DESIGN OF GROUND DELAY PROGRAMS CONSIDERING THE STAKEHOLDER PERSPECTIVE

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ABSTRACT

A Ground Delay Program (GDP) is an initiative used by the FAA to manage the rate at which aircraft demand arrival at capacity-constrained airports. In this paper, we adapt a framework developed by Mitchell et al. (1997) to identify and determine the importance of the key stakeholders in the design of a GDP. Comparing our results with current practice, we find that passengers and the federal government do not receive consideration that is commensurate with their level of importance. We conclude with suggestions for how the FAA might address this disparity in the design of GDPs.
INTRODUCTION
A Ground Delay Program (GDP) is a strategic air traffic management initiative used by the Federal Aviation Administration (FAA) to manage the arrival demand at a single, arrival capacity-constrained airport. During a GDP, aircraft that are scheduled to land at the airport are intentionally delayed on the ground prior to their departure at the origination airport so as to reduce the possibility of future airborne delays prior to arrival at the destination. Although ground delay results in airline schedule disruptions and additional labor costs, it is generally perceived as preferable to airborne delay on the whole by both the FAA and commercial airlines because it reduces fuel costs, as well as overall airborne congestion, and promotes the safe management of aircraft by air traffic controllers. However, the benefits are less clear for specific airlines, aircraft, and their passengers, as the flights that realize a reduction in airborne delay costs (“winners”) may be different from those that are assigned ground delay (“losers”).

In the academic literature, the assignment of ground delay is represented as the ground hold problem, a comprehensive review of which can be found in Hoffman et al. (1) and Ball et al. (2). A common approach is to solve for an assignment of ground delay to aircraft using a mathematical programming model. The models in the literature have been developed to capture various elements of the problem as they occur in practice, such as airport arrival capacities that are uncertain and change dynamically (e.g. Richetta and Odoni (3), Mukherjee and Hansen (4), and Hanowsky (5)) and networks of airports and en-route sectors that may include multiple capacity-constrained elements (e.g. Vranas et al. (6), Bertsimas and Stock-Patterson (7)).

A general criticism of the models in the literature is that they assume that the objectives of a GDP as made in practice are appropriate, properly reflecting the interests of multiple stakeholders. For example, ground delay assigned by the traffic manager preserves, wherever possible, the order of flight arrivals as determined by airline schedules. This order underscores an implied assumption that each scheduled flight deserves an equal priority to use an airport; however, in reality aircraft are not “equal” in various dimensions and may also accrue delay-related costs very differently.

Alternatively, in this paper, we present an analysis that identifies the key GDP stakeholders, or groups that can affect or are affected by the outcome of a GDP, and their relative importance. The results suggest that, while the design of a GDP in practice does consider the most important stakeholders, other groups, such as passengers and the federal government, do not receive a level of consideration that is commensurate with how each is affected by or affects the outcome of a GDP. Furthermore, research shows that it is possible to consider these groups in practice and that doing so may require changing both the implied assumption of aircraft equality and also the flights, airlines, and passengers that “win” and “lose” as a result of a GDP.

STAKEHOLDER METHODOLOGY
The concept of a stakeholder is based upon the seminal definition provided by R. Edward Freeman as “any group… that can affect, or is affected by, the achievement of an organization’s objectives.” (9) Stakeholders are an important topic in the field of organizational ethics, where authors such as Freeman and Phillips (10) suggest that, for both practical and ethical reasons, the consideration provided to various stakeholders by an organization should reflect the relative salience, or importance, of each.
It is interesting to note that in various transportation modes, the role of stakeholders, particularly the general public, has substantially grown over the years. If one goes back to the middle of the 20th century and the development of large-scale infrastructure, specifically the U.S. Interstate system, the planning for physical highway location was largely a professional matter negotiated between local, state, and federal transportation officials. In those days, one could hear many “horror stories” of huge land and home takings “necessitated” by the construction of interstate highways, particularly in urban areas.

As backlash against that high-handed treatment of the public by technocrats, there was a “stop the highway” movement, probably first evidenced in Massachusetts and California. In Massachusetts, in the early 70’s Governor Frank Sergeant called a moratorium on new highway construction within the beltway, Route 128, because of intense and organized opposition to projects such as the “Inner Belt;” in California, public pressure stopped the building of the Embarcadero Freeway on the waterfront in the San Francisco Bay Area.

Further, environmental stakeholders began to play more and more of a role as the environmental impact of highway infrastructure became clear. The Clean Air Act in the early 1970’s and subsequent amendments in fact mandated that environmental considerations be included as officials sought approval for any highway construction project. Now it is rare for a highway design to proceed without important inputs from the local community that is being directly impacted by the infrastructure construction process as well as, of course, its operation.

As motivated by this history of stakeholders in transportation projects, we present a two-part analysis to examine the role of stakeholders in the use of GDPs in air traffic flow management. In the first part, we offer a more detailed discussion of the design, use, and impacts of GDPs and then apply the Freeman stakeholder definition in order to identify a collection of stakeholder groups. In the second part, we determine the salience of each stakeholder group by applying a framework developed by Mitchell et al. (11).

The Mitchell framework classifies each stakeholder according to the attributes of power, legitimacy, and urgency that each possesses, which we define by adapting Mitchell’s definitions to the context of a GDP as:

Power: the ability to affect the design or outcome of a GDP
Legitimacy: the degree to which GDPs affects a stakeholder
Urgency: the need perceived by a stakeholder to change a GDP

Research by Mitchell (11) and Agle et al. (12) suggests that the more attributes possessed by a particular stakeholder, the more salient that stakeholder and the greater the consideration that the stakeholder should be given. Thus, for the design of a GDP, the most salient stakeholder is one with a legitimate and urgent need to influence the design of a GDP and the power to do so. The Venn diagram shown in Figure 1 illustrates the eight possible classifications into which we catalogue each stakeholder.
An additional feature of the Mitchell framework is that the various classifications may be used for prescriptive purposes. For example, a stakeholder that possesses power and urgency, but lacks legitimacy, is one that is able to influence a GDP and believes (incorrectly) that he or she or their organization is affected by the GDP. Such a stakeholder might act to needlessly interfere with the design or use of GDPs and is described as “dangerous.” One possible means of addressing a dangerous stakeholder would be to take steps to address that stakeholder’s misconceptions, leading to a reduction in urgency, and a change into a dormant stakeholder. As such, following the application of the framework to classify stakeholders, we suggest how the FAA might change the design of GDPs to better reflect the salience of the stakeholders.

**GDP DESIGN**

A GDP is designed in a three-step process. First, the national traffic manager, who is located at the FAA Air Traffic Control System Command Center in Herndon, VA, gathers information in regards to the airport arrival capacity and demand, typically four to six hours into the future. This information is likely to include meteorological forecasts, as well as the suggestions of representatives from regional air traffic control centers and
commercial airlines with operations at busy airports throughout the U.S. The solicitation of suggestions is formalized through a series of conference calls held throughout the day between these groups.

Based on this information, the traffic manager will decide whether or not to implement a GDP. This decision reflects the perception of the traffic manager as to how instituting a program would affect the overall efficiency of the national airspace system (NAS). For example, assigning ground delays to some flights will likely reduce the overall amount of airborne delay experienced by all flights prior to arrival at the airport, which reduces both the cost of fuel to airlines and the likelihood of costly flight diversions. Furthermore, by reducing airborne delays, a GDP may reduce the workload of air traffic controllers, thus facilitating air traffic safety, as well as the overall level of air traffic congestion.

Congestion is especially important because it may affect flights throughout the NAS, and not just those flying to the airport that is the focus of the GDP. Air transportation networks are complex, large-scale, and highly-inter-connected: a key emergent property of these networks is that delays in one part of the network may quickly spread to other areas, much like rush hour traffic on a highway. For example, severe weather over Tennessee might result in delays for flights from Boston to Chicago, even though these flights would not pass through or near the weather. Severe chronic delays, accidents, or network gridlock could change the competitive landscape or result in unreliable service. When viewed strategically, the reduction in congestion and improvement in safety, pose significant benefits to the air transportation industry: airports, airlines, passengers, related businesses, and society as a whole.

Once the decision to implement a GDP has been made, in step two, individual flights are assigned ground delay by an algorithm called ration-by-schedule (RBS). RBS allocates the available planned arrival capacity to scheduled flights in first-scheduled-first-serve (FSFS) order of scheduled arrival time (13). The difference between the time a flight is originally scheduled to arrive and the time it is assigned is translated into ground delay at the originating airport. The traffic manager is able to affect how RBS assigns ground delay by adjusting the planned airport arrival capacity and by exempting some aircraft from ground delay, either directly, or indirectly by postponing the time at which RBS is run, as flights that have already departed are not assigned ground delay.

A key property of the assignment of ground delay is that the amount of delay that is experienced, and the cost of that delay, will vary by aircraft. For example, flights typically land at an airport in the order in which they approach it from the air, much like traffic on a highway exit ramp. This first-come-first-serve (FCFS) order would be the same as the FSFS order assumed by RBS if every flight were to approach the airport as scheduled. However, in practice, a GDP will change the arrival order because exempt flights, such as international flights and those already airborne, are not assigned any ground delay and will approach the airport earlier, land earlier, and experience less delay relative to those that are assigned delay. Thus, although a GDP may benefit the system on the whole, it will certainly lead to negative consequences for some aircraft and create de facto winners and losers. Existing research (14) shows that the assignment of ground delay for a system-optimal GDP may be statistically correlated with aircraft type, origination airport, and airline, even though these factors are not directly considered
STAKEHOLDER IDENTIFICATION
A GDP stakeholder is defined as any group that “affects the outcome of or is affected by the outcome of a GDP.” Using this definition, an understanding of the process, a review of the academic and trade literature, and discussions with experts in aviation, we identified various entities as possible stakeholders. These entities, which include commercial airlines, general aviation, industry trade groups, airports, and businesses that provide goods and services to passengers and airlines, are shown in the taxonomy in Figure 2.

FIGURE 2 A taxonomy of various GDP stakeholders
Based on the taxonomy, the various entities can be categorized into eight stakeholder groups (Table 1). The groups are defined broadly and at a high level of organization so as to encompass many sub-groups. For example, the group “airlines” includes large commercial carriers, air taxis, and general aviation. Furthermore, the groups are defined in regards to GDPs: although passengers are part of society as a whole, they are unique among other groups in society because passengers, themselves, are delayed by GDPs. All stakeholders identified in the taxonomy are included in one of these eight groups in Table 1 (except those that are related to but not affected by specific GDPs, such groups that conduct FAA-related research).

By conducting the analysis at a high level of organization, many smaller stakeholders are combined into a single group. This not only makes it more likely that the most salient GDP stakeholders are included, but it also simplifies the analysis and discussion. A convenient property of the framework is that it may be applied to both groups or individual stakeholders, such that once the most salient groups are identified, subsequent studies could focus on the most important groups in order to explore the salience of individual stakeholders, such as specific airlines, in greater detail.

**TABLE 1 GDP stakeholder groups**

<table>
<thead>
<tr>
<th>Stakeholder Group</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Airlines</td>
<td>The collection of commercial, competitive, for-profit enterprises that operate and provide scheduled passenger and cargo air transportation service to airports in the U.S.</td>
</tr>
<tr>
<td>Airports</td>
<td>The operators of airports used for commercial flight service and that may provide other essential and non-essential services for airlines and their passengers.</td>
</tr>
<tr>
<td>Business</td>
<td>The at-large business community that benefits directly and indirectly from air transportation.</td>
</tr>
<tr>
<td>FAA</td>
<td>The Federal Aviation Administration; oversees the U.S. aviation industry. Includes the traffic manager, who is responsible for designing a GDP, as well as the facilities that manage en route and terminal flight operations.</td>
</tr>
<tr>
<td>Federal Government</td>
<td>The executive branch of the U.S. federal government; appoints and oversees the work of the FAA.</td>
</tr>
<tr>
<td>Local/Regional/State Governments</td>
<td>Local, regional, and state governments are responsible for the oversight of airport operators or benefit from the commercial impact of aviation</td>
</tr>
<tr>
<td>Passengers</td>
<td>Connecting and terminating passengers on scheduled flights</td>
</tr>
<tr>
<td>Society</td>
<td>Society-at-large</td>
</tr>
</tbody>
</table>
STAKEHOLDER RELATIONSHIPS
The Mitchell framework classifies stakeholders according to three attributes, each of which reflects, to some degree, the interactions between the different stakeholder groups. For example, the power of each stakeholder might be viewed as a measure of the ability of a stakeholder to influence the design and outcome of a GDP, either directly through the design process, or indirectly by influencing the FAA. Thus, before applying the framework to the groups outlined in Table 1, it is helpful to consider their interactions. We characterize the various interactions between the stakeholders as being one of three types: information, economic, and influence.

The first type of interaction is the exchange of information, most of which is to and from the FAA during the design of a GDP. For example, the FAA (represented by the traffic manager) collects information during the design process, such as flight schedules and the opinions of airline representatives, and communicates the resulting delays: assigned flight delays are provided to airlines and more general statistics are made publicly available through the internet. Airlines also communicate flight delays to passengers, and, for their part, passengers provide the airline with information both during a GDP, such as willingness to take alternate itineraries, and after, through feedback given to customer service representatives. Additionally, passengers may also communicate feedback from their experience to their government representatives. Figure 3 shows a map of the key information flows between stakeholders, with those specific to the design of GDPs highlighted in bold.

FIGURE 3 Flow of Information Between Stakeholders
The second type is economic exchanges related to the air transportation industry. For example, airlines purchase various goods and services from other businesses and employ more than a half million workers, including pilots, cabin crew, and ground personnel. Passengers also participate in additional economic activities, either directly though the purchase of rental cars, hotel rooms, etc., or indirectly through business transactions that are facilitated by travel.

Airports play a unique role in the flow of goods and services because they facilitate the transactions between airlines, their passengers, and other businesses that serve the needs of both. For example, not only do airports own and maintain essential infrastructure, such as runways and terminals, but they may also provide other goods and services to both airlines and passengers, such as fuel, food, parking, etc., either directly or through a third-party concession. In turn, airport operators receive payment from both airlines (e.g. rent) and passengers (e.g. passenger facility changes that are bundled into the price of a ticket), as well as from concessions and the direct sale of goods and services. In recent years, with the increase in hub-and-spoke operations leading to more in-terminal time for passengers, retail sales have also become an increasingly important revenue stream for airports. Finally, airports also provide transportation opportunities for local residents and businesses; this positive externality is a key reason why many municipalities and regional governments invest in the construction of airports.

FIGURE 4 Flow of Financial Capital Between Stakeholders
The role of the FAA in this system is to provide a management service to airlines and airports, ensuring the safe and efficient use of the NAS. From the perspective of the FAA, the economic benefits of air transportation are realized as funding, of which there are two sources: the federal government, which collects corporate and individual taxes and distributes some to the FAA, and the Aviation Trust Fund (ATF), which is funded by a tax on each commercial aviation ticket. Airlines and passengers provide funding to the FAA through the ATF; this contribution is required by law, as mandated by the Federal government. Of particular note, passengers are both a source of the financial capital for the FAA and an end recipient of the FAA’s services. However, all interactions between passengers and the FAA are through intermediary stakeholders, such as the airlines. Figures 4 and 5 show the general flow of financial capital and goods and services between the various stakeholders in regards to air transportation.

The third interaction is the ability of stakeholders to influence each other, which may be in the form of political power or represented by enforceable legal contracts. For example, federal, state, regional, and local governments are elected by their constituents, the general public. In turn, the federal government appoints the FAA administrator, who is ultimately responsible for the FAA’s policies. Finally, the FAA influences both airports and airlines through management, regulation, certification, and oversight of the industry, participating businesses, and infrastructure; one example of which is the assignment of ground delay to aircraft during a GDP.
Passengers also hold influence over the airlines as represented by the contract formed by the purchase of a ticket. Airlines are obligated to provide transportation once this contract is formed (subject to various stipulations). Even passengers who are bumped, or denied boarding, from their scheduled flight are entitled to compensation by law. Figure 6 shows the influence that the various stakeholder groups hold over each other.

**FIGURE 6 Flow of influence between stakeholders**

![Flow of influence between stakeholders](image)

**STAKEHOLDER ATTRIBUTES: POWER, LEGITIMACY, AND URGENCY**

In this section, we describe the power, legitimacy, and urgency of the eight stakeholder groups shown in Table 1. As developed by Mitchell, the framework classifies each of the three attributes on a binary scale; that is, it is assumed that a stakeholder either has, or does not have, power (and/or legitimacy and/or urgency). Of course, in reality, a stakeholder may possess each attribute to a varying degree. For this analysis, we compared the degrees to which the stakeholders possess each attribute and then determined an appropriate threshold at which to divide the stakeholders into a binary scale: those that possess the attribute (“high degree”) and those that do not (“low degree”). Figure 7, at the end of this section, compares and summarizes the stakeholders’ attributes.

The first attribute is power, which refers to the ability of a stakeholder to change the design and the outcome of a GDP. Clearly, stakeholders that participate in the design of a GDP, such as the FAA and, to a lesser extent, the airlines, have power. However, a
stakeholder also possesses a high degree of power if it is might use its relationship with the FAA to change the GDP-making process. Such stakeholders are the federal government, which has political influence over the FAA and is also directly responsible for funding the FAA operations, and the airlines, which provide information to the traffic manager. Other stakeholders, such as passengers and airports have a low degree of power because they do not directly influence the FAA or the design of a GDP.

The second attribute is legitimacy, which measures the impact of GDPs on a stakeholder. Airlines and passengers both have high legitimacy because the decisions made during the design of a GDP will affect the distribution of ground delay and, thus, the “winners and losers” of a particular GDP. However, the increase in the efficiency and safety of air travel – and the hoped-for corresponding economic benefits – that occurs as a result of GDPs mean that all of the stakeholders in Table 1 are impacted by GDPs to some extent.

We suggest that the stakeholders that benefit the most are those that are most directly connected to the air transportation industry and that benefits to other stakeholders are conferred through the various relationships. Other stakeholders with high legitimacy are the FAA and airports, both of which are directly related to the industry. Business and society are also directly related, although to a lesser extent: should the air transportation industry falter, both might find alternate means of satisfying their transportation needs. In this case, all four of these stakeholders are classified as having high legitimacy because of the potential for significant impacts. Lastly, the federal and state/local/regional governments are, comparatively, least directly impacted and are therefore classified as stakeholders with low legitimacy.

The third attribute is urgency, which reflects the need that is perceived by a stakeholder to change the design or implementation of GDPs. Urgency is a measure of perception; although the urgency of a stakeholder may increase with the magnitude of the impact of a GDP on that stakeholder; stakeholders that are unaware of the impact upon them, regardless of magnitude, will have low urgency, and those that perceive a need to act will have high urgency. Consequently, those stakeholders that are more directly related to a GDP, such as those that deal with them on a daily basis, will be more aware and have higher urgency.

The stakeholders with the highest urgency are those that perceive direct effects from GDPs: airlines and passengers, which are assigned delays, and the FAA, which initiates a GDP. An airport is also an urgent stakeholder to the extent that GDPs affect the flights and passengers at that airport. For other stakeholders, urgency may be in flux. While air transportation delays have been perceived as a problem by the air transportation industry for many years, the federal government has only recently pushed for a national solution to delays. Comments from President Bush and attention of the media to delays at airport, suggests that the perception of the impacts of congestion and delays – and, as a result, the perception of the impact of GDPs – may be increasing. Thus, while these other stakeholders are shown in Figure 7 as having low urgency, this status may change.
FIGURE 7 A comparison of stakeholder power, legitimacy, and urgency
Once the power, legitimacy, and urgency of the stakeholders are established, the application of the framework is straight-forward (Figure 8). The salience of each stakeholder is determined by the degree to which it possesses each of the three attributes. The most salient stakeholders are the airlines and the FAA, both of which are affected by the outcome of a GDP and have the ability and the willingness to influence the process. This result follows what is observed in practice; the traffic manager and various air carriers are able to and do participate in the decisions to initiate a GDP.

Each of the other stakeholders exhibits high levels for some, but not all three, attributes, which reduces the impetus for them to be considered during the design process. For example, passengers and airports are “dependent” stakeholders because they possess both legitimacy and urgency to a high degree, but lack the power to change the design or outcome of a GDP on their own. Business and society (“discretionary”) are also affected by GDPS but do not perceive an urgent need to act. On the other hand, the federal government (“dormant”) has the power to influence the FAA, but may also not perceive the need to act. Lastly, local/regional/state governments exhibit low values for each of the attributes and have relatively low salience.
CONCLUSIONS
The stakeholder classifications that result from the Mitchell framework allow us to draw some general conclusions about the design of a GDP in practice. First, the stakeholders identified by the analysis as the most salient, airlines and the FAA, are also the most active participants in the design process. These results suggest that the design of GDPS already considers the most important stakeholders; a conclusion that not only provides confidence in the current process, but also in the application of the framework. However, the results also indicate that two groups that are not currently given explicit consideration in practice, the federal government and passengers, may also be quite important and under-valued in the current process. Although both of these groups possesses some, but not all three attributes, each is in the position to gain a missing attribute either by changing itself or through the help of an intermediary.

The federal government is highlighted in the previous discussion of stakeholder urgency as one of three groups (indicated by the small arrows in Figure 8; the others are business and society) with the potential to become more urgent. The federal government is unique among these three because it is also a powerful stakeholder. Powerful and urgent stakeholders are described as “dangerous” because they may act in response to a perceived, but not legitimate, need, which could result in actions that are superfluous, wasteful, or counterproductive to the FAA’s objectives. For example, the federal government has made military airspace available for use by commercial aviation during periods of peak congestion—however, opening up this airspace has done little to relieve congestion around the busy New York airports or at the other major passenger hubs around the U.S.

Alternatively, passengers are one of two stakeholders described as “dependent” (the other is airports) because they are unable to change a GDP to better fit their needs and require an intermediary to act on their behalf. A re-examination of the relationships between the various stakeholders reveals how this might occur. As shown in Figure 6, passengers have influence over both the federal government and the airlines; the former by way of an election process (as part of society) and the latter through the contract formed by the purchase of a ticket. Thus, although passengers do not have power directly over the FAA, they may have power over stakeholders that do.

These results suggest that there is a risk that the federal government might use its power on behalf of the needs of passengers and that such action might not be desirable for either the FAA, airlines, or even the system on the whole. In the context of our initial discussion on the role of stakeholders in the development of highways, we could imagine the negative consequences if Congress were to usurp the power of the Federal Highway Administration in making highway decisions. Instead, we suggest that the FAA should incorporate more stakeholder perspectives into the design of GDPS; specifically, the FAA should:

1. Encourage the federal government to act in a way that promotes, rather that hinders, the FAA’s objectives
2. Proactively consider the needs of passengers during the design of a GDP and promote the benefits derived by passengers as a result.

Finally, we suggest that future research explore the means by which the FAA might consider passenger needs during the design of a GDP. For example, a model presented in Hanowsky (5) assigns ground delay to aircraft so as to minimize the cost of
delays to passengers, which is not (we emphasize) the way GDPs work now. For example, a full, large airplane may be assigned ground delay while a small plane may not be because of the various procedures discussed earlier. Initial experiments with the model suggest that a 40% reduction in total passenger delay cost is possible if aircraft are prioritized in order of the number of passengers. However, the resulting GDP would not only contradict the FSFS order currently used in practice, but it would change which flights – and which airlines – win and lose as a result.

We can reexamine the analysis presented in this paper to understand how such a program might impact the various stakeholders. A GDP that favors larger aircraft would reduce delays for the larger hub airlines, but increase delays for airlines with smaller aircraft and, as a result, reduce the quality of air transportation service to the cities served by small aircraft. Such actions might increase the urgency of many stakeholders; however, stakeholder salience depends on whether these stakeholders also possess a high degree of power (and legitimacy). In this case, the stakeholders that would be negatively impacted are smaller airlines and smaller cities, which will tend to have less power than the larger airlines and cities that benefit.

The lesson learned about the applicability of the Mitchell et al. framework suggests that further research could be conducted to examine the various stakeholders at a more granular level, to identify which airlines and passengers would win and lose as result of such a GDP and the salience of each. When there is not sufficient airport arrival capacity to meet demand, winner and losers are inevitable and differences among stakeholders will emerge. Ultimately, hard decisions need to be made; a stakeholder analysis can inform those decisions, help in identifying potential pitfalls, and point decision-makers toward pragmatic strategies.


(9) Freeman, Strategic Management: A Stakeholder Approach, Pitman, Boston, MA, 1984


(14) Hanowsky, "Efficiency vs. Equity in Dynamic Air Traffic Flow Management," INFORMS Conference (Seattle, WA), November, 2007