IT@Intel White Paper

Intel IT
Data Center Site Selection
February 2014

Selecting a Data Center Site: Intel's Approach

We have found that a well-defined site-selection process and a quantitative analysis of factors and trade-offs can transform raw data into useful information and insight, enabling informed decision making.

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Executive Overview

Intel IT and Intel Corporate Services, working as a team, have identified a range of factors to consider when choosing a data center site. When Intel experiences growth that requires investment in data center facilities, the project team uses this set of factors to select a site that maximizes Intel's return on investment.

These criteria help optimize construction and sustaining costs while meeting internal customers' computing and services requirements. They also assist in choosing a site that can accommodate future needs and concerns.

When selecting a site, we consider three criteria to be the most important:

- **Environmental conditions.** The region's climate and history of natural hazards
- **Wide area network.** The availability and cost of fiber and communications infrastructure
- **Power.** The availability and cost of electrical power infrastructure

We also evaluate the following:

- **Site-level criteria.** The factors associated with land acquisition, proximity to threats and resources, and the construction environment
- **Socioeconomic, workforce, and governmental criteria.** The factors associated with the social and economic stability of the region, the availability of a construction and sustaining workforce, and existing regulations, taxation, and incentives

The perfect site does not exist, and examining all the relevant site-selection criteria is challenging. However, we have found that a well-defined site-selection process and a quantitative analysis of factors and trade-offs can transform raw data into useful information and insight, enabling informed decision making. The result is a site choice that offers the most advantages, beginning at the preconstruction phase and continuing throughout the life of the data center.

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BUSINESS CHALLENGE

Data centers[1] provide the foundation for Intel's design of silicon products. In 2012 alone, Intel's data centers supported about 550,000 EDA-MIPS (electronic design automation–meaningful indicator of performance per system) and provided storage for 30 petabytes of Design data.[2]

Intel IT is dedicated to maximizing the business value of Intel's data center infrastructure and to establishing Intel as a leader in data center infrastructure and operation—similar to Intel's leadership role in its factories. Above all, data center site selection must align with Intel's global strategy of creating and extending computing technology to connect and enrich the lives of every person on earth. To that end, Intel IT has transformed our data center strategy using the following:

- A dramatic shift in the investment model
- Adoption of business-driven innovation and management
- Adoption of new metrics and a unit-costing model
- A holistic dashboard to measure data center health

Building a data center is a significant long-term investment. Working as a team, Intel IT and Intel Corporate Services maintain a pulse on the business. When business growth requires investment in data center facilities, the site-selection project team has learned the value of using site-selection criteria that maximize Intel's return on investment. These criteria help optimize construction and sustaining costs, meet internal customers' computing and services requirements, and accommodate future expansion needs.

[1] Intel defines "data center" as the following: A secured room used mainly to support production and preproduction computing, storage equipment for business, and mission-critical applications and storage of Intel intellectual property.

[2] See Figure 9 in the white paper "Intel IT's Data Center Strategy for Business Transformation."

SITE-SELECTION CRITERIA

Building on their years of experience in constructing data centers, Intel IT and Intel Corporate Services have collectively identified a range of factors to consider when choosing a data center site.[3] Some of these factors relate to the physical capacity of the data center, such as adequate WAN infrastructure and availability of water for cooling. Other factors relate to the business operations of the data center, such as the costs associated with the workforce, water, power, or land.

When selecting a site, we consider the following criteria to be the most important:

- **Environmental conditions.** The region's climate and history of natural hazards
- **WAN.** The availability and cost of fiber and communications infrastructure
- **Power.** The availability and cost of power infrastructure

We also evaluate the following:

- **Site-level criteria.** These criteria are associated with land acquisition, the construction environment, proximity to resources, and proximity to threats, such as natural hazards and workforce disruption.
- **Socioeconomic, workforce, and governmental criteria.** These criteria are associated with the social and economic stability of the region, the availability of a construction and sustaining workforce, and existing regulations, taxation, and incentives.

Most site-selection factors are interrelated. For example, the proximity to good roads and an airport can lower the cost of transporting construction materials to the site, shipping ongoing parts and supplies after construction, and managing business continuity.

[3] This paper focuses on site selection; it does not discuss the numerous data center design best practices that can significantly reduce a data center's operating cost. For more information on Intel's best practices for data center design, see the white paper "Facilities Design for High-density Data Centers."

Numerous decision factors relate to site selection. In this paper, we discuss the factors that in our experience have proved to be the most significant.[4] While a perfect site does not exist, a methodical analysis of the criteria and trade-offs can result in choosing a site that offers the most advantages, beginning at the preconstruction phase and continuing throughout the life of the data center.

Our Top Three Criteria

Our top three site-selection criteria are the ones that we think have the most potential impact on the business continuity, cost efficiency, and performance of a data center:

- Environmental conditions
- Fiber and communications infrastructure
- Power infrastructure

Each of these criteria represents a complex set of individual considerations, many of which present trade-off decisions. The following sections describe some of the analysis we perform when we examine these criteria.

[4] The discussion assumes that the data center will be built in a remote, an exurban, or a suburban area.

ENVIRONMENTAL CONDITIONS

Climate—the weather conditions prevailing in an area in general or over a long period of time—is a key consideration when we look for a data center site. We avoid sites that experience excessive wind, ice, or natural hazards such as poor air quality, floods, earthquakes, or volcanoes.

Climate

Climate can significantly affect the efficiency of data center cooling, which in turn affects sustaining costs. Climate can also affect the way the data center is designed (and, therefore, the cost of construction and operation). For example, depending on climate conditions, a data center may be able to use outside air cooling; depending on the prevailing wind direction, the data center may require active or passive air supply and exhaust solutions.

In general, dry, cold climates support the most efficient data center operation. The optimum temperature operating range for free cooling is 8–35°C (40–95°F), and the relative humidity (RH) should be 20 to 70 percent. Most current data center facilities and IT server equipment are designed to be used in these ranges. Of course, we check the specifications of the computer equipment to be installed in the data center to determine its temperature and RH operating ranges.

Cooling Degree Days: One Way to Assess Climate

A cooling degree day is a unit used to relate outside air temperature to the energy demands of air conditioning. One popular definition is the amount of energy needed to cool a home or business to a human comfort level of 18°C (65°F).

Whenever we can, we locate data centers in areas that have the lowest number of cooling degree days. For example, we considered cooling degree days during our last two data center builds in Guadalajara, Mexico, and Santa Clara, California. After we choose a general geographic area, we analyze cooling degree day charts and data to identify an optimal site.

Intel's Hybrid Cloud Strategy

Not all Intel services are hosted internally. Intel's hybrid cloud strategy requires Intel IT to weigh the advantages and disadvantages of several factors when considering cloud computing hosting options. The key consideration is the service itself. If a particular service offers a competitive advantage to Intel or is proprietary, we will likely host the service internally. If it is a commodity service, we find that the best value results from consuming that service—or offering it for use—from an external hosting source.

Hosting choice is not just about the cost. We also consider speed and agility, whether we host a service internally or externally. For example, one public cloud provider may be more expensive than another but may offer extra capabilities, such as enhanced performance, reliability, or security, making that provider the better choice for a particular service. Or outsourced hosting may be less expensive, but for a particular service that needs the highest level of security, we may need to host that service on our enterprise private cloud.[a]

The business challenges with cloud computing, as it relates to data center site selection, include understanding the services, the services' locations, and the customers we are required to support. We want to use our resources optimally and support a range of customer business and technical requirements.

[a] For more information on Intel's cloud computing practices, see the white papers "Best Practices for Building an Enterprise Private Cloud" and "Cloud Computing Cost: Saving with a Hybrid Model."

When examining climate, we gather weather data for at least the previous 10 years if possible. This amount of data enables us to determine if the area experiences periodic severe weather events. Ideally, this weather data comes from a weather station close to the potential site; airport weather stations are also a source of reliable weather data.

We also take into account historic severe weather events. For example, ancient stone markers in Japan warned against constructing anything below a particular elevation because of the risk of tsunamis—and the old warnings proved to be correct.

Precipitation is not usually a concern as long as the RH remains in the ideal range. However, in areas with torrential rains, equipment yards may need roofs to protect equipment and service personnel. The site must also have adequate stormwater management systems to handle runoff.

We also consider the building's orientation to the sun. In warm climates, we orient the building so that long expanses of the facade are not south-facing in full exposure to the sun. Instead, we orient the shorter side of the building to the south, design support areas on the south side of the building that do not have the same heavy cooling requirements as the data center, or do both. Also, we place the supply air intakes and exterior plenums in the shadows, if possible. In cold climates, a southern exposure can warm the building surface and warm the supply air entering the space if the data center uses air-side economizers.

Natural Hazards

Even in an ideal climate, an area that is prone to natural hazards may not be a suitable building location. Seismic events, floods, tornadoes, hurricanes, and volcanoes can all place the data center as well as suppliers of power and other services at risk. Volcanoes are particularly problematic. An initial volcanic eruption poses a local risk, and the resulting ash that is distributed according to the prevailing wind patterns poses a prolonged risk.

The prevailing wind patterns also affect where we place economizers. Winds greater than 32 kilometers per hour (20 miles per hour) can be disruptive, especially if the data center design includes free cooling. The wind influences air flows inside the data center through exhaust venting. If high-velocity winds occur in an area, we investigate alternative venting solutions so that the data center is designed properly from the beginning.

We avoid locating Intel data centers in areas that experience severe snowstorms and ice storms. These weather events can prevent employees from getting to the data center and can also make the power source unreliable.

Air quality can affect the efficiency and operational costs of the data center, equipment function, and employees' quality of life. In high-pollution areas with fine particulates, such as those resulting from diesel fumes, dust storms, or heavy pollen, the data center's supply air system requires more expensive carbon-type filters and more frequent filter changes—adding to initial and operational costs. Other air-quality issues we consider include the following:

- High sulfates and natural corrosives (salts) can damage circuit boards. Therefore, we avoid locating sites near oceans.
- Chemical pollutants, such as automotive pollution (smog) and smoke from local fires, can harm equipment and employee health. Therefore, we avoid locating sites in heavily wooded areas or near large sources of airborne pollution.

CRITICAL FIBER AND COMMUNICATIONS INFRASTRUCTURE

Various types of media, such as fiber, copper, satellite, and microwave, are used in WAN connectivity. The type of media used may depend on the service provider and its capabilities. We prefer physical media (fiber or copper) over satellite and microwave because the latter can be susceptible to interference and other atmospheric conditions. When evaluating a site's available WAN and other communications services, we look at the following:

- **Capacity.** Our high-performance data centers produce a significant amount of network traffic. For example, one of Intel's Design centers averages monthly inbound network traffic of 4.10 gigabits per second (Gbps), with a maximum of 6.73 Gbps. Outbound network traffic averages 1.56 Gbps with a maximum of 3.26 Gbps.[5] For the WAN, this site uses 30 Gbps of WAN bandwidth, divided into three WAN circuits of 10 Gbps each. In addition, this site uses 10 gigabytes of ISP bandwidth dedicated to Internet traffic.[6]

  Any site we choose for a data center must have adequate WAN fiber capacity for current as well as future needs—or at least the ability to add more fiber as demand grows.
- **Redundancy.** The ideal situation is to have multiple service providers that use diverse paths and separate main points of entry (MPOE), which is the physical location where the service provider's circuits are handed off at the Intel facility. The site's MPOEs should be significantly separated. For example, using a road as the separator is not considered significant; at our sites we aim to have one provider's MPOE on the east (or north) side of the site and the other on the west (or south) side.
- **Reliability.** In developed countries, service providers typically use right of ways to build and traverse their transmission network. This land could occur along railways or highways, or under power lines. Multiple service providers often use the same paths, which eliminates diversity and reliability during a localized event.

  In developing nations, service providers also use right of ways for their transmission network. But these paths may traverse open areas or be in areas under local or

[5] These are six-month measurements taken from the network devices where the compute servers are connected, so this traffic is directly related to Design batch jobs.

[6] We separate business and internal traffic from traffic destined for the Internet, which prevents business traffic from competing with Internet browsing.

Learning from the Mistakes of Others

The following examples illustrate the importance of having a WAN and communications infrastructure that is diverse and reliable:

- In the early 1990s an accident occurred at the rail yard just north of downtown Sacramento, California. As a result, many customers experienced a network outage because their network provider's underground fiber was installed along the railroad path. The fiber of a second service provider was in the same trench, so that service provider's customers were also impacted. In this case, even though more than one service provider was available in the area, using a common transmission path created a risk.
- Near the village of Sharana, Afghanistan (about 100 miles south of Kabul), ongoing conflict directly influenced the local community. Cellular towers were shut down during various times throughout the day (and usually all night), making cellular communications difficult. Also, safety concerns prevented service provider dispatch technicians from accessing certain areas. The result was an extended outage that lasted for several months until the area stabilized and the technicians could safely repair the transmission equipment.

regional control that may be less stable or secure. (See the "Learning from the Mistakes of Others" sidebar). Our goal is to have diverse, reliable WAN and communications infrastructure.

In addition, we prefer sites with hardened WAN access points to protect them from damage. For example, for better security we prefer WAN infrastructure to be belowground instead of overhead. We also prefer carriers that install the fiber or copper inside concrete or PVC ducts instead of direct burial.

CRITICAL POWER INFRASTRUCTURE

Similar to WAN and communications infrastructure, understanding the vulnerabilities and reliability of the power infrastructure components is an essential part of site selection. Our analysis includes review of the power distribution and utility service offerings up the line.

Ideally, the data center's power grid should be powered by two utility providers with good power quality to enable redundancy and reduce risk. The use of two diverse utility providers (not on the same local grid) can negate the need for an uninterruptible power supply (UPS), thus lowering construction costs significantly. We prefer a site that is served by two utility substations, each on an opposite side of our facility location. The substations must be sized in a way that matches our current and future needs; otherwise, new substations might have to be built at the same time as the data center is being built.

As part of the site-selection process, we perform a reliability analysis of the power distribution grid for the geography under consideration. We prefer underground power, which reduces risks from events such as lightning and bird strikes, tree falls, and theft of copper or other valuable materials.

If redundant utility providers are not available for a particular site, we investigate the best way to provide backup power using generators—powered by natural gas or diesel fuel—or other energy sources such as fuel cells. We consider the following:

- Generators can emit carbon dioxide, carbon monoxide, and particulates, which are often regulated (see "Taxes, Regulations, and Incentives").
- Fuel for generators can be stored either aboveground or belowground.
  - The advantage of aboveground storage is that it is easy to maintain, and fuel loss can be readily contained if a leak occurs. However, an accident or a fire can damage aboveground storage.
  - Belowground storage is more secure from accidents and theft than aboveground storage but is more difficult to maintain. If a leak occurs, it may be difficult to detect, and loss of fuel into the surrounding soil requires expensive cleanup.
- Fuel cells that use natural gas or liquefied natural gas (LNG) are another energy option.
  - LNG is more stable than natural gas and can be transported, but it requires storage tanks (usually aboveground).
  - If natural gas is available, the key considerations include whether the pipe's line pressure and volume (cubic feet per day) is sufficient for the project (both now and in the future), cost per cubic foot, the level of redundancy at or near the site, and the distance to the pipeline and gas hub. We prefer a site that is serviced by a main pipeline instead of a purpose-built branch pipeline.

The closer the data center is to the power generation source, the lower the cost per megawatt (MW) rate, because there is less line loss from resistance and less physical infrastructure between the data center site and the utility provider.

When selecting a site, we also consider the type of power available (hydropower or carbon-generated power). Some countries impose a carbon tax, which makes carbon-generated power more expensive than hydropower. (For a discussion of power-related tax credits, see "Taxes, Regulations, and Incentives.")

Making Trade-Offs

No site is perfect, and we have found that trade-offs are necessary when choosing a potential site. For example, the availability of inexpensive labor might lead to low site construction costs. However, the lack of a sophisticated labor force can lead to longer construction times. Power that's inexpensive may be unreliable.

Other trade-offs may involve the following scenarios:

- Being the second or third major construction project in a new location, instead of the first, usually means material and labor are readily available. However, competition for labor and materials can drive up prices, and having competitors nearby can raise concerns about the safety of intellectual property. In addition, having several high-tech facilities in the same area can lead to increased employee turnover.
- The area containing a potential site might present several strengths, such as a constitutional government and a familiar system of laws, low labor costs, high language and education standards, highly educated engineering talent, and a growing middle-class market. However, the same area might also present a complex set of regulations, tax structures, and multiple layers of government entities that could slow negotiation and construction.

Site-Level Criteria

Some site-selection criteria are specific to a certain site. For example, we consider the criteria associated with acquiring a particular parcel of land, that parcel's proximity to threats and resources, the construction environment, and sustaining cost considerations.

LAND ACQUISITION

Many areas have only a few parcels of land available for development. When we look at a potential building site, we first consider whether it is large enough to accommodate the data center building(s) and auxiliary equipment, such as cooling towers, generators, and other equipment. In many regions, the parcel must also be able to accommodate stormwater runoff ponds (see "Taxes, Regulations, and Incentives"). Finally, the parcel should support the ability to expand the site in the future, if necessary.

The location of the site is also an important factor. We prefer sites that can support business continuity if accidents or disasters occur. How quickly emergency responders can reach the site is a consideration. We avoid locations near a major highway or an elevated highway because potential fuel truck accidents pose a significant risk. We also avoid locations near a steep slope because the geology may create a potential risk of mud or rock slides.

The cost of the land is a major criterion. We choose sites with an appropriate cost per square meter (acre) and prefer sites with single owners because multiple owners can slow negotiations and purchasing activities. We also avoid parcels with easements because they represent potential legal issues and loss of property due to eminent domain.

We also consider the cost to bring infrastructure—such as power, water, telecommunications, and fiber—to the site. We often have to make trade-offs (see the "Making Trade-Offs" sidebar). For example, tax deferrals and other incentives can offset upfront land costs. Or adequate WAN fiber may already be present in an area, but power and water are not nearby and are expensive.

PROXIMITY TO THREATS

In addition to the environmental conditions already discussed and the risks discussed in the sections "Socioeconomics" and "Workforce," here are some other risks we consider when choosing a site:

- **Neighboring land use.** If a site is on the glide path of an airport or could sustain damage from pollutants that originate on bordering land, we probably will not consider that site a good candidate for a data center.
- **Security considerations.** The need for excessive security can increase costs. For example, in some areas, perimeter fencing or guards may be necessary to safeguard the property. Or local requirements relating to citizenship and background checks for support personnel and suppliers can make operating the data center burdensome.

PROXIMITY TO RESOURCES

Choosing a data center site must also take into account access to several other types of resources, including water and public infrastructure.

Water

Water is a key resource for data centers because evaporation is often the most cost-efficient cooling method. This method uses a lot of water. For example, a 5-MW design could use 40 million gallons of water per year in a mild climate.

Saving Water

Our rigorous climate assessment enables us to save 28 million gallons of water per year at our data center in Santa Clara, California. The location has a mild climate, which allows us to use outside air as the free cooling solution, instead of relying on evaporative cooling.

We look for sites that have two water sources sufficient not only for the cooling towers but also for other industrial needs and the fire suppression system. Such sources could be external to the site, or, if the site is over an aquifer, we may drill a well onsite. In addition to availability, we also consider the direct cost of water, the cost of drilling a well if necessary, and the cost and logistics of managing water waste.

Public Infrastructure

When weighing the advantages and disadvantages of a site, we consider its proximity to various aspects of public infrastructure, including the following:

- **Major transportation routes.** Proximity to a major airport or other transportation venues, such as railroads, trucking routes, and distribution warehouses, can improve logistics and reduce the costs associated with shipping supplies (both during construction and over the lifetime of the data center).
- **Emergency response services.** When located nearby, these services, including hospitals, fire departments and emergency response personnel, and law enforcement, can provide fast response and rescue times. In some cases, Intel may agree to provide funding for fire or police departments. Fulfilling these agreements can increase initial costs but may be required for the development agreement, permitting, or construction.
- **Military bases.** Emergency services located on a military base could be dispatched off-base to assist other first responders if necessary. In many countries, the presence of a military base is associated with a stable area and most likely has a solid utility and communications infrastructure.
- **Public transportation.** This factor might be important in urban areas where workers might not have a car but less important in remote, exurban, and suburban sites.

CONSTRUCTION ENVIRONMENT

Construction processes vary around the world, and we acknowledge that ideas differ as to quality, schedules, and safety—all of which can affect construction cost, quality, and schedule as well as Intel's reputation. Therefore, when choosing a site, we investigate the following:

- Availability of design and contractor resources and construction materials
- Permitting processes (see "Taxes, Regulations, and Incentives")
- Local safety and performance standards
- Availability of appropriate skilled trades in appropriate quantities (see "Workforce")

We also consider the costs associated with site construction, such as the potential need to build new roads; acquiring, shipping, and securing construction materials; construction labor and availability; and securing the site during construction.

CONSIDERATIONS FOR SUSTAINING COSTS

After a data center is built, we expect it to remain in operation for many years. Therefore, we choose sites that present opportunities to lower sustaining costs whenever possible. Examples of such opportunities include the following:

- **Long-term contracts.** A data center has the potential for many long-lived contracts for services, such as facility and equipment maintenance, landscaping, and utility contracts. Negotiating long-term contracts can reduce the data center's operating costs.
- **Transport costs.** We analyze the cost and risk to ship compute equipment to the site. We consider logistics, customs, and security.
- **Materials costs.** We analyze the cost and availability of materials necessary during the lifetime of the data center, such as filters, batteries, and spare parts.

Understanding the Construction Environment

We found it essential to understand the impact a large construction project may have on the local economy.

In one case, a major high-tech company decided to build a new data center in an area where construction activity was high. As a result, the company had to work with Tier 3 suppliers in the local industry. Because these suppliers did not have the necessary materials or level of expertise for such a major project, the company had to send an expatriate program manager who was originally from that area, in order to effectively manage this difficult situation with suppliers. The lack of skilled resources also resulted in cost overruns and issues with overall construction materials and workmanship, and had an adverse impact on the schedule.

Learning from this experience, the company launched a new strategic objective for future projects. Company representatives intend to visit the region, identify the Tier 1 suppliers, and build relationships with them in advance of construction.

Intel has experienced similar problems, and we have learned the importance of knowing the capabilities and players in the local economy where we are going to build. Even though Intel has well-developed standards and methodologies, suppliers may not be able to meet the expectations associated with those standard and methodologies. We strive to be aware of the economic impact of our construction projects and the availability of suppliers who meet our strict construction requirements.

Avoiding Areas with Corruption

In the past, Intel has experienced challenges in certain regions where bribery is accepted as a common practice and is used to obtain government contracts. Bribery, in any form, is clearly against Intel's corporate governance and ethics policies. We discovered that in these areas, suppliers and local decision makers fully expect "facilitation payments." If we did not make these payments, we discovered we would be held in low esteem and receive lower quality service. Based on this experience, we now avoid constructing data centers or other projects in areas where local business practices are not conducive to the construction that follows site selection.

Optimizing the Talent Pool

Intel has developed a feeder program in its efforts to enhance the quality and effectiveness of its hiring program for college graduates. Intel's programs provide internship experiences to students at the freshman and sophomore college levels. Intel also encourages employees to volunteer and support local schools. For example, employees participating in the A Day in the Life of an Intel Employee and Junior Achievement programs prepare lesson plans to teach students for a day.

By locating an Intel facility near a university, our employees can more easily interact with students and foster a positive impression of the engineering profession. The results are far-reaching—students around the globe receive encouragement, and more students remain in their engineering and finance programs. Most importantly, Intel, the students, and the educational community forge lasting relationships.

Socioeconomic, Workforce, and Governmental Criteria

Another set of criteria that we examine focuses on the following:

- Social and economic aspects of a region
- Workforce issues
- National, regional, and local governmental taxes, regulations, and incentives

These types of criteria are important aspects of site selection because they can potentially affect the long-term costs associated with the data center as well as business continuity.

SOCIOECONOMICS

Naturally, we prefer to locate our data center in areas that offer political and social stability rather than in ones that are prone to riots, crime, or corruption. We have found it best to locate data centers in regions that are characterized by moderate economic conditions. Small economies may not support the necessary level of services, supplies, and workforce; expensive economies may drive up the cost of building and sustaining the data center.

WORKFORCE

To construct and operate a data center, we need an adequate supply of skilled workers and a stable workforce. Therefore, we carefully research the available workforce in the area to determine if the skills we need exist, if wages are affordable, and if any workforce stoppages have occurred recently.

The following list gives examples of the types of workers we need to build and staff an Intel data center:

- **Construction.** Skilled workers, such as framers, concrete workers, electricians, and plumbers, contribute to a successful construction project.
- **Information technology.** IT personnel, such as network staff, system administrators, and data center architects, help keep the data center running after it is built.
- **Facilities and maintenance.** Facility technicians and other maintenance staff maintain chillers, UPS, power distribution equipment, and more throughout the life of the data center.
- **Security.** Security staff help protect Intel's intellectual property and corporate data from theft or damage.

We have found that locating a data center near a source of new talent, such as near a university or IT training school, can provide a readily available, skilled talent pool (see the "Optimizing the Talent Pool" sidebar).

TAXES, REGULATIONS, AND INCENTIVES

The local, regional, and national taxes, regulations, and incentives can affect virtually every consideration for choosing a data center location. Therefore, as part of our due diligence when researching potential sites, we include these items in our analysis.

Taxes

Local, regional, and national governmental entities can all levy taxes. In general, we have found that the lower the taxation rate, the lower the data center cost. In particular, we determine whether data center equipment is taxed as property and whether a sales tax is applied to construction materials, data center equipment, and ongoing data center supplies. We also investigate whether tax incentives already exist or can be negotiated.

Regulations

Like taxes, regulations can be enforced at the local, regional, and national levels. Regulations that we consider when choosing a data center site include the following:

- **Land and title zoning**. Obtaining the correct zoning for a particular parcel of land requires engagement with the local authority having jurisdiction (AHJ). Before discussions with the AHJ begin, we develop an understanding of the current zoning and the appropriate processes for change.
- **Water.** Some areas may regulate water usage and waste. Also, stormwater regulations can affect the size of the land parcel required. Storage ponds can take up as much as 40 percent of a site's

land. These types of regulations can also stipulate specific landscaping requirements.

- **Fuel storage and emissions.** These regulations vary by city, county, and region, and can be associated with significant fines for infractions.
- **Local restrictions.** Some areas may have building height restrictions, and local zoning may restrict certain power options such as solar, smart grid, micro-grid, natural gas power generation, or fuel cells. Additional permitting may be required for clean energy. Some locales restrict data center capacity and the number of allowable data centers, because of the power density that a cluster of data centers or a large data center create. Zoning requirements may also exist for communications technologies, such as satellite, infrared, and microwave.
- **Customs regulations, fees, and tariffs.** These requirements can affect the logistics of transporting equipment in and out of the country, both during and after construction.

Incentives

Areas that are pro growth and pro business generally offer incentives to attract major construction projects that will potentially create a significant number of family-wage jobs, generate local investment in community resources such as education and healthcare, and provide steady tax revenues over time.

These regional, national, and local incentives can help offset taxation and other costs.

In our experience, incentives can take the form of land, cash, and tax reductions or deferrals. Incentives can also be services, such as customs, training, or permitting. For example, a county might waive traffic impact and permitting fees, or a region might offer tax credits for technology implementation and energy savings. As another example, the use of photovoltaic (solar cells) may be associated with rebates or incentives. However, the incentive may not be enough to compensate for the space required—solar power requires about 20,200 square meters (five acres) per MW.

When selecting a data center site, we research what has been done before with regard to incentives in each area being considered. Then, when we have reduced the potential number of sites to just a few, we engage with the relevant economic development agencies to understand the details, request proposals, and make counter proposals.

However, incentives are only one of many considerations and do not carry excessive weight in our analysis. As Brian Krzanich, the former general manager of Assembly Test at Intel, said, "Government incentives can come and go. Decisions need to be long term."

METHODOLOGY FOR ANALYZING CRITERIA

Examining all the relevant site-selection criteria may at first seem overwhelming. But a methodical approach to analysis can help make sense of this diverse and sometimes contradictory data. We have a well-defined site-selection process, during which we narrow down a long list of potential sites to a few. We use quantitative analysis to transform data into information and insight, which enables us to make informed decisions.

Overview of the Site-Selection Process

At Intel, we use the process illustrated in Figure 1 to select a site. When the need for a data center arises, we first define the scope of the project, and then we start the site-selection process. Using the criteria discussed in this paper, we narrow down our focus from a world scan to a short list of specific locations. Once we have this list, we assess the infrastructure and, if possible, negotiate incentives with the appropriate governmental entities. This step leads to the development of the comprehensive net present cost of each alternative and a recommendation to the Intel decision maker.

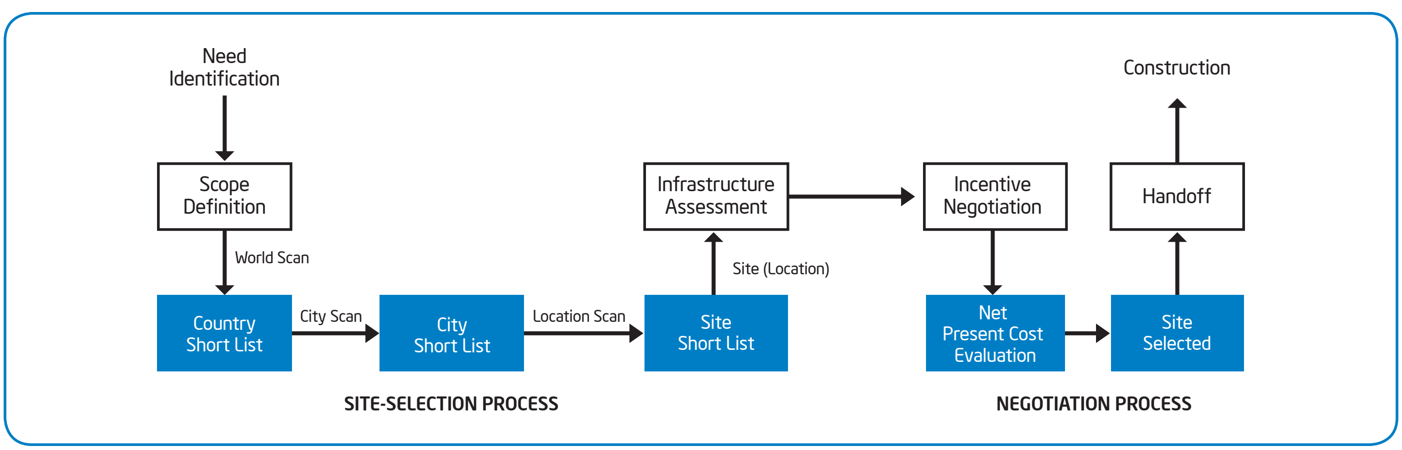

Figure 1. A well-defined site-selection process enables us to narrow down a global list of sites to the few that best meet our site-selection criteria.

Table 1. Sample Utilities Infrastructure Spreadsheet

Utilities Infrastructure Parameters	SCORE		Resolution Path
	OPTION 1	OPTION 2	
Power Reliability			
Power Quality			
Alternative Energy Options			
Electricity Rate Price			
Power Infrastructure Cost			
Power Infrastructure Timing			
Power Available Capacity			
Percentage of Utility Load			
Utility Financial Stability			
Privatized/Deregulated/Monopoly			
Power Customer Service			
Power State-of-the-Art Equipment			
Future Stability of Power Resource			
Power Line Specifics			
Water Reliability			
Water Infrastructure Cost			
Water Infrastructure Timing			
Sewer Reliability			
Sewer Infrastructure Cost			
Sewer Infrastructure Timing			
Natural Gas Reliability and Capacity			
Natural Gas Rate Price			
TOTAL SCORE			
AVERAGE SCORE			

Table 2. Sample Ranking System

Ranking	Definition	Resolution Path
1	HIGH RISK	▪ Potential show stoppers ▪ No resolution path developed ▪ Requires immediate focus
2	MEDIUM RISK	▪ Detailed solution path developed but not fully demonstrated ▪ High confidence level for success
3	LOW RISK	▪ Fully demonstrated capability ▪ Meets or exceeds boundary conditions
4		
5		

Table 3. Sample Weighting System

Category	Weight	Explanation
Talent	45 percent	▪ Engineering graduates and school ranking
Cost	25 percent	▪ Gross domestic product per head count – 18 percent ▪ Country gross domestic product - 7 percent
Risk	15 percent	▪ Personal and business risk
High-Tech Job Creation	15 percent	▪ High-tech jobs created by the local economy (having other high-tech employers in the area is preferable because they provide an established talent pool)

After a site is selected, we make the land purchase and hand off the project to the construction manager, who must ensure the project complies with the scope, schedule, and budget requirements associated with constructing and operating the data center.

Quantitative Analysis

For the detailed analysis of the sites on the short list, we engage content experts from the various business groups at Intel. They investigate the existing and forecasted conditions at each site in a variety of areas. We then use a spreadsheet to score and rank each site-selection criteria for the sites under consideration. We create a tab for each general criteria category, such as utilities and environmental hazards, and develop a rating system. Each line item on a tab receives a ranking.

Table 1 shows a sample of such a spreadsheet, relating to the utilities infrastructure. We give each criterion a score for multiple site options, with notes recorded as appropriate. Table 2 illustrates a possible ranking system. Each scoring column has a total score and total average score calculated at the bottom of the tab.

When the tabs and rankings are complete, we use a weighting system, similar to the one shown in Table 3, to roll up all the individual rankings into a general recommendation for the best site.

Using this weighting system, we were able to rank and filter a list of 181 possible countries in which to locate a new facility, into a list of only 24 countries—a much more manageable number for further analysis. The weighting system helped eliminate countries with relatively small or expensive economies, those associated with high risk (such as personal, transportation, property, and business risks), and countries with low talent and job-creation levels.

Analysis in Hindsight

Our information gathering and analysis continues even after we select a site. In order to test our assumptions and decisions, we analyze the operational efficiency of a data center several years after it is built. This after-the-fact analysis can supply insights and help hone the site-selection process for future projects.

For example, at one site that we were expanding, our uninterruptible power supply battery replacements exceeded our original estimates, putting us at risk for exceeding our hazardous waste permitting allocation. Tracking battery replacement might seem like a trivial detail, but it underscores the need to understand the permitting associated with a site. It also shows how important it is to understand what is being added during an expansion and what the future ramifications of such an expansion are.

CONCLUSION

When Intel experiences growth that requires investment in data center facilities, we use a set of site-selection criteria in order to maximize our return on investment. These criteria help us choose a site that optimizes construction and sustaining costs, meets internal customers' computing and services requirements, and accommodates future expansion.

We have found the following criteria to be the most important:

- **Environmental conditions.** The region's climate and history of natural hazards.
- **WAN.** The availability and cost of fiber and communications infrastructure.
- **Power.** The availability and cost of power infrastructure.

We also consider site-level criteria (those factors associated with land acquisition, proximity to threats and resources, and the construction environment) and socioeconomic, workforce, and governmental criteria (such as regulations, taxation, and incentives).

While no site is perfect, our well-defined site-selection process and a quantitative analysis of factors and trade-offs result in a site choice that offers the most advantages from preconstruction throughout the life of the data center.

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ACRONYMS

AHJ	authority having jurisdiction
EDA-MIPS	electronic design automation–meaningful indicator of performance per system
Gbps	gigabits per second
LNG	liquefied natural gas
MPOE	main point of entry
MW	megawatt
RH	relative humidity
UPS	uninterruptible power supply

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