

PLANNING FOR PEAK DEMANDS IN TRANSPORT SYSTEMS – AN AGENDA FOR RESEARCH

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Abstract

This paper is a pioneering effort in developing key concepts for peak demand transport. Peak demands in transport systems occur during mega-events, e.g. the Olympic Games or mass evacuations, which strain the pre-existing transport capacity far beyond its maximum limit. The author defines mega-events in the transport context as follows: a transport mega-event is an extraordinary temporary combination of mass transport flows, requiring the involvement and coordination of all available metropolitan transport modes with different service levels and requiring temporary and long-term modifications to the transport system. Peak demands as analyzed in this paper go far beyond the regular congestion levels, and constitute exceptional levels of passenger demand. Transport agencies have to extensively plan for those peak demands, for which many agencies start their planning efforts from scratch or draw on common practices within the same mega-event group (e.g. evacuations). This paper intends to jumpstart thinking outside the box by cross-comparing transport practices for various mega-events that have relatively little in common. The contribution of this paper is to identify six common key concepts among those different mega-events. Based on these findings the author concludes that these concepts are indeed applicable to any transport mega-event and suggests further inquiry into the field of peak demand transport planning.

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INTRODUCTION

Urban transport systems around the world experience extraordinary pressures when momentous perturbations of regular commuting patterns require cities to outperform any transport challenge they have ever faced. Mega-events, such as sporting competitions, world expositions, pilgrimages, or hazards require accommodation of millions of passengers, straining the pre-existing transport systems beyond the maximum. Whereas analysis of transferable lessons' within such mega-events has progressed (Bovy, 2008; McEntire, 2007), this cross comparative research would provide an apex for new ideas, awareness of potential pitfalls, and indications for successful applications. Given these mega-events continuously grow in frequency, scale and magnitude, it is essential that transport planners identify alternative and better practices to move passengers safely and securely.

Driven by the premise that there indeed exist similarities in transport among intrinsically different mega-events, this paper constitutes a pioneering effort of comparative inquiry to leverage existing knowledge for peak demand transport. In analyzing transport measures across three mega-event types, the paper identifies six common key concepts that are transferable from one to the other. To broadly foreshadow the paper's conclusions, Figure 1 provides an overview of the analytical framework cross comparing three types of mega-events. The solid boxes indicate the topics analyzed in this paper, and the dashed boxes show the potential for future exploration.

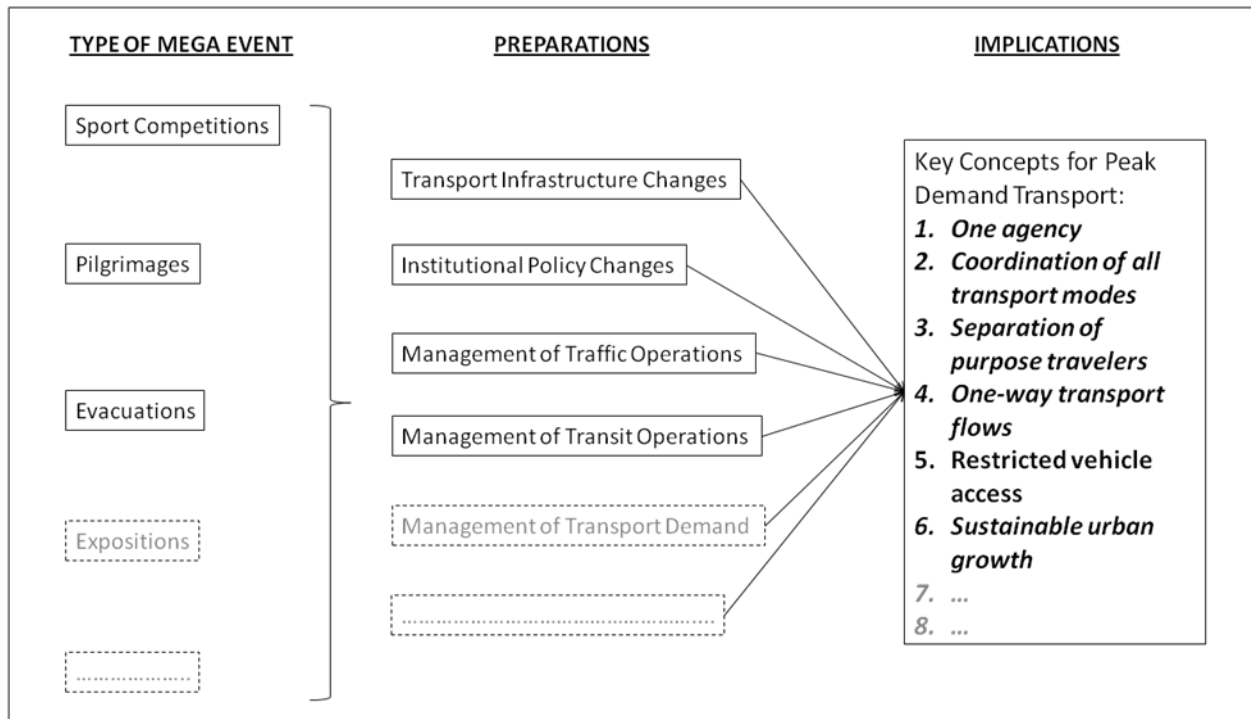


Figure 1: Analytical Framework for Key Concepts for Peak Demand Transport

Drawing upon seven case studies, the author compares transport management initiatives undertaken by world cities to host the Summer Olympic Games (Barcelona, Atlanta, Sydney, Athens), to evacuate urban areas (Miami, New Orleans) and to manage the Hajj, the annual Muslim pilgrimage (Makkah). Semi-structured face-to-face interviews with lead transport planners in selected mega-event cities were audio recorded and transcribed. Further data

exchange via email and content analysis of planning documents and transport plans, incl. transport agencies' preparedness guides and governmental instructions published on websites, constituted the methodological foundation for this work.

This paper is useful to transport planners seeking innovative ideas for transport management for peak demands. It highlights the potential to leverage knowledge across mega-events. In particular for evacuations, traffic problems are becoming an inhibiting factor in complying with evacuation orders, because current transport practices impinge on people's ability to get out of harm's way (Dow & Cutter, 2002). Therefore, experts have emphasized the need to include public transit within the planning framework (Committee on Disaster Research in the Social Sciences, 2006). In creating a conceptual framework on potential strategies to manage peak demands in transport systems, this paper initiates a stepping stone for future inquiry.

EMERGING TRENDS IN TRANSPORTATION FOR MEGA-EVENTS

Cities across the world face the challenge of staging mega-events in the pursuit of protecting lives, economic growth, or religious diligence. To make the concurrent events successful, transport systems—as the backbone of the cities—have to function flawlessly. There are at least three distinct mega-events that require cities to plan for peak demands in their transport systems: mass evacuations, pilgrimages and sport mega-events. In all instances, the transport systems experience elevated pressures to perform with excellence under highly uncertain conditions.

In recent years, mega-events have grown in frequency, scale and magnitude. The number of hazards approaching coastal areas followed by evacuation orders has grown significantly along with a rapid increase of populations residing in hurricane-prone regions (Barrett, Ran, & Pillai, 2007). Due to climate change and urbanization, these trends are likely to continue. Because of the growth in the Muslim population along with their increasing economic wealth in the past decade, demand for travel to the Hajj has increased significantly (Royal Embassy of Saudi Arabia, 2008). The number of cities applying to host the Olympic Games has grown exponentially in recent years as cities vie to acquire or confirm world city status (Essex & Chalkley, 2002). Along with the interest to bid, this mega-event has drawn more and more participants and visitors to these world cities.

Along with the increasing frequency of these mega-events, their staging has required more resources. Whereas Beijing [US (2000) \$21.8 billion (BOC, 2000)] and London [US (2007) \$16.4 billion (LOC, 2008)] spent double-digit billions to improve their infrastructure prior to the Olympics, Saudi Arabia spent \$125 billion to accommodate the expected growth of the Hajj (Al Jazeera English, 2009, November 25). Comparatively, evacuations have caused lesser spending (~\$27 million during Hurricane Gustav) (Montz, 2010), yet their increasing frequency may start to affect the states' budgets.

Understanding and defining peak demand transport

As of today, little research exists on peak demand transport patterns and their management, even though these extreme events continue to grow rapidly. Especially for mega-events, a research agenda has yet to emerge. Robbins et al. (2007) advocated for such an agenda because facilitating mobility is key to any event's success. Bovy (2002) has given the broadest characterization of mega-events in terms of transport. He characterized them as having an unusual magnitude and volume of spectators, a geographical and spatial concentration of traffic flows (depending on the event's schedule), and a superposition of various categories of

transport flows on the usual urban traffic. They required the development of innovative temporary transport, traffic management and ticketing schemes, appropriate agreements between organizers and authorities, and a systematic development of security. Leaning on Bovy's (2002) characterization of mega-events, the author defines mega-events in the transport context as follows:

A transport mega-event is a unique temporary combination of mass transport flows, requiring the involvement of all available metropolitan transport modes with different service levels and requiring temporary and long-term modifications of a transport system.

For sport mega-events, da Silva (2003, p. 209) proposed five characteristics that determined their magnitude and impact on the transport system:

1. *size*: number of visitors, as well as direct participants and personnel hired for the event;
2. *concentration*: duration of the event, duration and magnitude of traffic peaks;
3. *foreseeability*: periodicity of the event and the time available to prepare it;
4. *additional cost* of extra transport demand, compared with existing transport demand;
5. *level and capacity* of existing transport system.

Whereas da Silva (2003) focused these characteristics on the same specific event under the assumption that all transport modes would be used, he ignored specific circumstances of different mega-events; e.g. for evacuations the car is the primary transport mode. When comparing the Olympics, the Hajj and evacuations, five key variables jump to mind that crucially determine the pre-planning options and transport measures implemented into the transport systems. Whereas the size and concentration of the selected mega-events greatly exceed other comparable events in the same category, frequency, predictability, cultural background, mobility scale, and the type of transport mode varies greatly across the three mega-events (Table 1).

Table 1: Planability of mega-events

	Sport Mega-Events: Olympic Games	Pilgrimages: Hajj	Evacuations in: Miami/New Orleans
Frequency (same city)	Unique	Repeated	Repeated
Predictability (years)	Expected	Expected	Unexpected
Cultural background	Celebration	Religious Diligence	Forced movements
Mobility Scale	Urban	Regional	Regional
Primary type of transport mode	Rail	Bus	Cars

Sources: the author

Even though these fundamental differences exist, the transport task – moving millions of people in a short period of time – remains the same. In all of the case studies, significant planning efforts are necessary to surmount the challenges these events impose on a city's transport system. Cross comparison of the applied transport practices can provide an apex for new ideas, awareness of potential pitfalls, and indications for successful applications. Given current trends in mega-event growth, transport planners need to identify better practices to move millions.

Transport planning for sport mega-events, pilgrimages and evacuations

Efficiency, effectiveness, and safety are the three keywords used in transport planning for these exceptional events (Bovy, 2006; ECMT, 2003). Cars, shuttles, taxis, buses, trains, boats, planes, biking, and walking are means of transport systems to handle passenger peak demands, yet only their carefully coordinated usage allows them to function efficiently and move passengers safely. There are three distinct mega-event types that merit comparative inquiry for analysis of peak demands: The Olympic Games, the Hajj and Evacuations.

The Summer Olympic Games

The Summer Olympic Games have become the largest sporting event in modern times held in different cities every four years. The function that Olympic transport assumes is to connect competition (sports arenas) with non-competition venues, such as the Olympic Village, hotels, the airport, etc. (Bovy, 2005). Transport's role, as the crucial backbone of the city, is to maintain stable linkages and ensure that almost all other major Olympic city functions can operate unimpeded (Bovy & Protopsaltis, 2003). At the same time, Olympic transport has to maintain normal traffic conditions for residents. Olympic transportation flows reach peak loads of 1.7 million passenger trips per day (Bovy, 2004a, slide 7), for which the city has seven years to prepare. Table 2 provides an overview of the distribution of passenger peaks at venue clusters in four Olympic cities. To coordinate these peak transportation demands, a variety of measures are necessary (Kassens-Noor, forthcoming).

Table 2: Passenger estimates by Olympic area in four Olympic cities

	Barcelona 1992		Atlanta 1996		Sydney 2000		Athens 2004	
Sport events at locations	13	Montjuic	20	Center	20	Homebush	10	OLYMPIA
	7	Diagonal					10	Faliro
	5	Vall d'Hebron					7	Helleniko
	4	Parc del Mar						
Facilities at locations	5	Montjuic	11	Center	14	Homebush	6	OLYMPIA
	6	Diagonal					4	Faliro
	5	Vall d'Hebron					6	Helleniko
	2	Parc del Mar						
Passengers on peak day at locations	100,000	Montjuic	400,000	Center	400,000	Homebush	150,000	OLYMPIA
	n.a	Diagonal					75,500	Faliro
	n.a	Vall d'Hebron					75,000	Helleniko
	n.a	Parc del Mar						

Source: NBCSports 1991, BOCOG 1993, ACOG 1993, BOOZ Allen 2001, deFrantz 1998, ORTA 2001, (Papadimitriou, 2004), (Transport Department, 2000), Archives du CIO / Olympic Games Barcelona 1992 / transport.

The Hajj

The Hajj, the fifth pillar of the Islamic faith, is the annual pilgrimage to several holy cities in Saudi Arabia (Figure 1). Meditation and prayers take place during six days in early December (Al-Kodmany, 2009). On the first day, pilgrims move out of Makka to Mina. On the second day, pilgrims proceed to the plain of Arafat and after sunset to Muzdalifah. On the third day they return to Mina, where they stay for the next three or four days performing further rituals of the Hajj (Ahmad Wali, et al., 1999).



Figure 2: Hajjis route

Source: Ministry of Hajj 2010; <http://www.hajjinformation.com/main/j40.htm>

Over the past 15 years, the Hajj has seen a steep increase of ~70% in the number of pilgrims, peaking in 2008 with 1.7 million (Royal Embassy of Saudi Arabia, 2008). The Hajj constitutes an once-in-a-lifetime obligation for those Muslims who have the physical and financial ability to undertake the journey, yet the constrained open space and limited transport options allow a fixed number of pilgrims to conduct the Hajj amidst their growing numbers. Hence, the King of Saudi Arabia decided to almost triple the area (called Holy Haram) available to safely and diligently conduct the Hajj. Upon completion, 118,000 pilgrims per hour will be able to conduct the Tawaaf – circling the holy stone, Kaaba, within the Holy Haram (Ministry of Hajj, 2008b). The city's current dependence on cars and buses as the sole option for public transport is neither sustainable nor suitable in the long-term. Given the projected growth of the Hajj, the Saudi Arabian government has decided to invest in new transport options and infrastructure to accommodate the pilgrims' journeys.

Evacuations

Evacuation describes the process of moving people away from potential or actual hazard for the purpose of safety. Transport evacuation planning has primarily relied on the use of automobiles. In recent years, traffic problems have become an inhibiting factor in complying with evacuation orders (Dow & Cutter, 2002). This limitation was evident just before Hurricane Katrina struck New Orleans in August 2005, when many could not heed the warnings due to a lack of a transport option (Syzerhans, 2006). Litman (2006) emphasized the need to include public transit in evacuation planning, yet many public transit agencies lack comprehensive plans for emergencies (Schwartz & Litman, 2008). However, recent publications by experts highlight the potential public transit has for evacuations (Transportation Research Board, 2008). Given that during Hurricane Katrina an estimated 1.1 million people had to evacuate New Orleans (Bureau of Labor Statistics, 2006), the American cities' primary dependence on cars and buses as sole evacuation options is questionable.

KEY COMPONENTS OF PREPARING TRANSPORT SYSTEMS FOR PEAK DEMANDS

The analysis section investigates the combination of infrastructural modifications, short-term institutional policies, and temporary operational measures implemented in the urban transport

systems to cope with the peak passenger demands triggered by three mega-events. Through cross comparison, the author develops common key concepts for peak demand transport. The following sections analyze transport measures implemented in four categories: Transport Infrastructure, Institutional Policies, Management of Traffic Operations, and Transit Operations.

Transport Infrastructure

In preparation for staging these mega-events in cities, governments have decided to completely build new or upgrade existing infrastructure to improve mobility and accessibility in the metropolitan region and accommodate the travelers' journeys. The following table provides an overview of the scale of improvements comparing the Olympics in Athens, the Hajj and Evacuations (Table 3).

Table 3: Exemplary transport Infrastructure for mega-events

	Olympics	Pilgrimages	Evacuations	
	Athens	Hajj	New Orleans	Miami
Road infrastructure	<ul style="list-style-type: none"> more than 100 km of new roads 90 km of upgraded roads 	<ul style="list-style-type: none"> 40 projects for civil roads 	none	none
Transit infrastructure	<ul style="list-style-type: none"> 9.6 km of metro line 23.6 km of tram network 32 km of suburban rail 	<ul style="list-style-type: none"> 4.5 km Monorail within Makkah 444 km Jeddah - Makkah-Madinah railway link 	none	none
Active infrastructure	Walking paths around venue clusters	Walking paths around holy sites of the Hajj	none	none

Sources: (ATHOC, 2002; FDOT Office of Information Systems, 2010; Louisiana Department of Transportation and Development, 2008, 2010b; Miami-Dade County, 2008; Ministry of Hajj, 2010f; Royal Embassy of Saudi Arabia, 2009b)

The scale of new infrastructure being built for the Olympic Games is immense as demonstrated in Table 3. New highways along with massive expansions of existing road corridors are common features in the run-up to any Olympic Games. In recent years, host city governments have also completely overhauled their transit systems, e.g. Beijing expanded its subway network by 25% and London established Stratford station as the new international rail station connecting the UK with Europe (LOC, 2008; Xinhua, 2008). For Olympic organizers, the preference of using high capacity rail systems for moving visitors and residents during the Olympics has acted as a catalyst for some of these investments (Bovy, 2004b). In terms of active transport infrastructure, all host cities have decided to establish walkways and biking paths around Olympic zones and downtown areas witnessed upgrades ante-Olympics.

Due to the expected growth of the Hajj, Saudi Arabia is undergoing massive infrastructure improvement costing US\$125 billion (Al Jazeera English, 2009, November 25). Because busses would not suffice as the only means of public transport to accommodate the Hajj, the government has begun an ambitious effort to improve roads around Makkah (Al Jazeera English, 2009, November 25). Over 40 projects for civil roads are planned in addition to two new public transit options. The Makkah-Madinah Rail Link (MMRL), to be operated by the Saudi Railway Organization, will link Jeddah to Makkah and Madinah trailing along part of the pilgrim's route (Ministry of Hajj, 2010f). Most pilgrims arrive by plane in Jeddah, so the government expects 50% of the pilgrims to switch to the MMRL, which would significantly release the congestion on Makkah's road system.

Furthermore, the minister of transport, signed a contract in May 2009 to build a new monorail system for Makkah (Royal Embassy of Saudi Arabia, 2009a, 2009b). Concerns about crowd safety have further prompted investment in new active transport infrastructure. Because 345 pilgrims were killed in a stampede, the government approved a project to expand the Jamarat Bridge at a cost of more than US\$1 billion (BBC News, 2006, January 12; Usher, 2006, January 17). The MMRL stops will be located close to many of the sacred places to allow access by foot and protect the majestic nature of the sites. This expansion to Makkah's active infrastructure is expected to facilitate the movement of more than two million pilgrims.

Specifically for evacuations, no additional infrastructure is being built (Meyer, 2010; Montz, 2010). Because evacuations have been primarily conducted via road systems, researchers have argued that the existing transport infrastructure is not made for evacuation-level demand and should not be (Wolshon, 2006). However, investments into Intelligent Transportation Systems (ITS) have supported evacuation operations in the past. Especially advancements in ITS have helped accommodate the travelers' journeys in providing real-time information to evacuate urban areas.

In summary, only Olympic host cities and Hajj host cities have upgraded their transport infrastructure to adapt to temporary needs. For the Olympics, the investments made were mostly aligned with the strategic plans of the city, however short-sighted planning has occurred in the run up to the mega-event, e.g. the rail-loop to Sydney's Homebush (Dobinson, 2008). Given the Hajj is an annually occurring event; investments were geared to facilitate future movements. Saudi Arabia's transport preparations to accommodate the pilgrimage's growth aim to provide high-capacity transportation systems that make it unnecessary to use private transport upon arrival in Jeddah. For evacuations, transport investments to support the expected transport flows have been minor primarily in the Intelligent Transportation Systems (Florida Department Of Transportation, 2010b). Potentially more frequent occurrences of hazards might spur thinking about permanent investments long term to adapt to a future of climate change and more frequent evacuation orders.

Institutional Policies

Institutional policies include responsibilities, structure, management, and operational practices of transport agencies during a mega-event. Best practices and cooperation experienced during a mega-event could improve the efficiency of the transport agencies by removing bureaucratic barriers long-term.

In order to coordinate the Olympic travel flows, a single entity for transport is created to oversee all traffic functions. This umbrella organization oversees communication and exercises control across jurisdictions (ministries, department, planning councils, etc.). The traffic command, control, and communication center is the heart and brain of this games-time transport system. It allows efficient and real-time transport and security management. Communication is an increasingly important function within the organization and towards the public and the media. Hence, a single transport spokesman takes responsibility for all internal and external communications via all media (Bovy, 2004a, p. 56). Transportation during the event is free of charge for Olympic ticket holders, who may use any transport mode prior and post a competition. This institutional policy was implemented to attract riders to the public transport systems.

In Saudi Arabia, the Ministry of Hajj is responsible for the overall management of Hajj pilgrimages. For transportation, the so called "General Cars Syndicate" (GCS) is in charge, whereas all transport companies providing services to pilgrims must be registered with the GCS,

obtain relevant permits, and comply to their rules (Ministry of Hajj, 2010a). Its responsibilities include securing comfortable buses for the transport of pilgrims, monitoring bus services of the individual transport companies, and providing prompt assistance in case of bus failures (Ministry of Hajj, 2010c). Therefore, the General Car Syndicate has established workshops along the highways and wireless communication networks all along the roads used by pilgrims. In comparison to the Olympics, the General Cars Syndicate does not assume any coordination functions as of yet and only intervenes in case of failure of single transport agencies (Ministry of Hajj, 2010c). Pilgrims can select one of eight transport options which range in cost from SAR240 to SAR535 [\$64-\$143 (2010)], which need to be paid to the Unified Agents Office prior to departure from their home country (Ministry of Hajj, 2010d). Each of these options comes with varying degrees of service provision from the government.

The Louisiana Department of Transportation and Development (LDOTD) manages state emergencies throughout Louisiana. It plans evacuation routes and provides highway maps, emergency contact numbers, training, and manuals for state emergency preparedness. Its responsibilities are to put into effect contra-flow highway systems and close roads to provide for efficient evacuation (Louisiana Department of Transportation and Development, 2010a). In Florida, the State Safety Office, headed by the Chief Safety Officer Marianne A. Trussell, handles all safety concerns including mass emergency (Florida Department of Transportation, 2010c). Within this office, the Emergency Management Office is responsible to prepare for, respond to, and recover from any emergency disaster that may occur (Florida Department of Transportation, 2010a). Online information sources further prepare citizens for evacuations. The City of Miami Government provides help to the carless by dedicating bus pick-up points, shuttles and evacuation centers (Miami-Dade County, 2010). These transport options are free of charge to the users. If the president declares a disaster, local governments are reimbursed for expenses related to the disaster (including evacuations). If a presidential declaration is not made, but the Governor of Florida signs an Executive Order, the expenses are paid for by the state. If neither is done, the local government pays (Meyer, 2010).

In summary, for all mega-events cities established a single transport entity that would coordinate movements of the mega-event travelers. It is crucial that this center assumes joint command and communication functions to ensure the safety of travelers. Whereas this entity was only established short-term for the Olympics, the Hajj and evacuations have a dedicated authority, assuming control and responsibility for transport operations.

Management of Traffic Operations

Traffic Operations measures are implemented in the road network during mega-events with the intent to ease and prioritize traffic flows and to guarantee free flow traffic for certain groups of travelers.

For the Olympics, host cities have usually invested in a brand new Traffic Management Center (TMC) to coordinate all transport activities. Furthermore, extensive investments are undertaken by host cities in the newest Intelligent Transport Systems (ITS) to coordinate traffic flows, and the Games have virtually become test-beds for innovative transport technology (Atlanta Department of Planning and Development & Corporation for Olympic Development in Atlanta (CODA), 1993; Attiki-Odos, 2007). In close proximity to the clustered sporting arenas (~1-2 km), firm restrictions on private and public transport are imposed, frequently not allowing any private cars (Bovy, 2004a). The only groups of vehicles granted access are the Olympic Family Members (OFM) and emergency vehicles. In order to enforce the no access policy while

avoiding gridlock, circular one-way traffic is enforced around the central cluster of venues (Papadimitriou, 2004). Furthermore, the OFM and emergency services have exclusive ingress and egress routes to the centers of activity (Bovy, 2004a). Passenger movements within the circle have strict priority before any other transport mode.

For the Hajj, the Ministry of Hajj coordinates all traffic operations. The Ministry of Hajj has established Group Dispatching Control Centers on four major highways to manage the flow of traffic coming into Makkah. The Centers are under the authority of the Ministry of Pilgrimage and operate 24 hours a day (Ministry of Hajj, 2010e). During the Hajj, private vehicles are forbidden from entering the central area of Makkah (Patrick Hook Associates, 2004).

Given that evacuations rely primarily on cars as the primary transport option, traffic management and innovative measures are of essence in securing the safety of the travelers. Louisiana's evacuation plan calls for four different measures to handle traffic increases in case of approaching disasters. (1) The Contraflow plan reverses the direction of portions of expressways and interstates to allow traffic to go the opposite way, thereby doubling the available capacity of highway systems to accommodate fast exit of a region. (2) Phased evacuation describes the process of evacuating certain areas at a certain time based on their geographical locations. Those citizens living on the coast are allowed to leave before those farther inland. For example, people living in New Orleans leave 50 hours before a tropical storm is forecasted to reach the coast, while those in Baton Rouge leave 30 hours before (Louisiana Department of Transportation, 2010). (3) Placing a curfew disallows people from being outside or driving during a hurricane (Public Information Office, 2004). (4) The closure of roads and bridges protects citizens from driving into flooded roads. In Florida One-Way Evacuation operations and Contraflow Plan are also the primary modes of moving citizens out of harm's way (Florida Department Of Transportation, 2010d). Implementation of these evacuation strategies required new ITS systems and appropriate signage to help those evacuating (Florida Department Of Transportation, 2010a). The Florida's Intelligent Transportation Systems Program also deploys traveler traffic information through the radio (Florida Department Of Transportation, 2010b).

Table 4: Traffic Management Strategies for mega-events

Peak Demand Event	Olympics	Pilgrimages	Evacuations
New and/or significantly overhauled Traffic Management Centres	X	X	
New Intelligent Transportation Systems	X	X	X
Surveillance Cameras	X	X	
Variable Message Signs	X		X
Reorienting Routine Traffic	X	X	X
Driving Restrictions around main event site	X	X	
Driving Restrictions in Inner City	X	X	X
Parking Restrictions around event sites	X	X	
Parking Restrictions in Inner City	X	X	

Road Closures and Line Restrictions	X	X	X
Priority Provisions for Cyclist and Pedestrians	X		
ContraFlow			X
Phased Traffic			X

Sources: (Florida Department Of Transportation, 2010a, 2010d; Florida State Emergency Response Team, 2010; Hart & Sullivan, 2008; Kassens-Noor, forthcoming; Louisiana Department of Transportation and Development, 2010a; Patrick Hook Associates, 2004; Usher, 2006, January 17)

Table 4 provides an overview of measures implemented in mega-event transport systems. Through restrictive The basic difference between these three mega-events in terms of traffic operations is evident; whereas the Olympics and the pilgrimages insist on banning private vehicles in participating in the movements, evacuations rely on the use of individual cars. Therefore extreme measure such as the contra flow systems are implemented during evacuations. However, the same way of thinking is also employed for the Hajj and the Olympics just on a smaller scale; circulation systems around Olympic venue clusters or for internal building circulation within the buildings around the Holy Haram (e.g. stairs) are one-way only.

Management of Transit Operations

This category comprises measures implemented in the public transport system during the time of a mega-event, with the intent of providing easy access to venues (be it shelters, sport facilities, or open gathering spaces) and smooth transport flows across cities and regions.

The main transport lesson host cities learned was that no single transport mean is sufficient to transport Olympic crowds. To support the transport operations in addition to rail systems, two new bus networks, called the “Olympic priority lanes” are added to the regular transport system (ORTA, 2001): (a) The first one serves visitors connecting the venues from collated hubs throughout the entire transport system (park and ride services, main railway stations, etc.). (b) The second one exclusively transports Olympic Family members (OFM) connecting key venues, such as the Olympic village, the airport, and the main Olympic stadium. Within the inner city, the public transport system handles the needs of the masses (visitors and residents) by connecting the venues with the local hotels and other attractions. Emergency response is also kept as separate flows throughout the Games. Preparations for the Games have frequently led to an upgrade of the transport fleet towards environmentally friendlier alternatives.

For the Hajj, Transport is primarily via bus systems – connecting the holy cities (Ministry of Hajj, 2010c). Pilgrims have the choice of purchasing eight different categories to choose a journey, depending on choice, price and individual ticket issued (Ministry of Hajj, 2010a). Just recently the Saudi government has added one thousand new buses to accommodate future Haajjis having 18,700 buses at its disposal (Ministry of Hajj, 2008a). In addition to bus transit, the Makkah-Madinah Rail Link will help to facilitate pilgrim transit during the Hajj after its completion (Ministry of Hajj, 2010f). Employees of the Unified Agents Office are based at the airport in Jeddah to help facilitate bus transit for passengers arriving at the Kingdom.

Louisiana’s Department of Transportation and Development primarily relies on cars for evacuations. For the carless, local busses collect citizens in each of the parishes and transport them to central points (Parish Pick-up Points). Thereafter, state transportation services take them to dedicated shelters. For example, during Hurricane Gustav, 1,200 people were

transported by bus and 1,500 by train out of New Orleans (Hart & Sullivan, 2008). Another exception constitutes evacuation of pets and their owners. The Louisiana Department of Agriculture and Forestry along with the Louisiana State Animal Rescue Team worked together to quickly inaugurate bussing system in order to transport pets and their owners from the danger of Hurricane Gustav (Department of Agriculture and Forestry, 2008). In Florida, evacuations are conducted in a similar manner, whereas the most reliable form of transport is one's own car. The carless are encouraged via the official website FloridaDisaster.org to organize ride-shares in case of emergencies (Florida Department Of Transportation, 2010a). Florida's DOT also provides information on other forms of transportation such as buses, airlines, trains and ships when hazards approach, primarily providing information on their arrival and departure time (Florida Department of Transportation, 1999). Most large metropolitan coastal communities have a bus system in place to assist residents with transportation out of surge zones and into safe shelter, preferably within each county (Meyer, 2010).

Table 5: Transit Management Strategies for mega-events

Peak Demand Event	Olympics	Pilgrimages	Evacuations
Extensive Bus Network for Spectator Services	X	X	
Exclusive Bus Routes for special services	X	X	X
Free Public Transport with Entrance Ticket	X		
Park and Ride Facilities	X		
Shuttle Services from Park & Ride	X		
Shuttle Services from Rail to event sites	X		X
Encourage Day Charter Bus Trips	X	X	
Encourage Walking and Biking	X		
Operation of Trains 24/7	X		
Operation of Busses 24/7	X	X	
Ride Sharing			X

Sources: (Department of Agriculture and Forestry, 2008; Florida Department of Transportation, 1999, 2010a; Ministry of Hajj, 2010a, 2010b, 2010e)

In comparison, the Olympic Games implement a variety of transport measures to handle the peak demands in and around the cities. Past experiences showed that more than 80% of spectators used public transport during the Olympic Games (ORTA, 2001). While the Hajj is conducted only via bus transport, the Saudi Arabian government has realized the need to invest into regional public transit infrastructure to accommodate future haajjis. At least two distinctive passenger groups is a common feature in all mega-events: OFM vs. visitors, pilgrims vs. cities' populations, emergency vs. general evacuees. All transport agencies have felt the need to dedicate exclusive space, e.g. road space, staging areas, to such services as they are crucial for the event's success.

DISCUSSION OF KEY CONCEPTS FOR PEAK DEMAND TRANSPORT

There are striking similarities between the peak demand transport tasks across mega-events. Adding 2 - 2.5 million people to the existing transport capacity of a city, transporting all people to or from several centers of activity, and implementing strict safety and security measures for their journeys are only a few of the parallels. At the same time, the differences require a careful examination of the transferability of mega-event transport concepts. Key differences range from the mindful consideration of the spirituality of the pilgrims' journeys founded in millennial traditions (Al-Kodmany, 2009), as well as the consciousness of continuous transport flow throughout the years vs. once-in-a-century Olympic peak demand. Despite such differences, all mega-events had six key concepts in common that should be applied by future cities to handle peak passenger demands.

1. **One agency:** private, public, and active transport have to be directed by one umbrella organization that holds the power over communication and control across jurisdictions. For the Olympics, this is accomplished through establishing a central coordination entity is established for the duration of the Games. For the Hajj, the Central Car Syndicate assumes such a role, yet only in case of failures of transport operations. For evacuations, the State governments hold control and have the power to initiate evacuations.
2. **Coordination of all transport modes:** the key in providing smooth transport operations is the coordination of all transport modes whether they are private, public or active. For this control and communication mechanism, the transport systems are frequently equipped with a variety of Intelligent Transportation Systems (ITS), which play a vital role for smooth transport operations. These ITS solutions include control cameras across the city, variable message signs to inform the travelers, etc. All operations are coordinated via Traffic Management Centers situated in the central city or along travelled routes.
3. **Separation of purpose travelers:** at least two distinctive passenger groups are present during all mega-events, and the one with the most critical needs should have exclusive rights-of-way: the OFM's have exclusive bus lines, the pilgrims have dedicated busses, and emergency services have rights of way. Ideally these passenger groups should move separately on dedicated and exclusive travel routes to enhance security, safety and reliability of such services. When dealing with large crowds over short distances, transport measures that give priority to pedestrian flows are necessary. Open space allowing free pedestrian movements is crucial for providing safety in case of a panic situation.
4. **One-way transport flows:** backtracking of travel flows should be a no-go for any mega-event. Providing the shortest possible route to the destination without reverse flows minimizes disruption and time delays for all travelers involved. Whereas the contra-flow systems during evacuations are the extreme examples, the same measure is used for circulation systems around Olympic venue clusters or for internal circulation within the buildings around the Holy Haram (e.g. stairs).
5. **Restricted vehicle access:** access for vehicles should be limited within walking distance around centers of activity. There is a strict no car access policy for Olympic venues, and the area around the Holy Haram is also kept car-free during the Hajj. For evacuations, the opposite so far has been true. Car usage is greatly encouraged during

evacuations, evidenced by car-sharing as the preferred evacuation option for the carless. Given the lessons learned by large mega-events to use public transit instead, evacuation planners should consider using the available public transit modes of their cities. Arguing that Miami and Louisiana do not have many public transit modes available would be the easy way out. Atlanta's staging of the Games showed that busses can be borrowed prior to such events from neighboring cities, counties or states if - and only if - such plans are in place prior-event.

6. ***Sustainable urban growth***: mega-events have catalyzed development of cities and their surroundings. Due to the pressures to stage the mega-event successfully, some questionable choices have been made in the past, e.g., building infrastructure that is not useful to citizens in the long-term. To avoid such potential pitfalls, city governments should align the development of sustainable transport and meeting the momentous transport needs. Hence, it is vital for the city to invest in mass transport systems and to implement innovative measures that both accommodate the peak demands and contribute to the sustainable growth of the city. This is by no means to suggest that state governments should invest in infrastructure solely intended to serve evacuations. However, long term decision-makers should include adaptation to climate change impacts in infrastructure development decisions.

SETTING A RESEARCH AGENDA FOR PEAK DEMAND TRANSPORT

This paper constitutes a pioneering effort towards developing a framework for peak demand transport. Further inquiry should compare mega-events that – at first glance – have little in common, yet very similarly require transport systems to outperform any transport challenge they have ever faced. The six key concepts outlined in the discussion can be seen as a starting point in developing a comprehensive and holistic plan for gaining knowledge and developing best practices that can be leveraged across mega-events to enhance safety and efficiency of peak transport operations. Given the increasing frequency, scale and magnitude of such mega-events, knowledge sharing and further inquiry is of essence to face the growing challenges these mega-events impose on transport systems.

The author proposes the following research phases in leveraging knowledge across various mega-events:

Phase 1: Identify transport operations for different mega events

Mega-event transport practices have to be understood for each type of mega-event before advancing to a cross-case analysis. Through literature reviews, content analysis of existing transport plans, interviews, observations, and various other methodologies, a comprehensive list of transport measures applied during mega-events shall be developed.

Phase 2: Rank best practices in transport operations

The transport measures identified in Phase 1 shall be sorted according to an impact factor, ranking the most successful measures at the top of the list. The development of this impact factor is of crucial importance and requires detailed analysis of various influences that determine a successful transport outcome. As examples, the impact factor should consider the efficiency of passenger movements, the preparation efforts, the costs and many other quantitative and qualitative aspects that determine “success” of a mega-event transport

operation. Furthermore, comparison across countries, cultures, and mega-event types acknowledges and identifies practices that may work in one place, but not in others.

Phase 3: Theoretical framework of peak demand transport

Cross-comparison of the ranked outcome lists will provide a theoretical framework on peak demand transport measures and an apex for new ideas on how to manage temporary mass travel flows across different mega-events. Whereas the cross-comparison shall focus on similarities in transport demand management to transfer successful practices, it is also important to carefully analyze the differences. Through such cross-comparison researchers can determine which concepts can be transferred and implemented in transport systems and mega-events around the world.

Phase 4: Applicability of theoretical framework across mega-events

To test the applicability of the theoretical framework on transport practices during different types of mega-events, further qualitative inquiry is necessary. Surveys and interviews shall be used to test the peak demand concepts prior to actual implementation. Test-events and quasi-experimental research design can aid further in refining the theoretical framework. Through multiple feedback loops, the theoretical framework can be refined and new concepts tested during future mega-events.

The importance in leveraging knowledge across mega event is particularly evident from current transport practices during evacuations; the majority of the academics, practitioners, or specialists suggest to provide public transport to those in need, such as the elderly, poor, citizens with special needs, tourists, and those without access to a car (Transportation Research Board, 2008). Yet growing urbanization, local effects of climate change, and “near disasters”, e.g., when Florida drivers were stranded on the roads during Hurricane Floyd (Husock, 2009), question the current thinking. In comparison, best practices in moving hundreds of thousands of people during the Hajj or the Olympics emphasize the need to extensively use public transit, even banning cars completely from centers of activity, as they block the efficient operation of organized transit systems. Thus, transport planners could significantly learn from other mega-events and remedy current evacuation problems quickly to prepare for future hazards.

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