

performance in buildings. This includes the ability of such materials to withstand typical shock, impact, vibration, or abrasion effects over the life of a building. There are now measurement methods for many of these properties, but the relationship of the results to serviceability requirements is in need of technical support.

- There were no validated tools to analyze the dynamics of building fires and their effects on the structural system that would have allowed engineers to evaluate structural performance under alternative fire scenarios and fire protection strategies. While considerable progress has been made in recent years, significant work remains to be done before adequate tools are available for use in routine practice. NIST had to further develop and validate tools to investigate the fire performance of the WTC towers.
- Building code provisions for sprinkler installation in office buildings were an option in lieu of compartmentation. NYC has since promulgated local laws to encourage installation of sprinklers in new buildings, and is now considering a law to require sprinklers in existing buildings. The WTC towers were fully sprinklered by 2001, about 30 years after their construction.
- Active smoke management systems and/or combination fire/smoke dampers were not required in fully sprinklered buildings by the 1968 NYC Building Code or any subsequent, retroactive provisions.
- With a few special exceptions, building codes in the United States did not, and do not, require the use of fire-protected elevators for routine emergency access by first responders or as a secondary method (after stairways) for full building evacuation of occupants in emergencies.
- Firefighters moving up the stairs did not significantly lengthen the average time evacuees spent in the stairways. However, the climbing rate of the firefighter was hampered by the presence and movement of the evacuees.
- The separation of the three stairwells in each tower exceeded the requirements of the 1968 NYC Building Code. On some floors, the separation distances were not as large as the current model building codes require, while on other floors, the separation distances significantly exceeded the provisions in those codes.

8.6 FUTURE FACTORS THAT COULD HAVE IMPROVED LIFE SAFETY

In the course of the Investigation, NIST and its contractors were aware that there were modern, emerging, or even imagined capabilities that could have increased the survival rate of those in the WTC towers, had they been in place on September 11, 2001. These are listed here, not posed as recommendations for implementation, but presented for completeness in the portrayal of the findings of the Investigation. NIST has not conducted studies to evaluate the degree to which building performance and human factors could have been improved on September 11, 2001, had the capabilities been available.