as an Effective Tool in Sustainable Urban Design," *HBRC Journal* 9, no. 2 (2013), https://doi.org/; and Marohn, *Strong Towns*.

41. Tadi, Manesh, and Zanni; Rehan; and Marohn.

42. Maestas et al., "Defining Success."

43. Maestas et al.

design throughout their entire careers. The current corporate option for planning and constructing these complicated projects is to employ architect-engineering firms outside of the government. A shift in career fields in the civil engineering squadron to accommodate the workforce necessary to accomplish and construct modernized bases may be feasible.

While revised Unified Facilities Criteria and area development plans would allow for new bases to be modernized, existing bases would struggle to adapt their current makeup. Separate policies and guidance may be needed to determine how an existing base might align with the modernized base design. This would allow for each base to determine the critical path to success through incremental change optimized for their unique locations.

Further, adapting bases to the modernized base design would have impacts on the local economy. For example, car dealerships close to bases rely on military members purchasing a vehicle to navigate both the local area and on base. Current transportation corridors into and out of the base would need to be reevaluated for traffic flow. Gradual changes to the base would generate stress on the local economy as city and transportation design would need to incorporate the proposed end state. While these gradual modifications could benefit a city seeking to progress toward a people-centric environment, the rate at which a base changes may differ from the rate at which the surrounding city changes to integrate with a modernized base design.

Lastly, the modernized design will differ between continental United States bases and deployed locations. The current Air Force stock of deployed structures as well as the inherent difference in likely adversary attacks changes the underlying base design for deployed locations. Inclusion of life-cycle analysis for supporting infrastructure at deployed locations may benefit the location. This analysis will allow base commanders to determine the most efficient equipment and infrastructure that can provide the support necessary to generate their operational effort in both friendly and adverse environments.

## Conclusion

The Air Force's currently established car-centric design for its air bases is not an optimal solution against present and future disruptive events. A people-centric design may be a better solution to the security and integrity challenges it faces. Removing POVs from the base road systems would encourage consolidation efforts for both facilities and supporting infrastructure. In addition to enhancing rapid cross-base transit, consolidated facilities will become multifunctional. Each change will maximize sustainability while ensuring that a modernized base design can adapt to attack scenarios now and in the future.