Value Proposition: Allocator-Aware (AA) Software

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Value Proposition:

Allocator-Aware (AA) Software

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Abstract

The performance benefits of supplying local allocators are well-known and substantial [Lakos, ACCU'17]. Still, the real-world costs associated with orchestrating the integration of allocators throughout a code base, including training, supporting tools, enlarged interfaces (and contracts), and a heightened potential for inadvertent misuse cannot be ignored. Despite substantial upfront costs, when one considers collateral benefits for clients – such as rapid prototyping of alternative allocation strategies – the case for investing in a fully *allocator-aware* (*AA)* software infrastructure (SI) becomes even more compelling. Yet there remain many "concerns" based on hearsay or specious conjecture that are either overstated or incorrect.

In this densely fact-infused talk, we begin by introducing a familiar analogy to drive home the business case for *AA*SI. Next we identify four syntactic styles based on three distinct models: C++11, C++17, and a brand new language-based approach being developed by Bloomberg for C++23 (or later). Costs – both real and imagined – will be contrasted with performance as well as other important ("collateral") benefits. The talk will conclude with a closer look at the economic imperative of pursuing a low-cost language-based alternative to *AA* software in post-modern C++.

Purpose of this Talk

Current state of affairs…

- Local Allocators -> performance!! [Lakos, CppNow'17]
- There are, however, *real-world costs*
- There are also important *collateral benefits*
- Yet there remain "concerns" (a.k.a. F.U.D.)

Purpose of this Talk

What we will do today …

- Present the four *AA* software styles
- Separate real from imagined costs
- Discuss important collateral benefits of *AA*
- Address common "concerns" surrounding *AA*
- Advocate for supporting *AA*SI today
- Make business case using detailed analogy
- Hint at what C++2y allocators might look like

Outline

1. Introduction
2. Styles for *Allocator-Aware (AA)* Software
3. Performance Benefits
4. Costs
5. Collateral Benefits
6. “Concerns”

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Introduction

Dynamic memory allocation is important!

- **`new`**/**`delete`** usually adequate
- Custom allocation is sometimes advantageous
  - (and sometimes it's absolutely necessary)
- But implementing custom allocation is costly.
- Thus, we are motivated to create (now): *Allocator-Aware (AA) Software* Infrastructure
  - *(and soon): BB20V* (Bloomberg's 2020 Vision)

Introduction

Two approaches to custom memory allocation:

- Design bespoke (custom) data structures when needed.
  - Best possible performance
  - High development/maintenance costs
- Build on *Allocator Aware (AA)* components
  - *Nearly* best possible performance
  - Much lower costs

Introduction

Two approaches to custom memory allocation:

- Design bespoke (custom) data structures when needed.
  - Best possible performance
  - High development/maintenance costs
- Build on *Allocator Aware (AA)* components
  - *Nearly* best possible performance
  - Much lower costs **+ some collateral benefits**

Introduction

<u>A</u>irline <u>A</u>nalogy to *<u>A</u>llocator <u>A</u>wareness (AA)*:

- *First Class*
  - Best possible
- *Economy*
  - Cheapest possible

Introduction

Airline Analogy to *Allocator Awareness (AA)*:

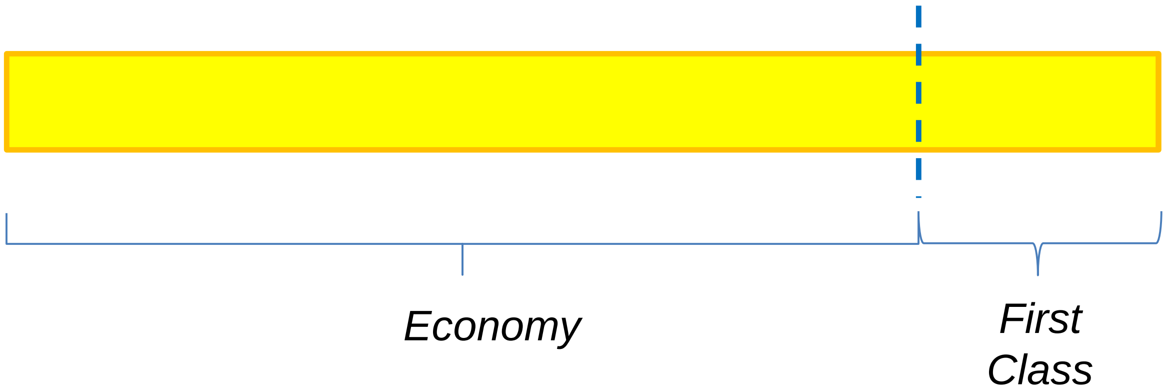
- *First Class*
  - Best possible
- *Economy*
  - Cheapest possible

Client Perspective

Client Perspective

Introduction

Client Perspective



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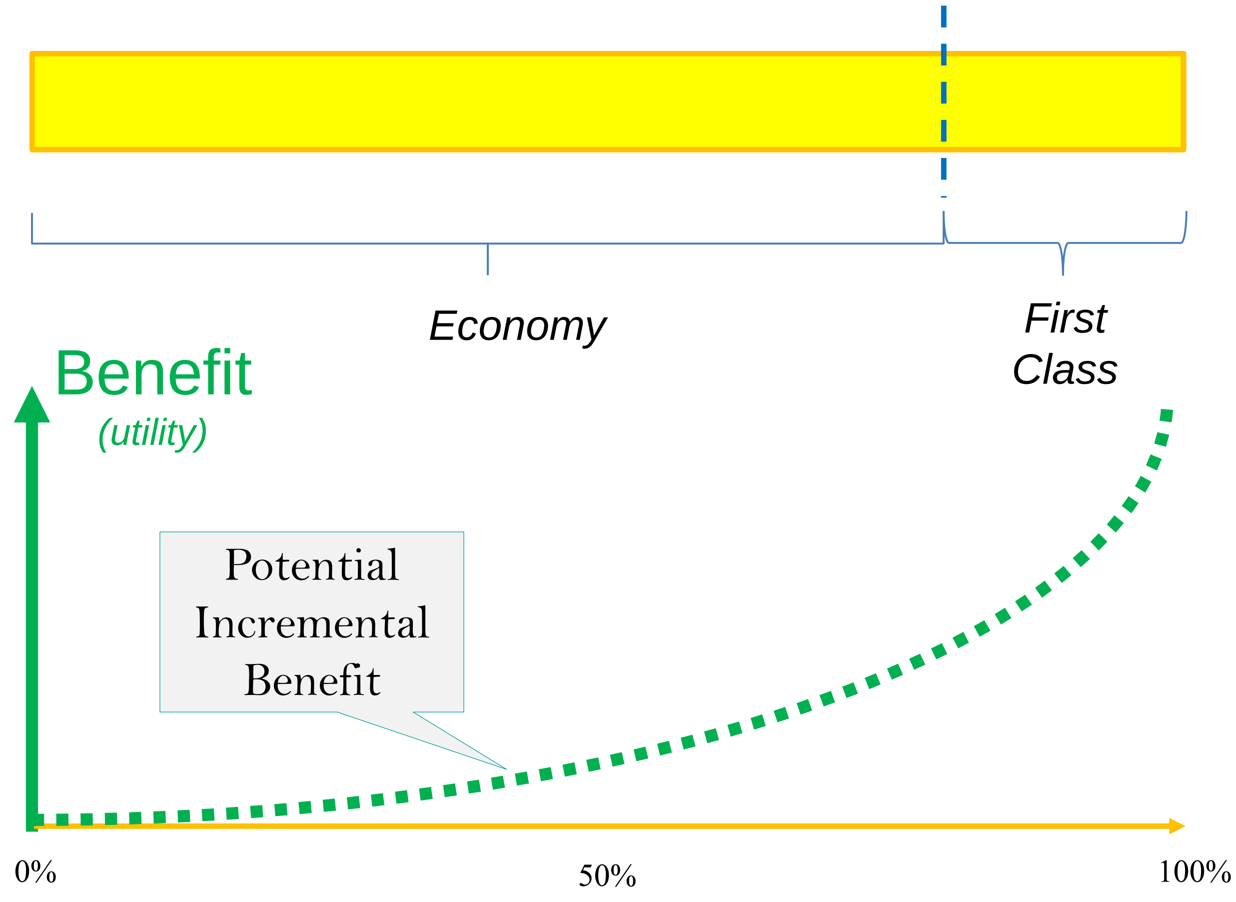

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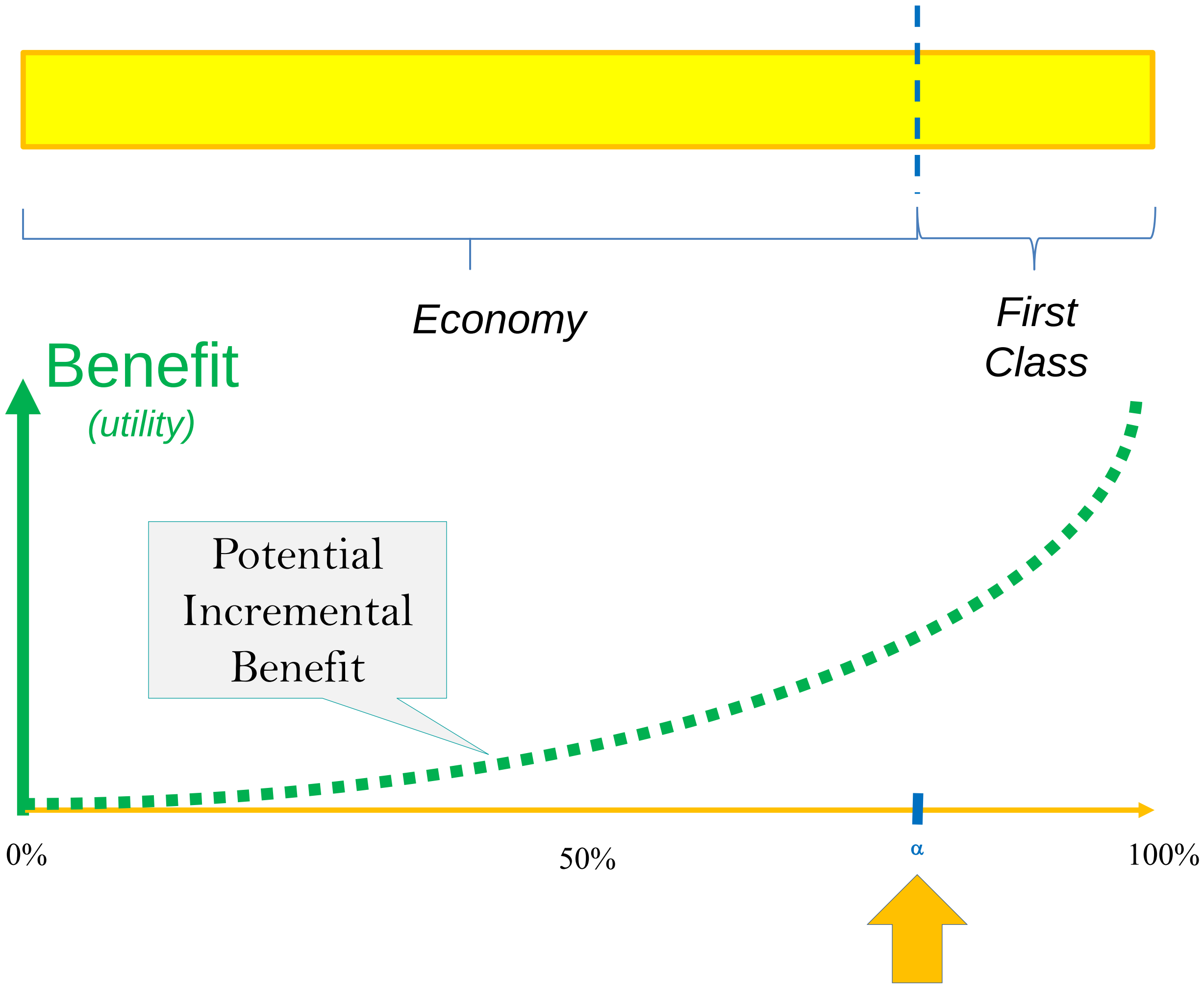

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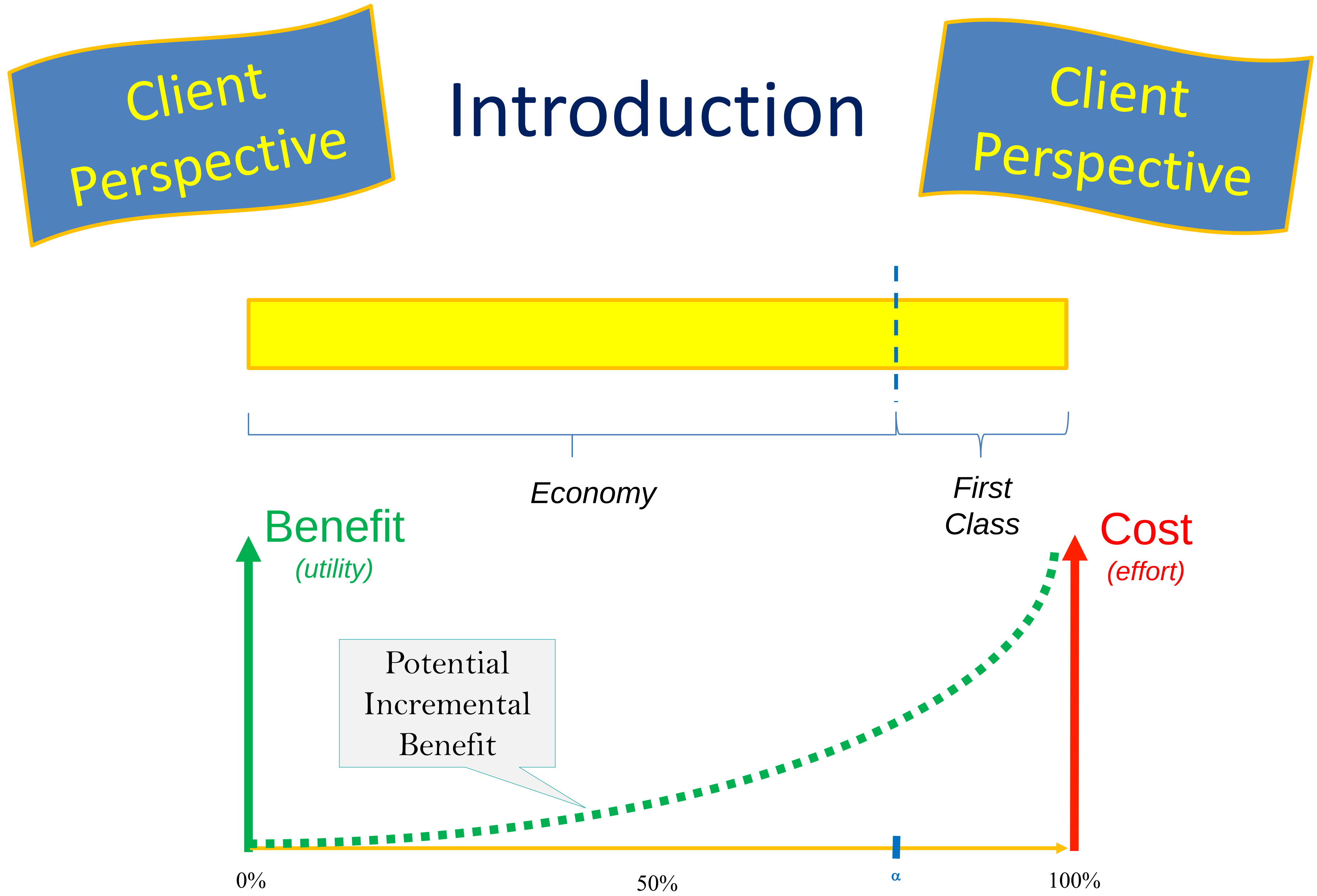

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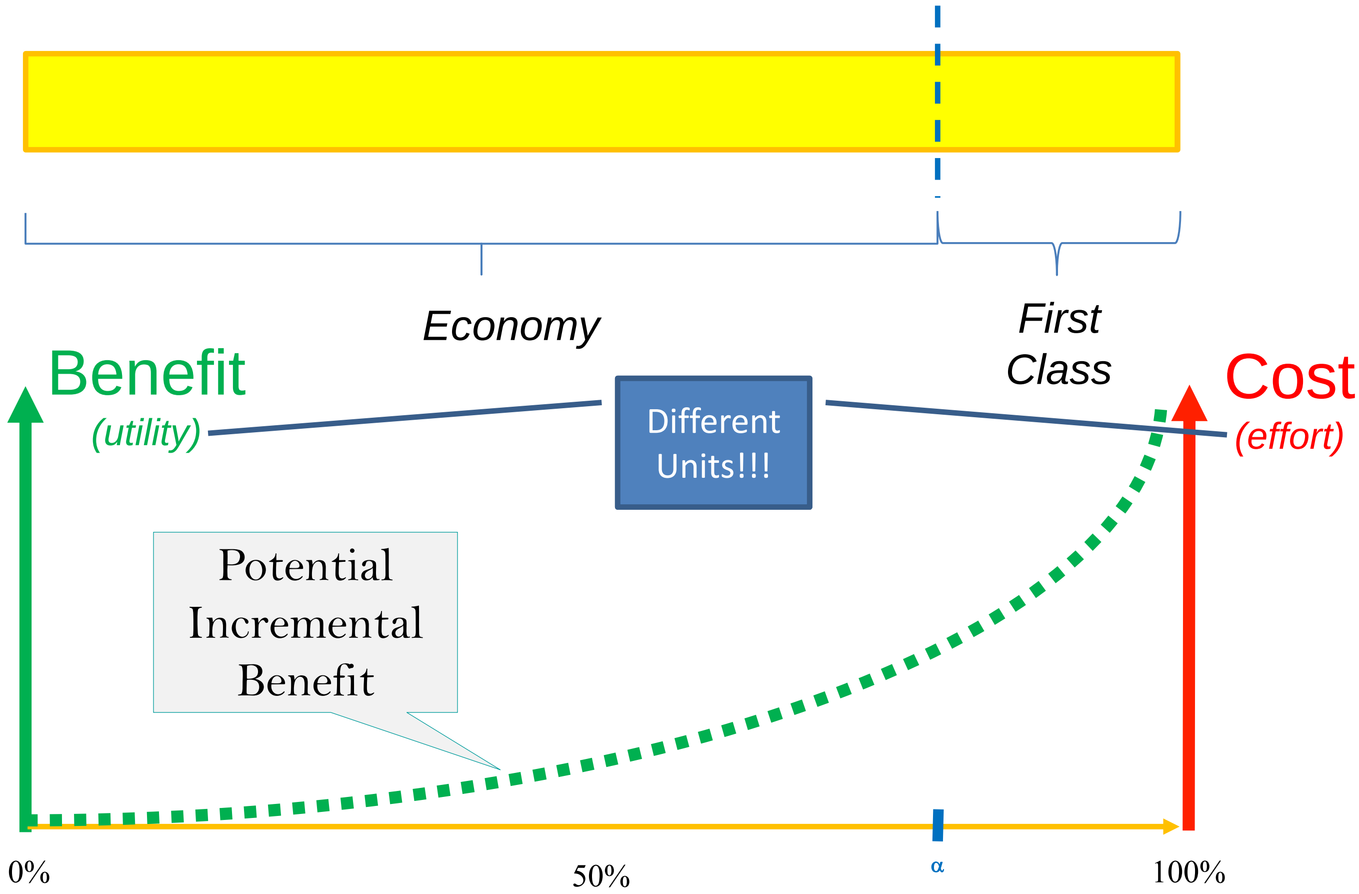

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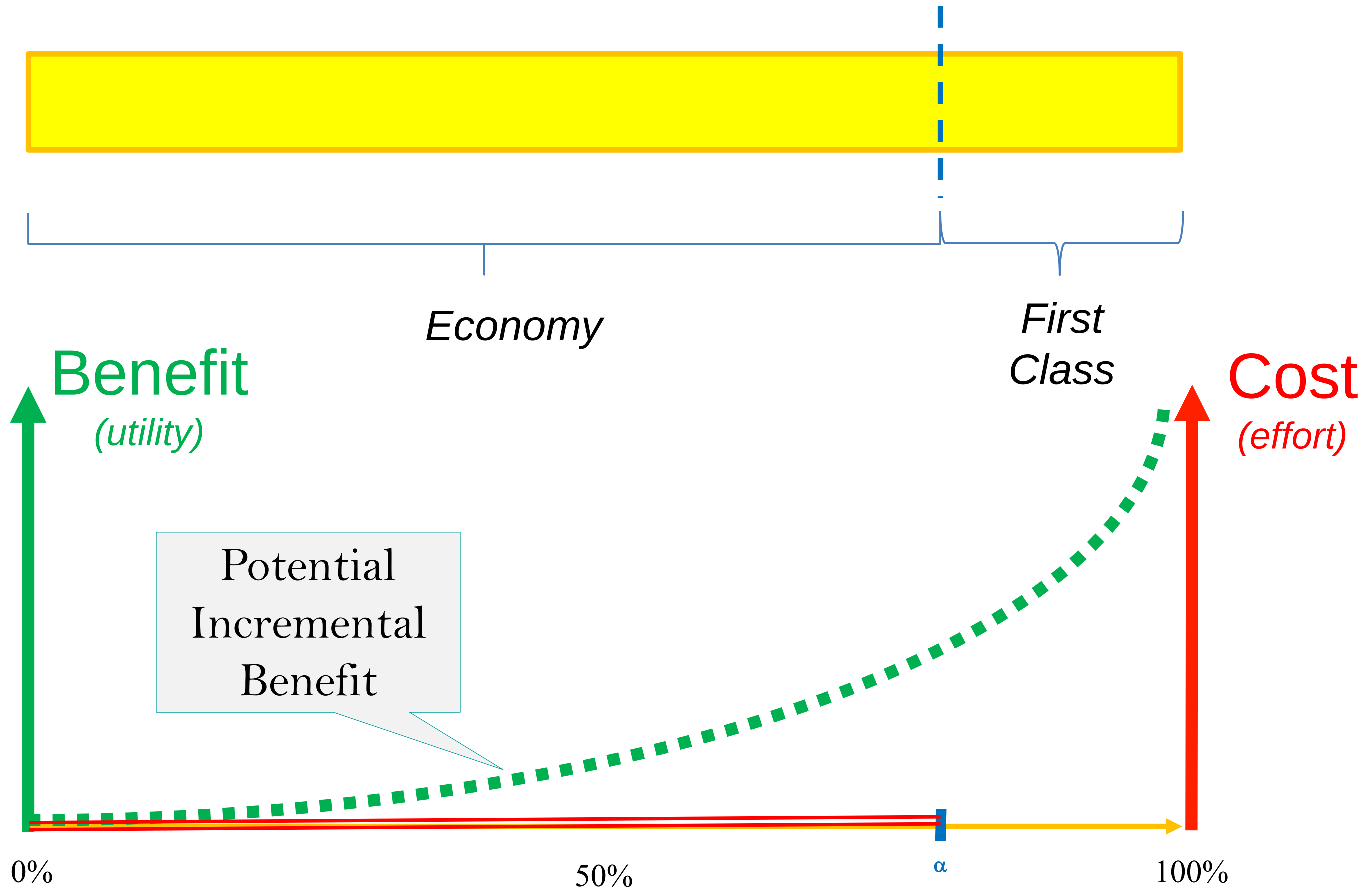

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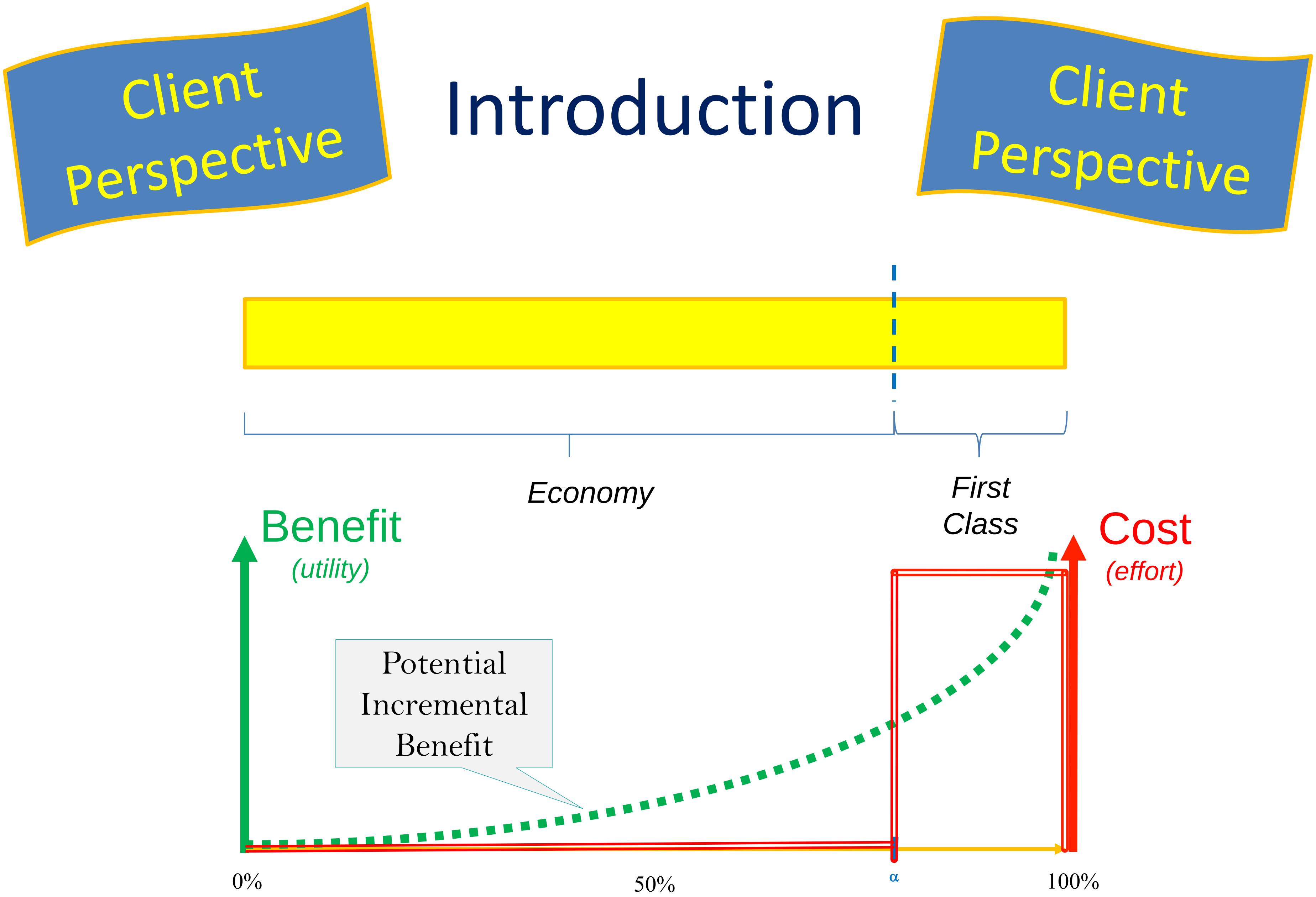

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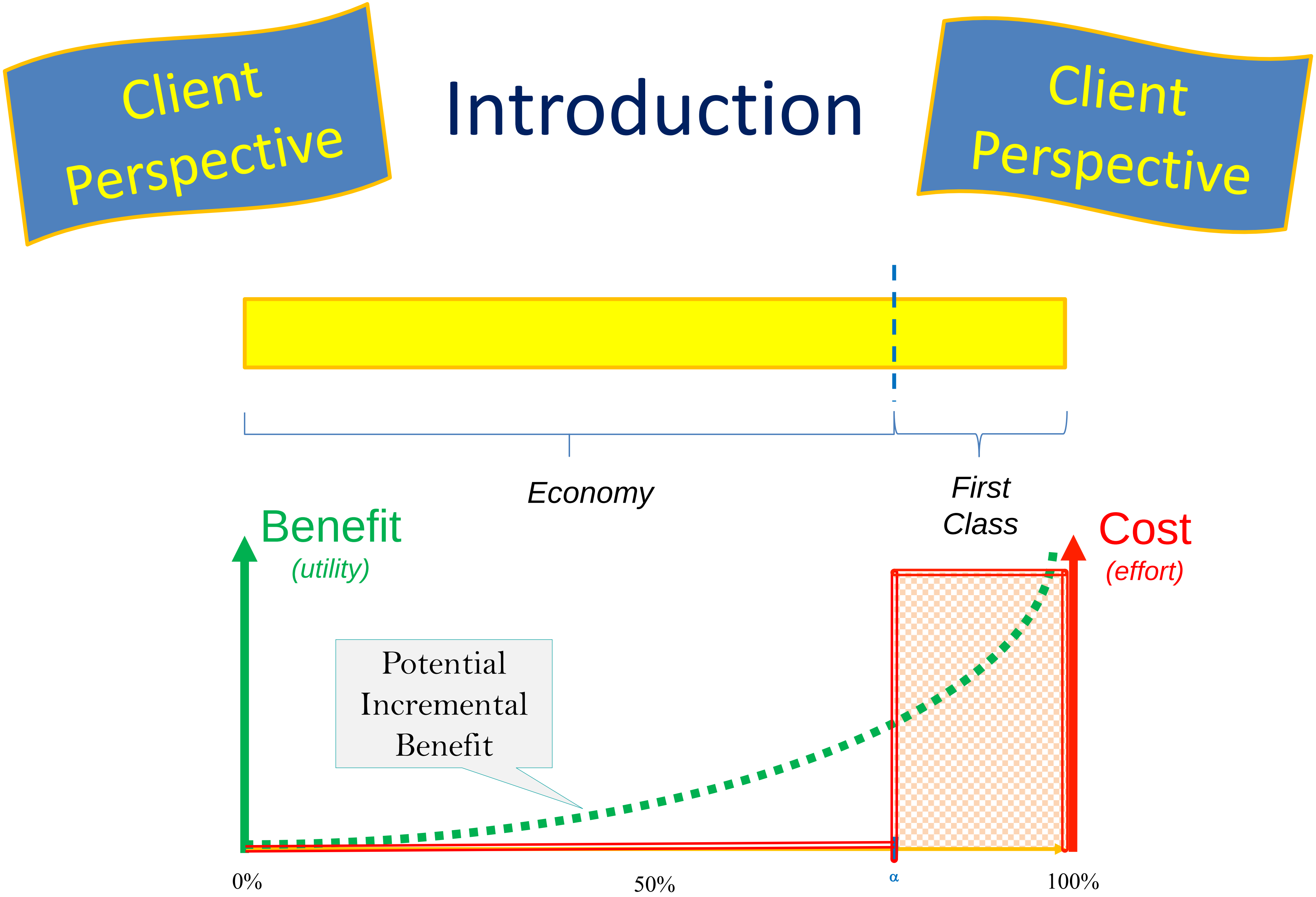

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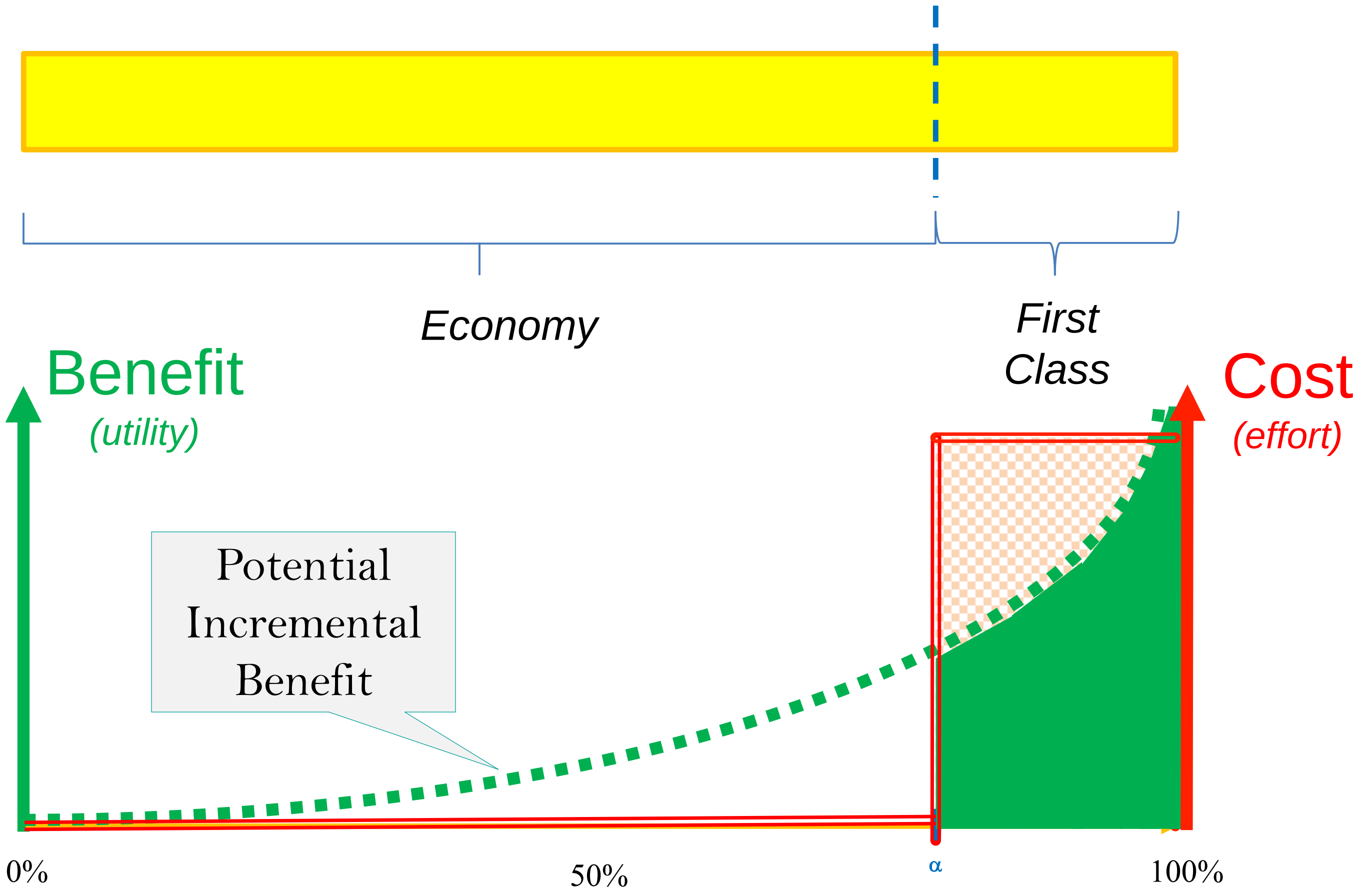

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Airline Analogy to *Allocator Awareness (AA)*:

- *First Class*
  - Best possible
- *Economy*
  - Cheapest possible
- ***Business Class* and *Premium Economy***
  - **Almost as good as first class**
  - **Costs just slightly more than *Economy***

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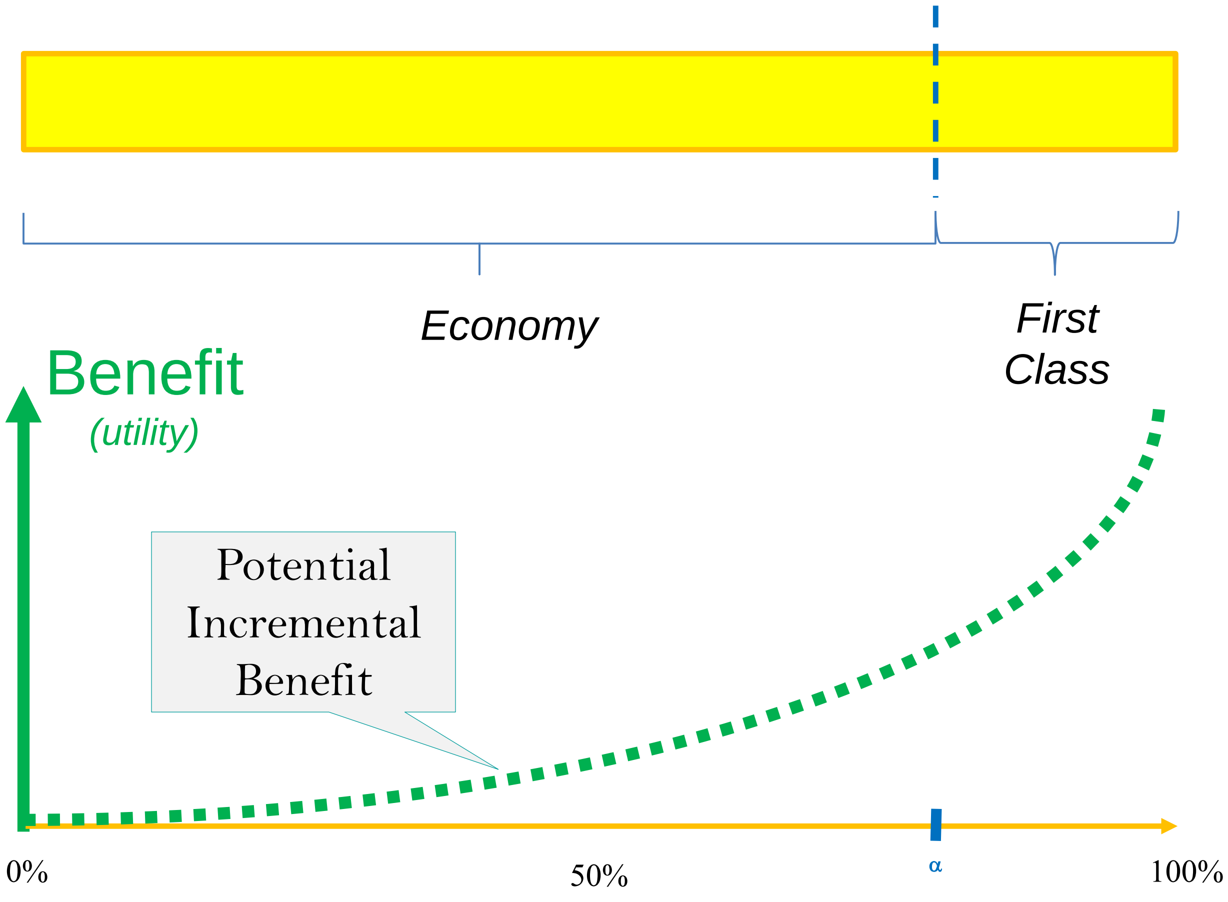

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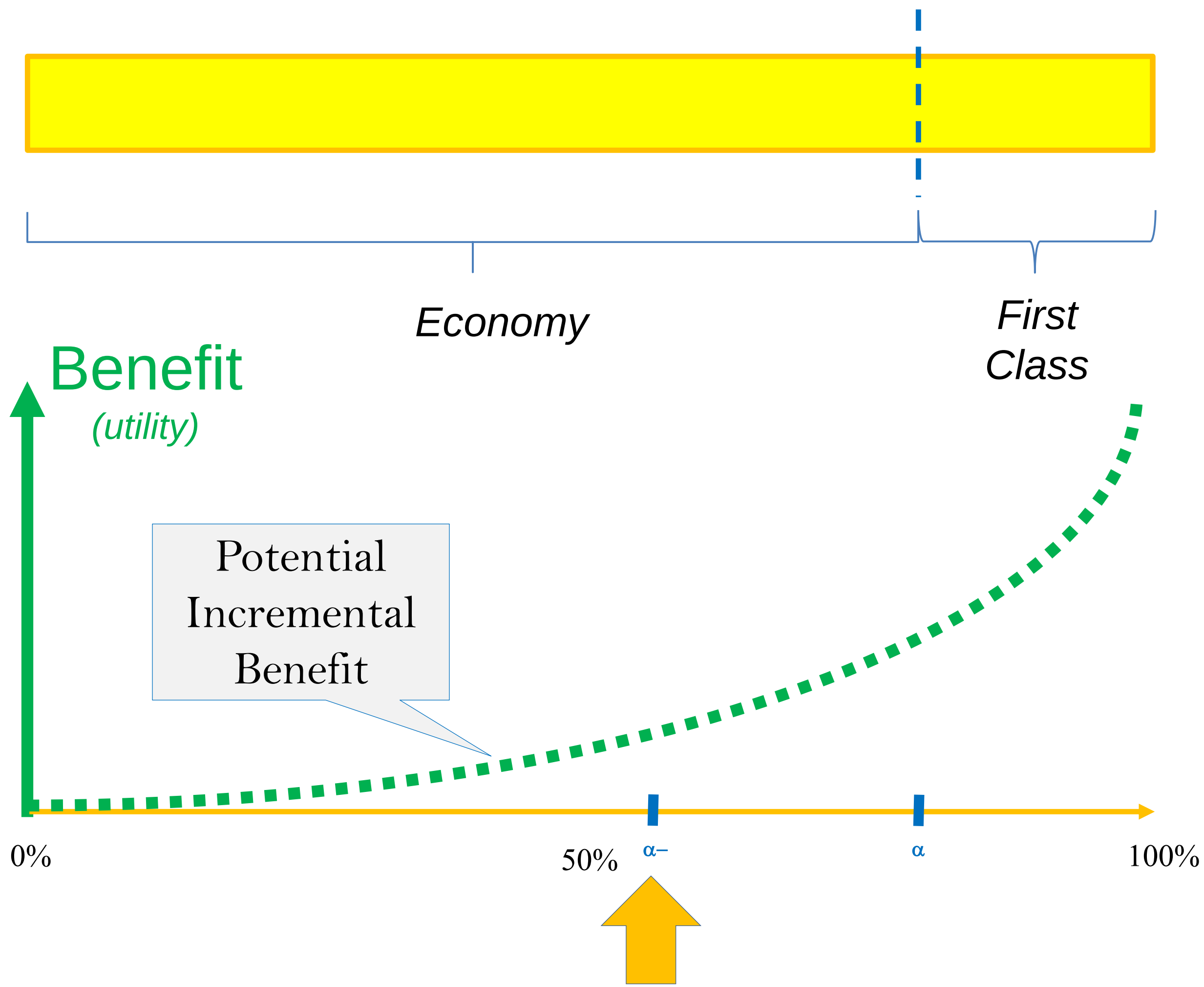

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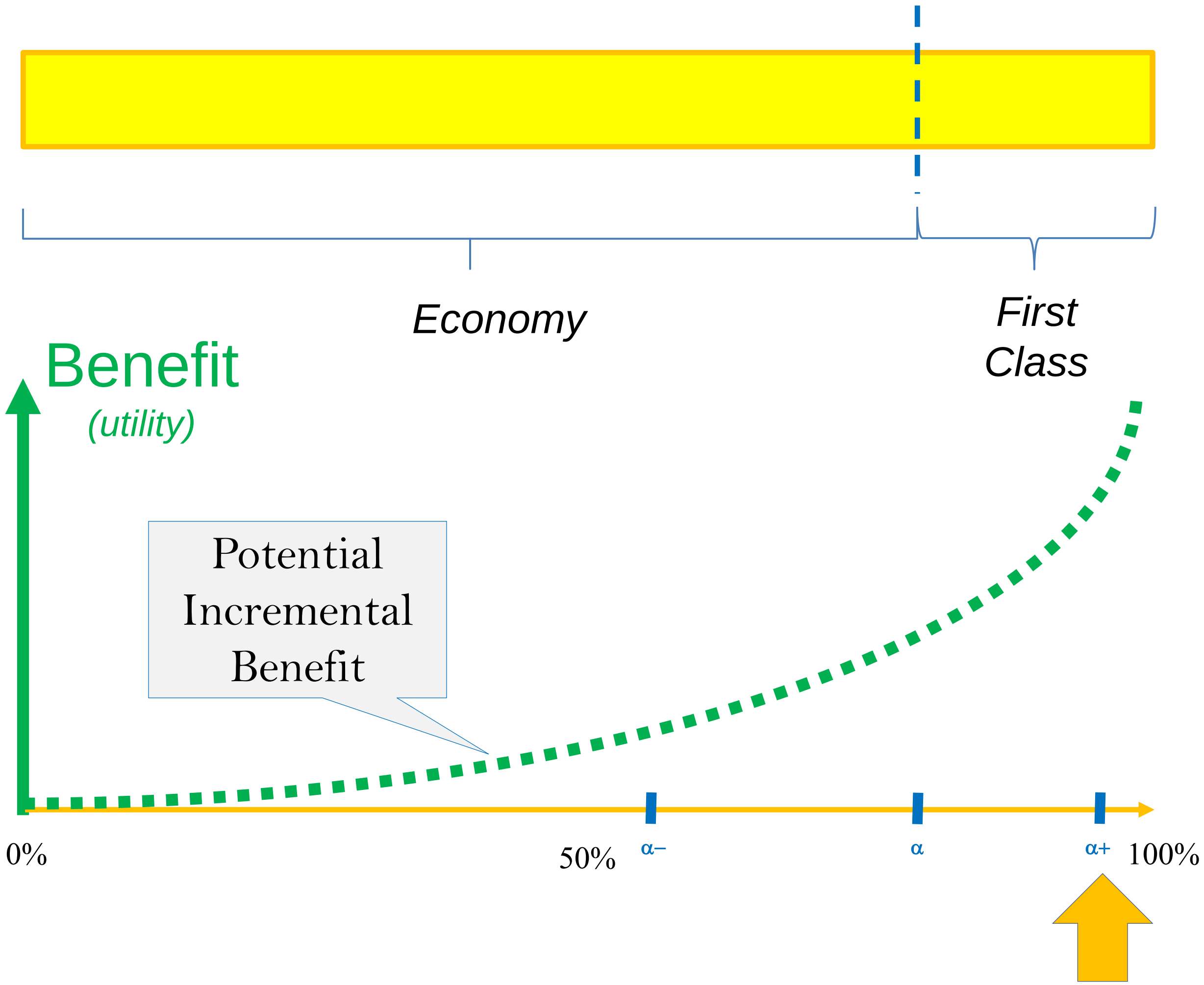

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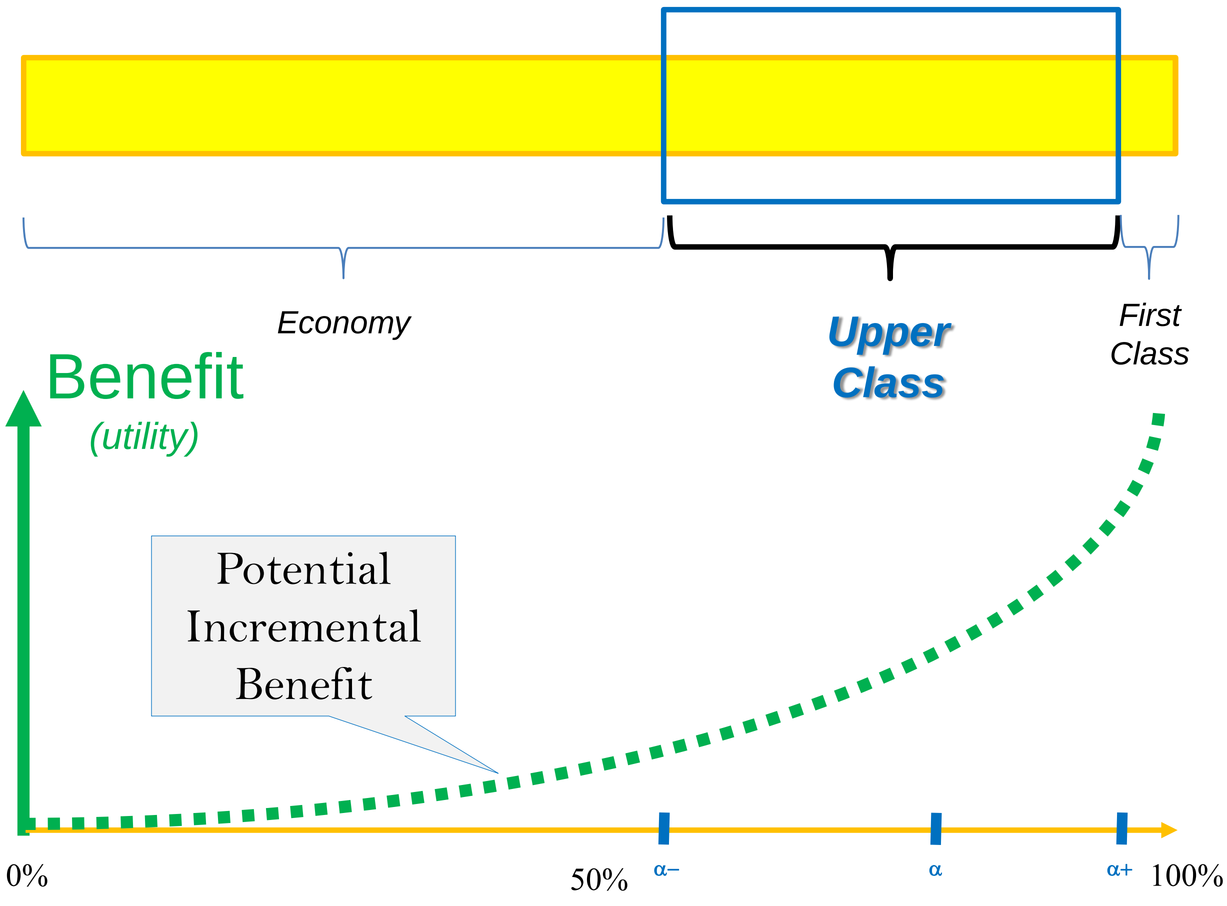

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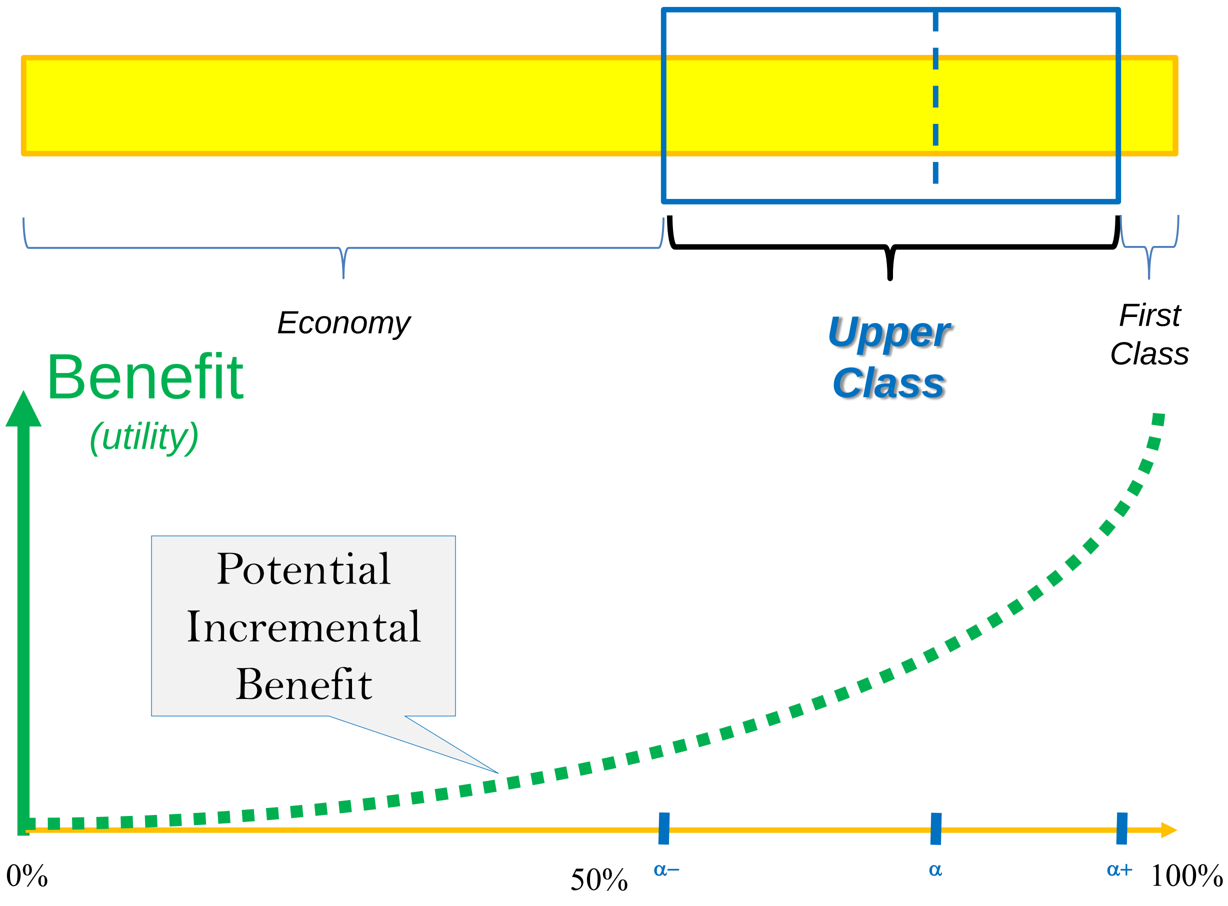

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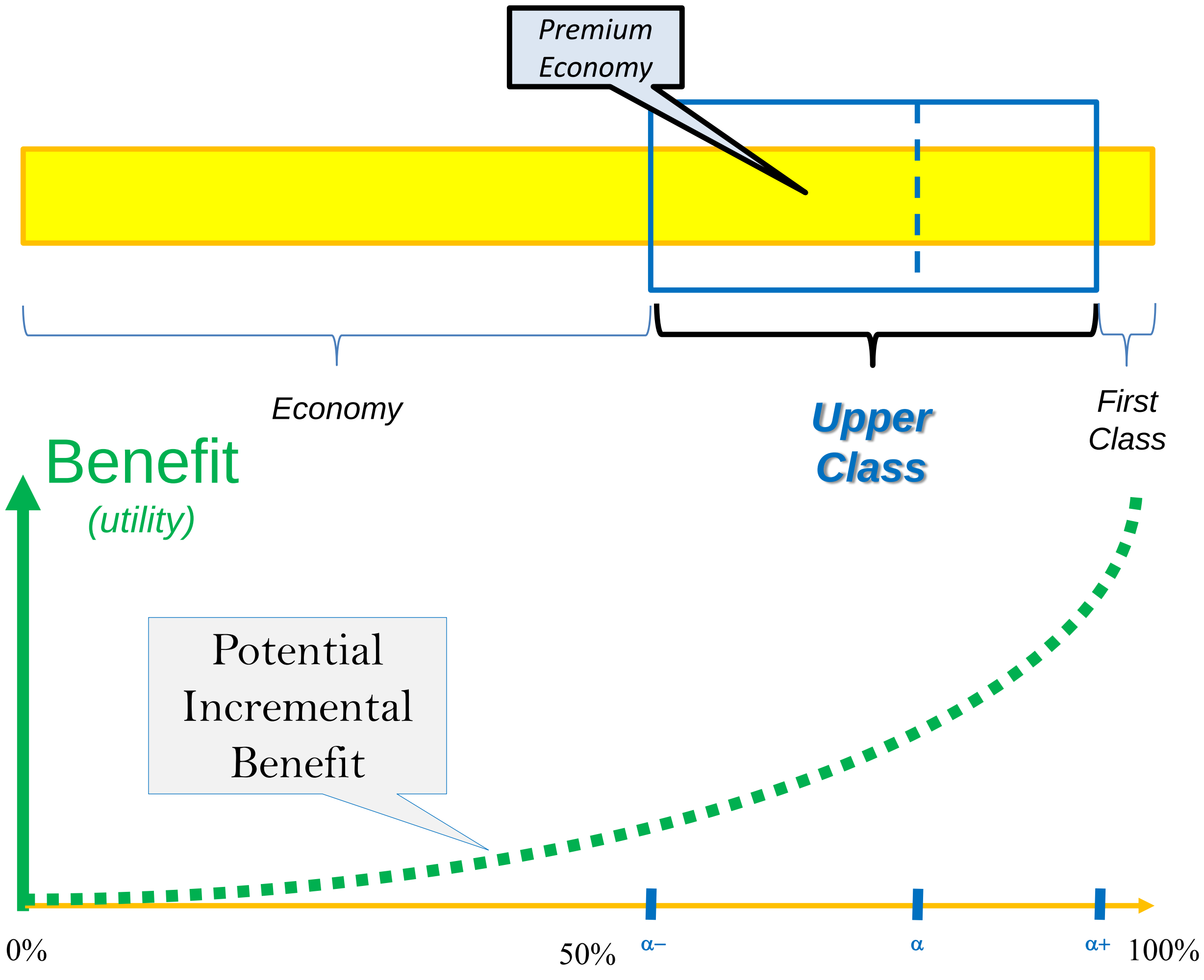

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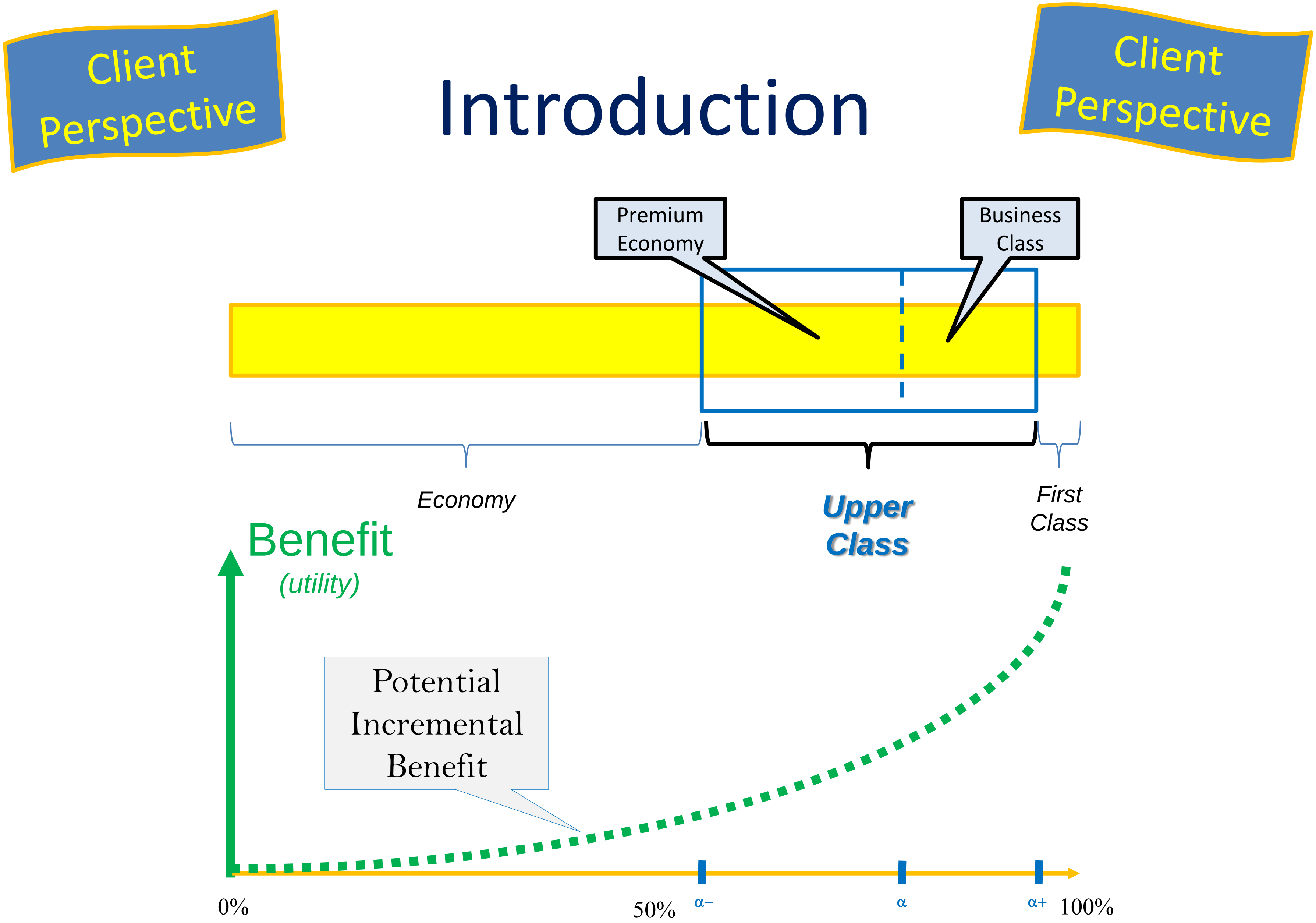

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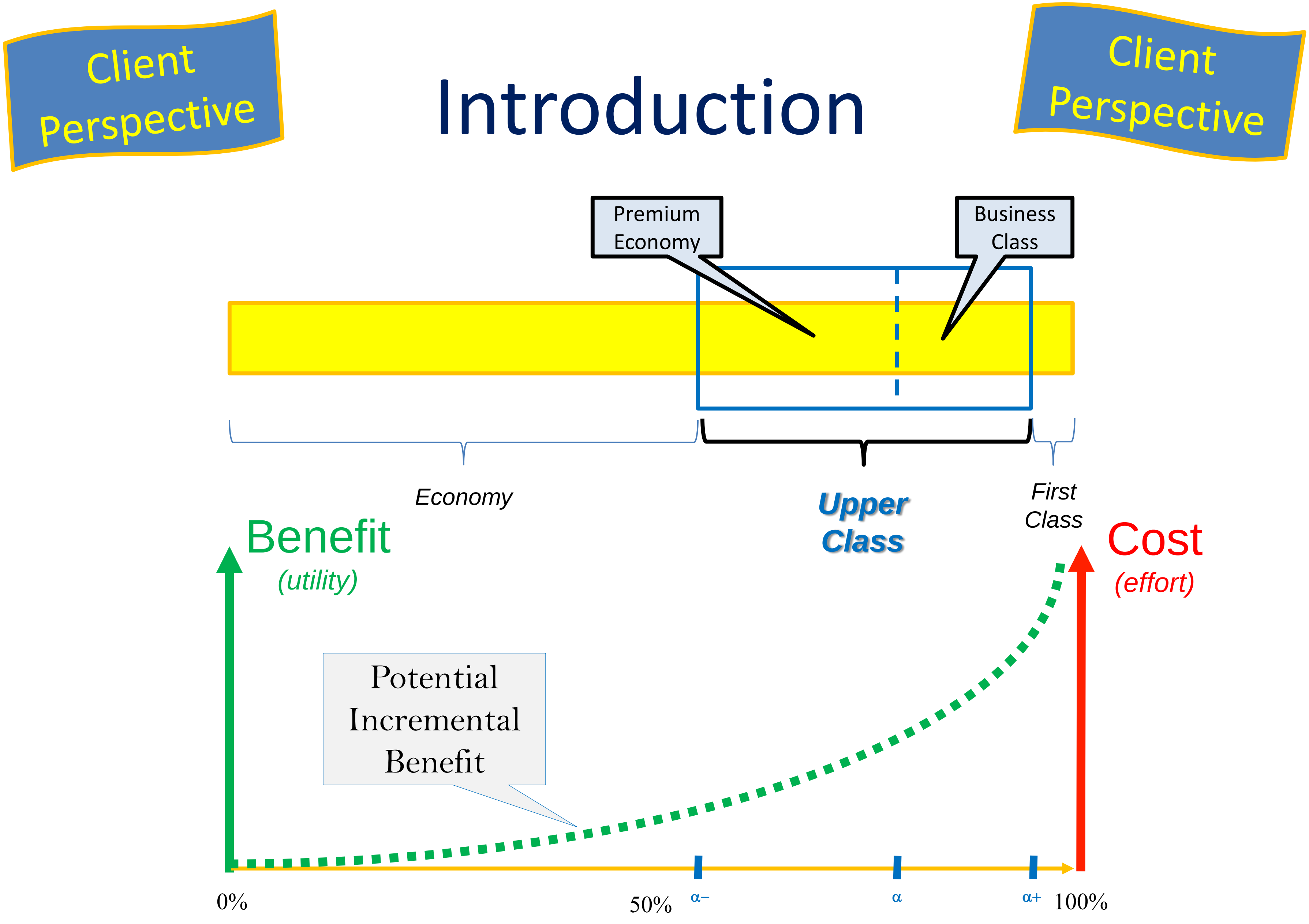

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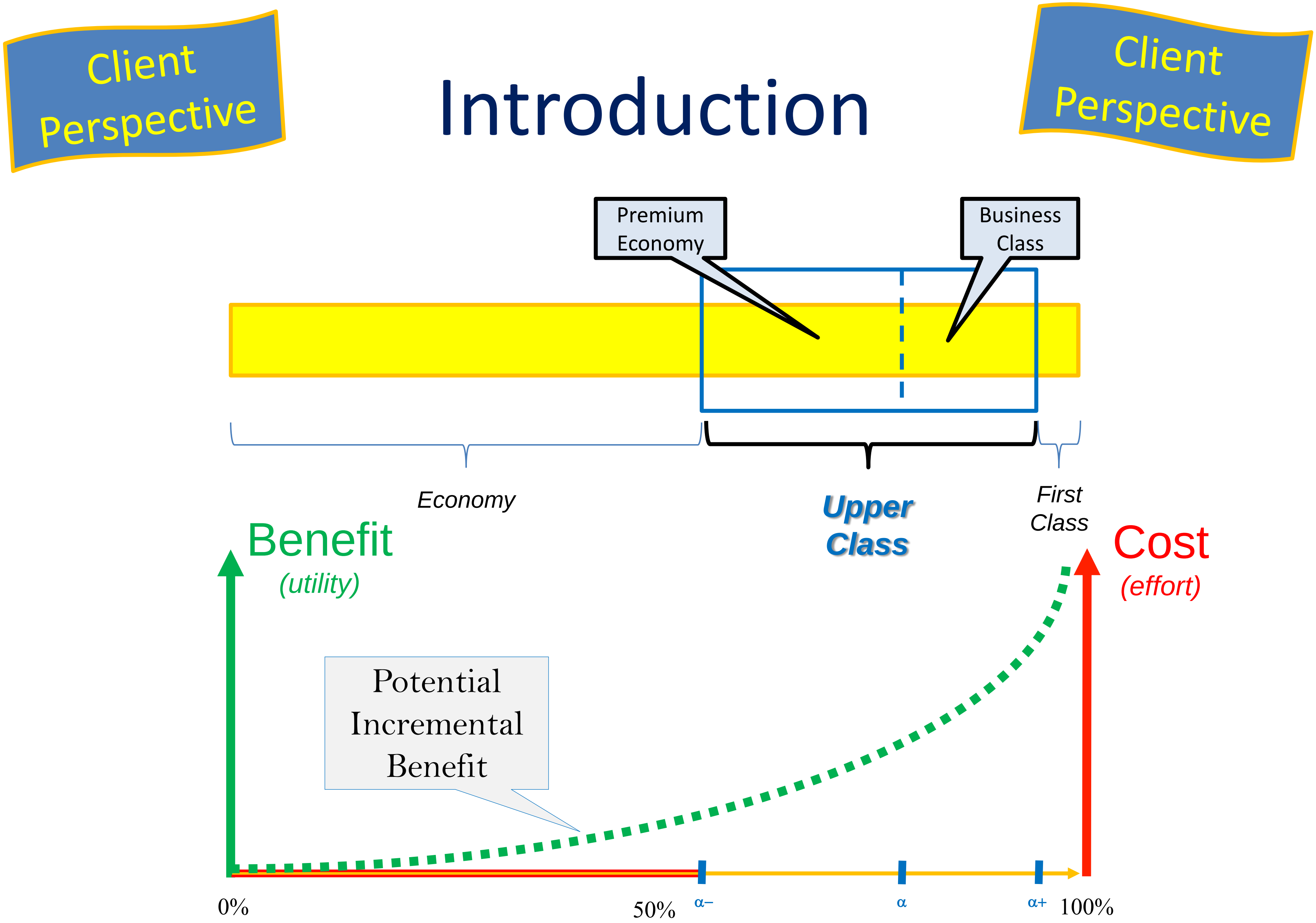

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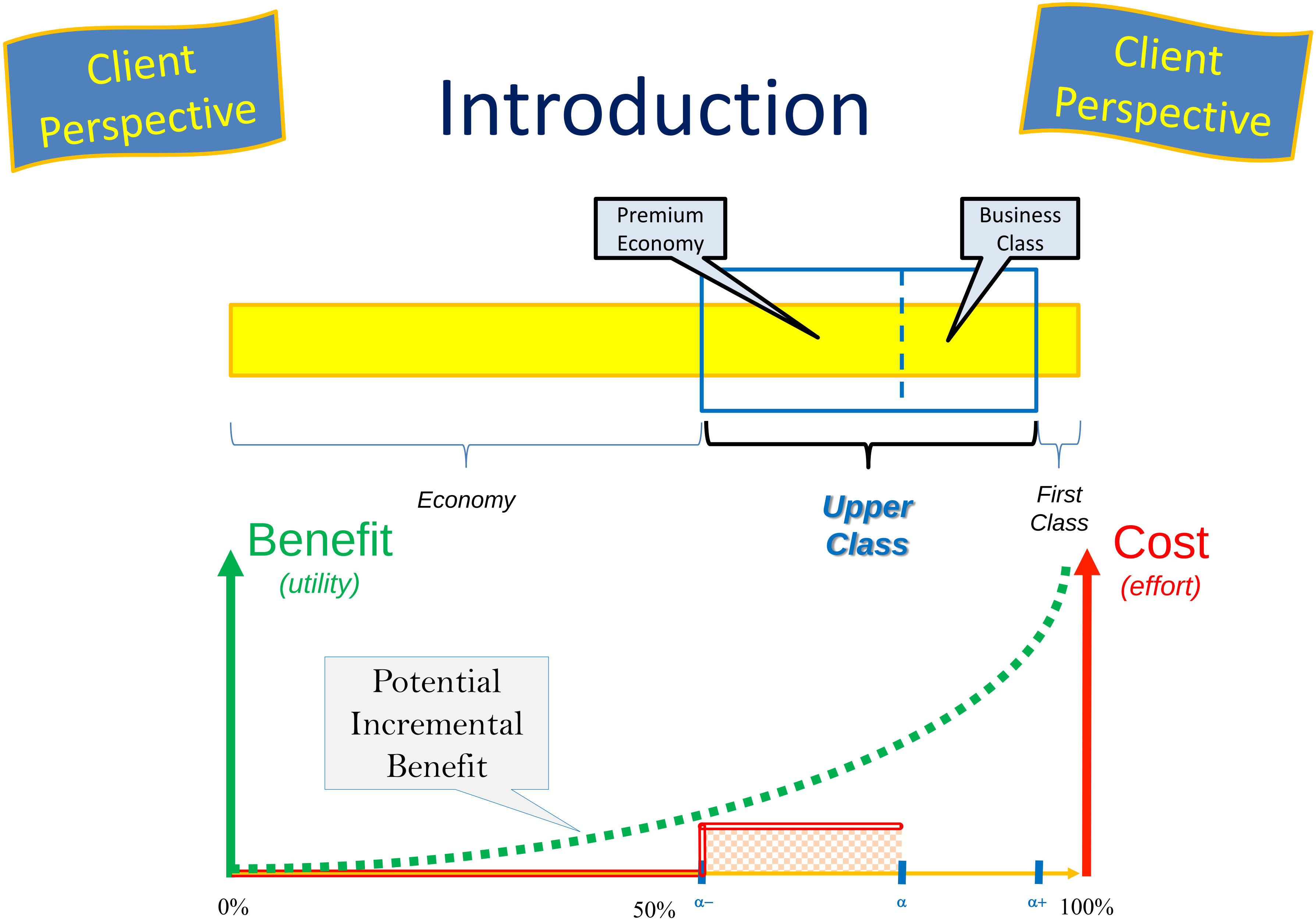

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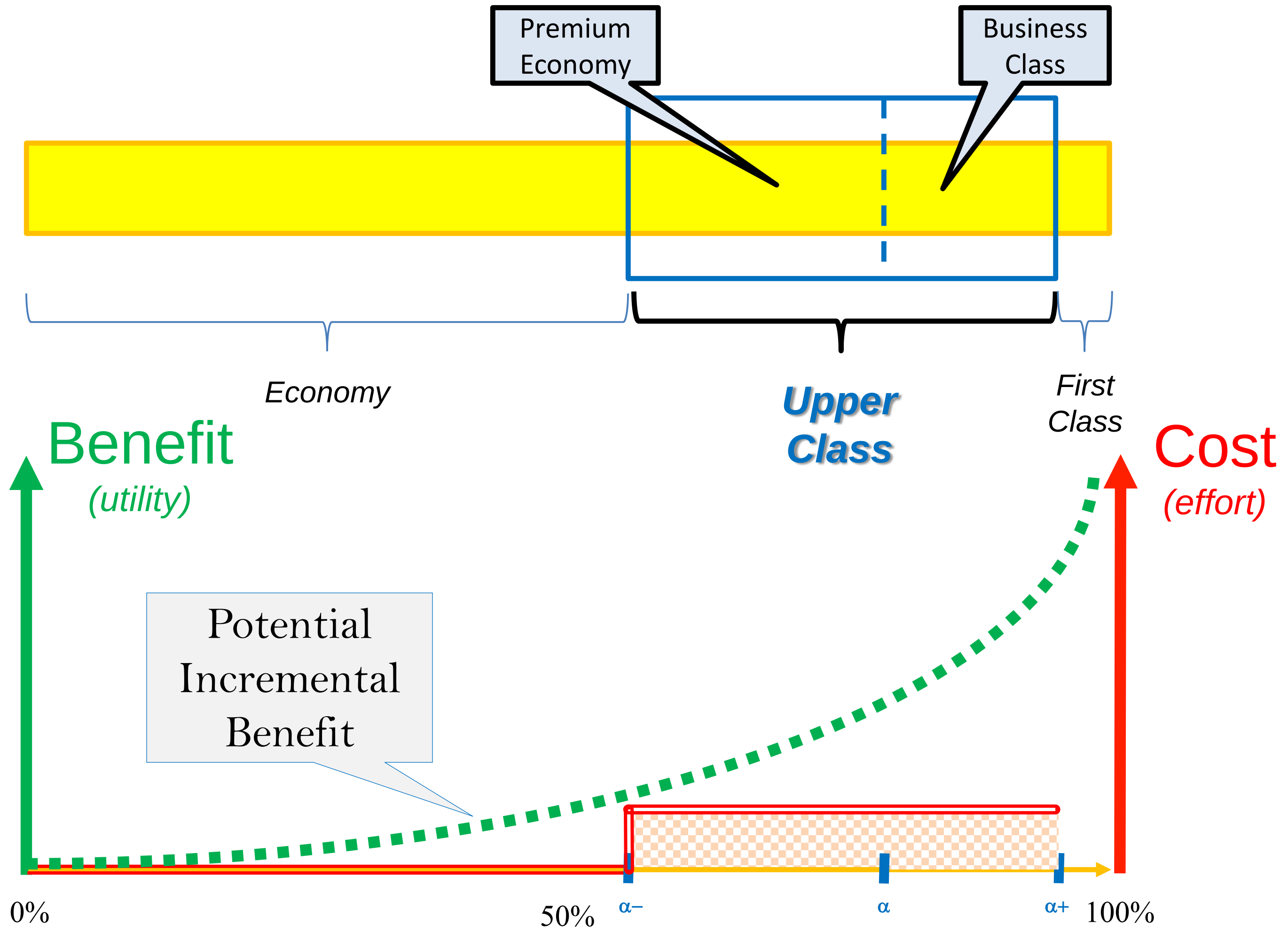

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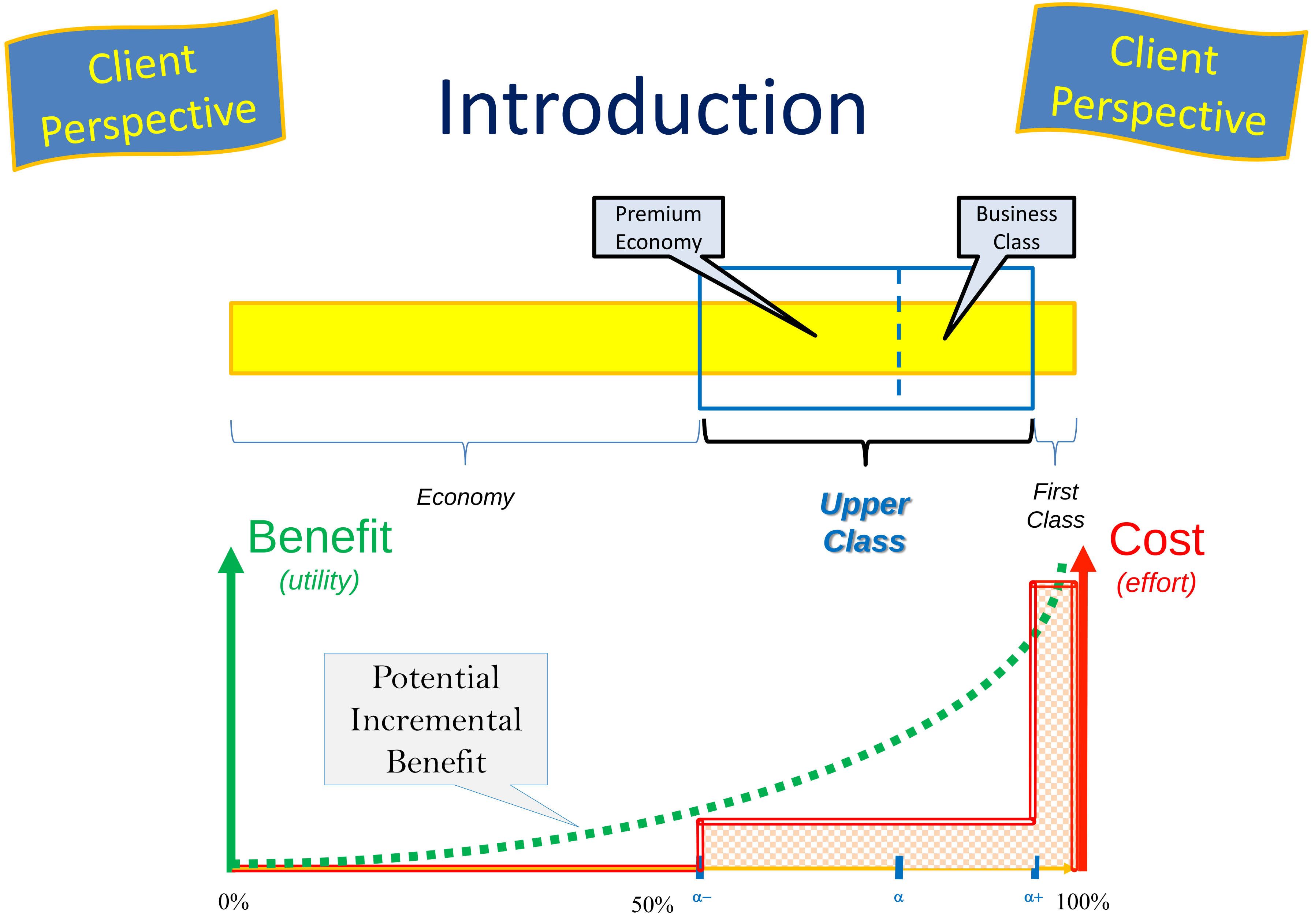

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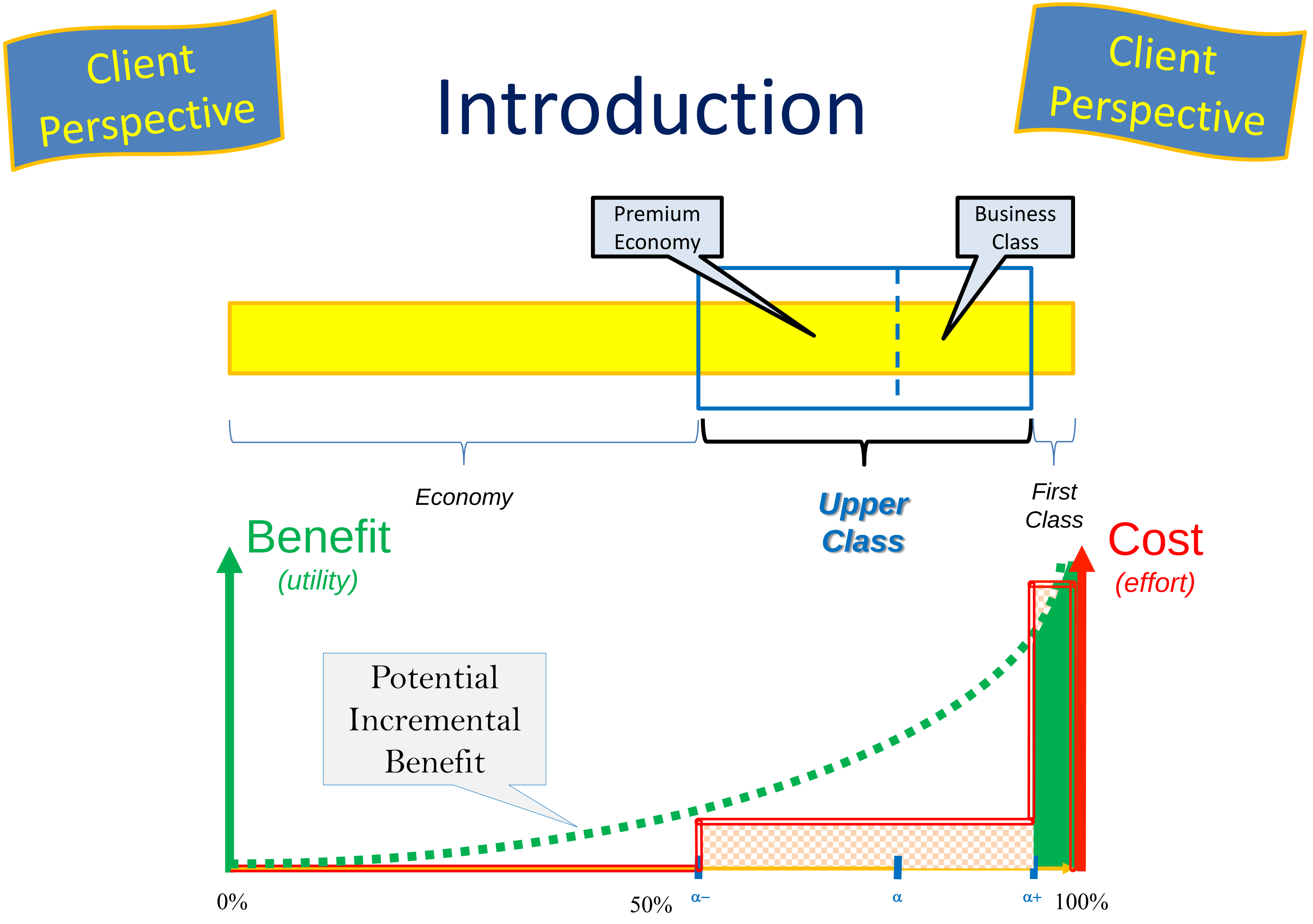

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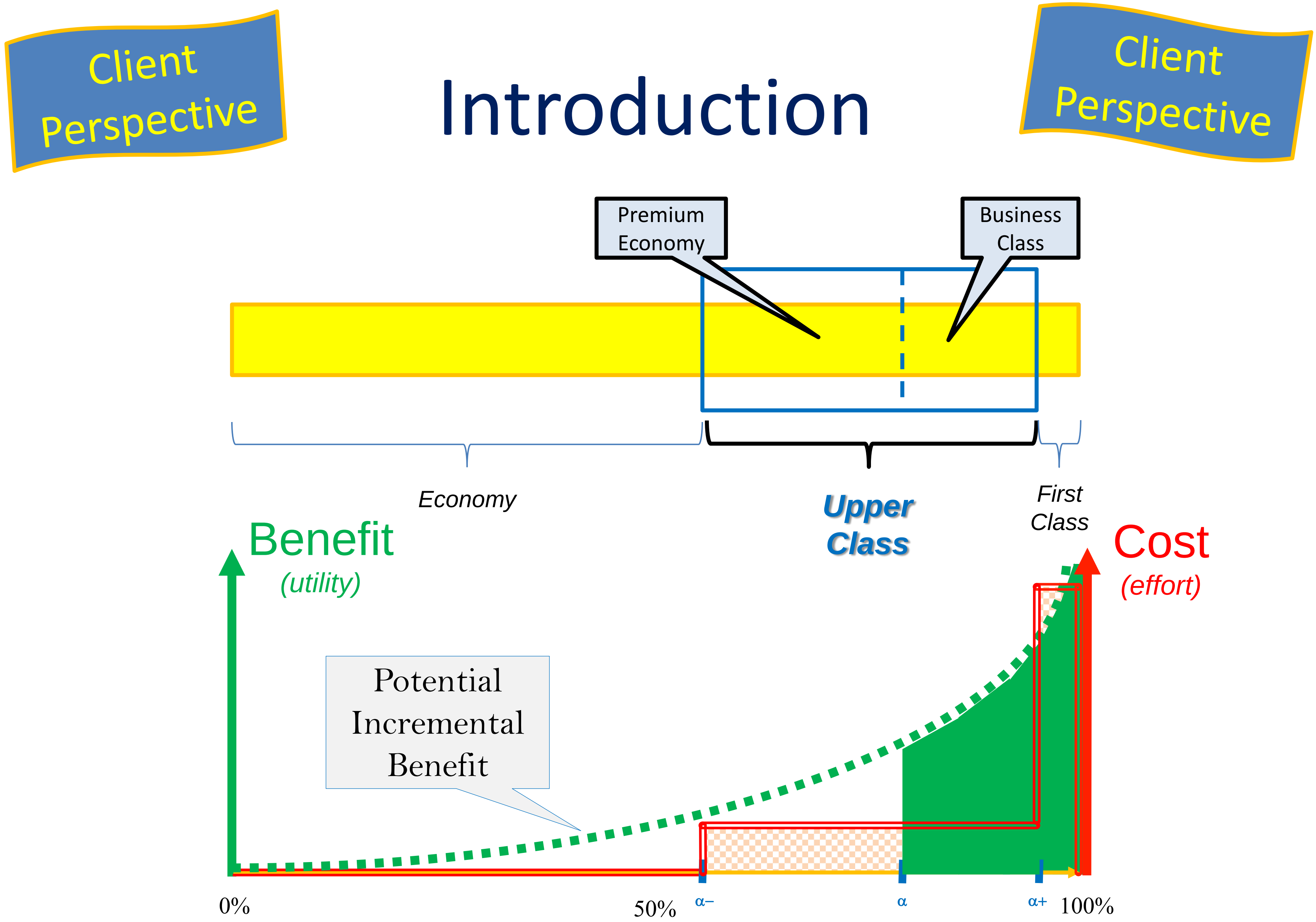

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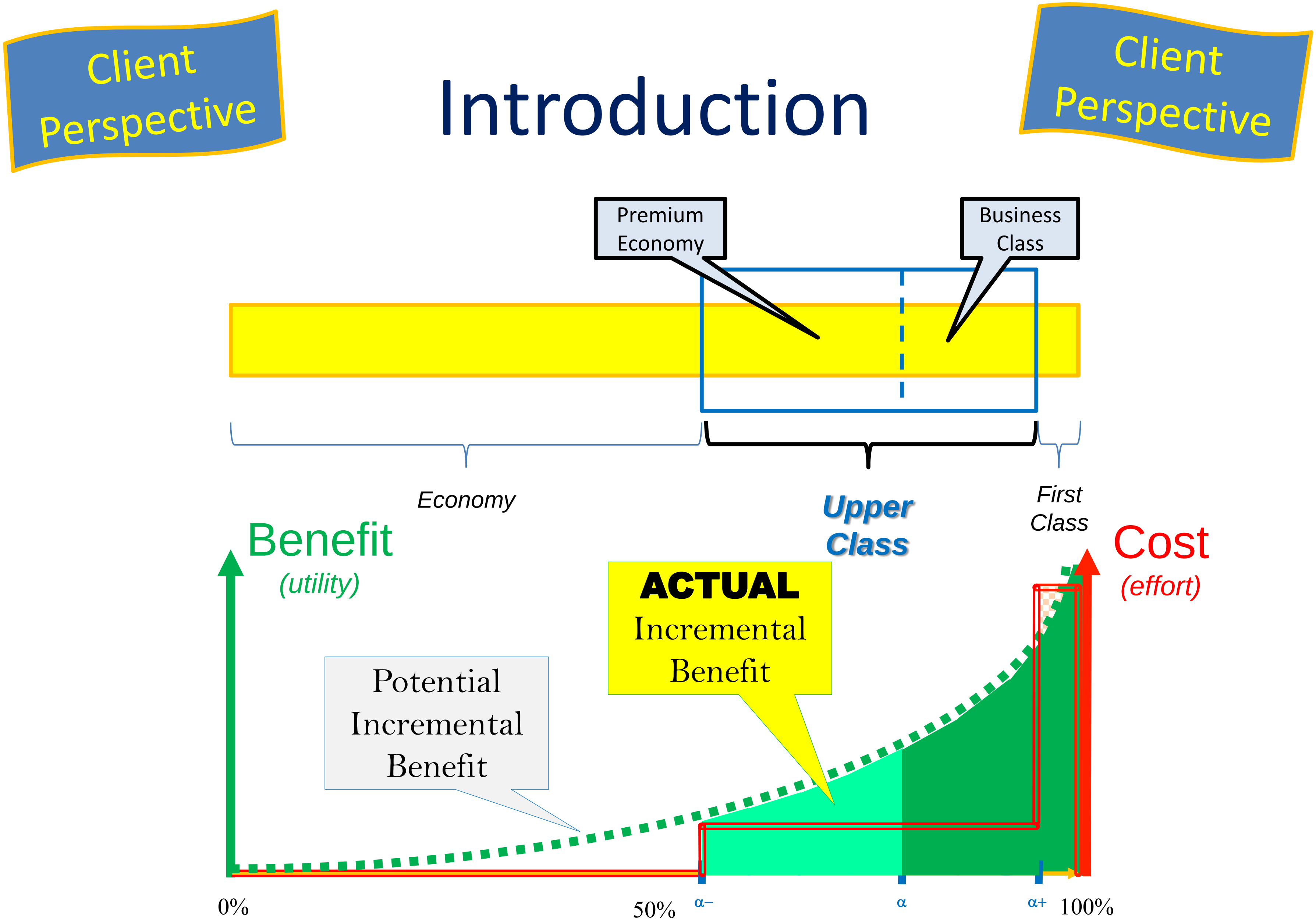

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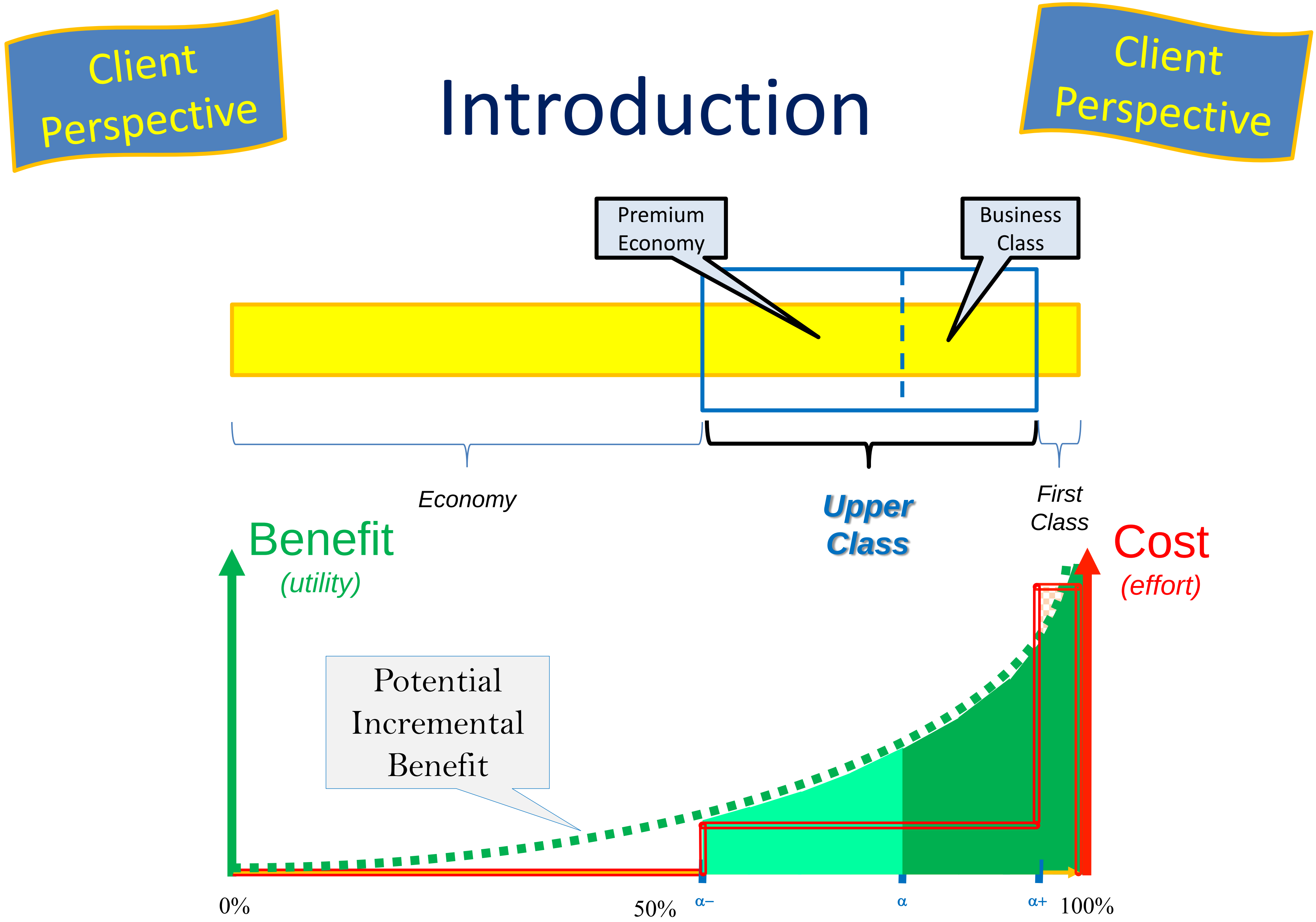

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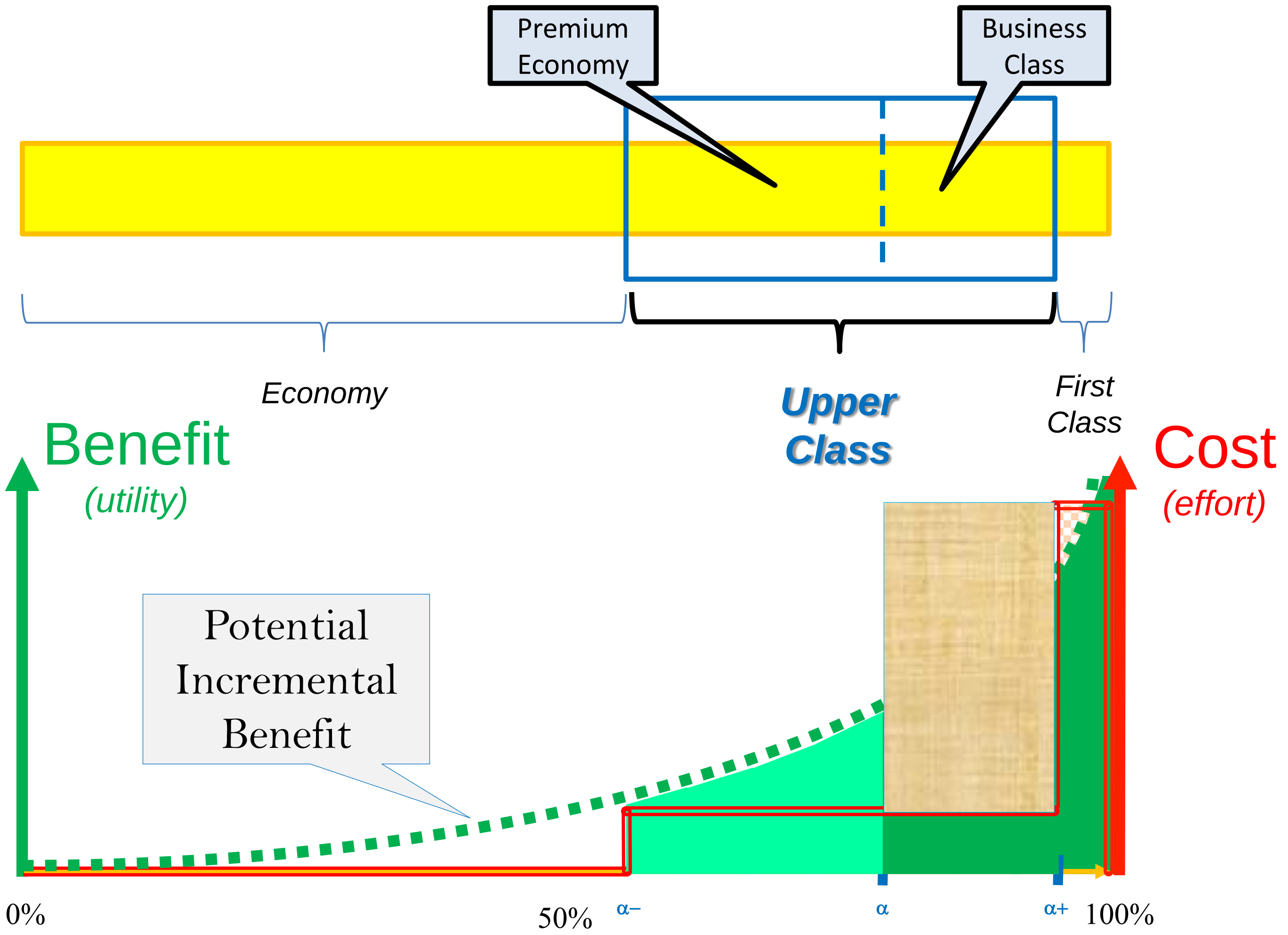

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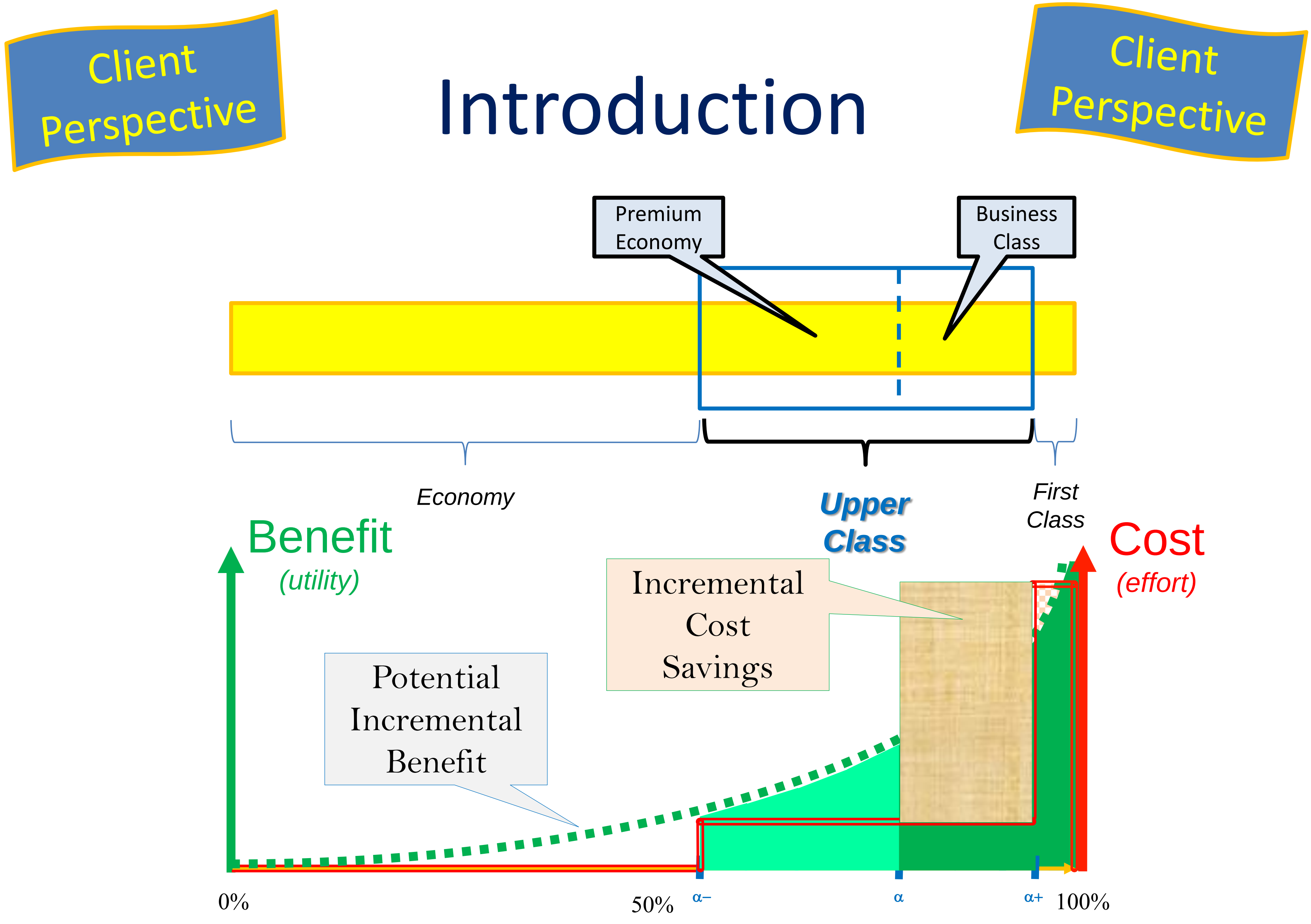

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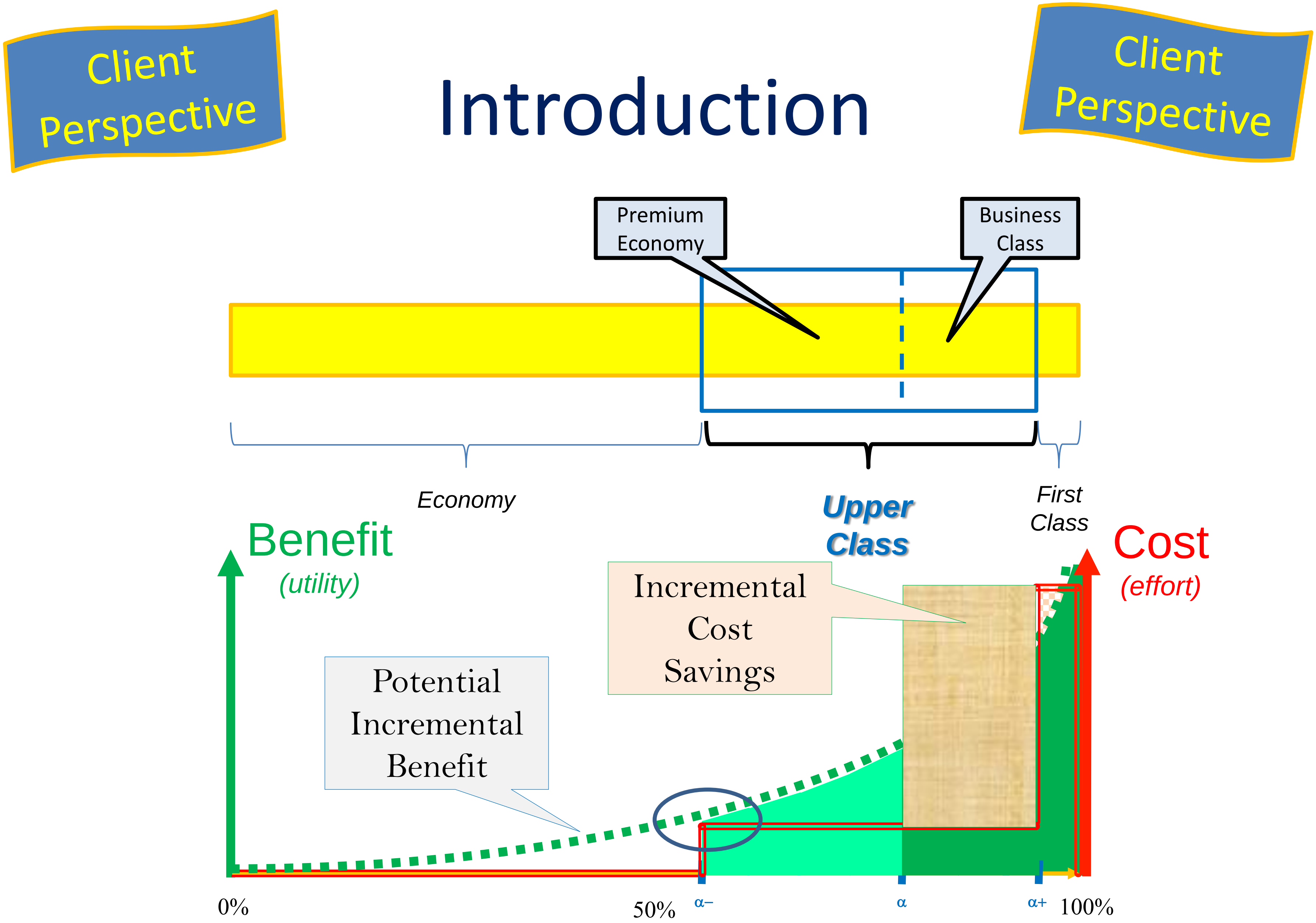

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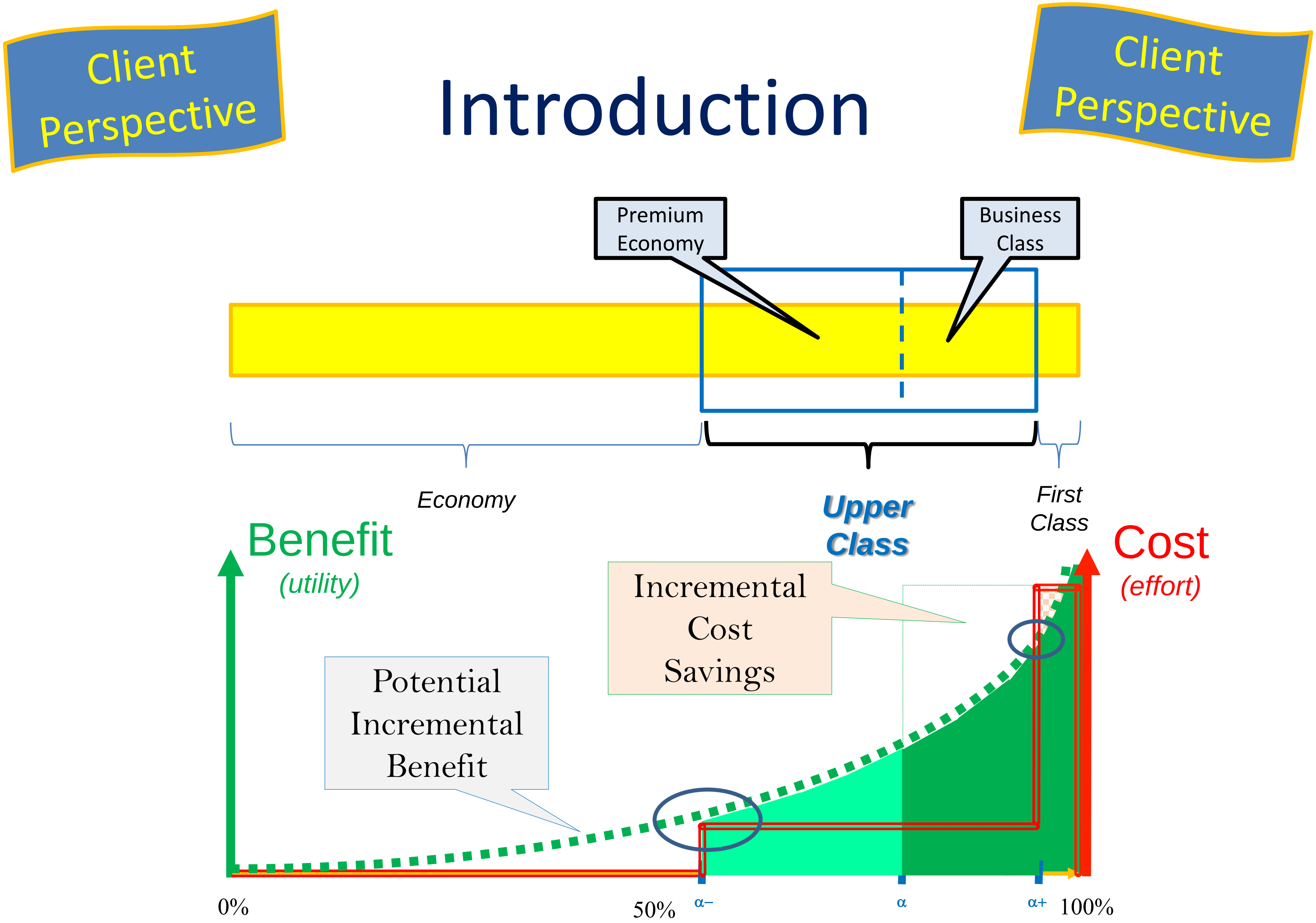

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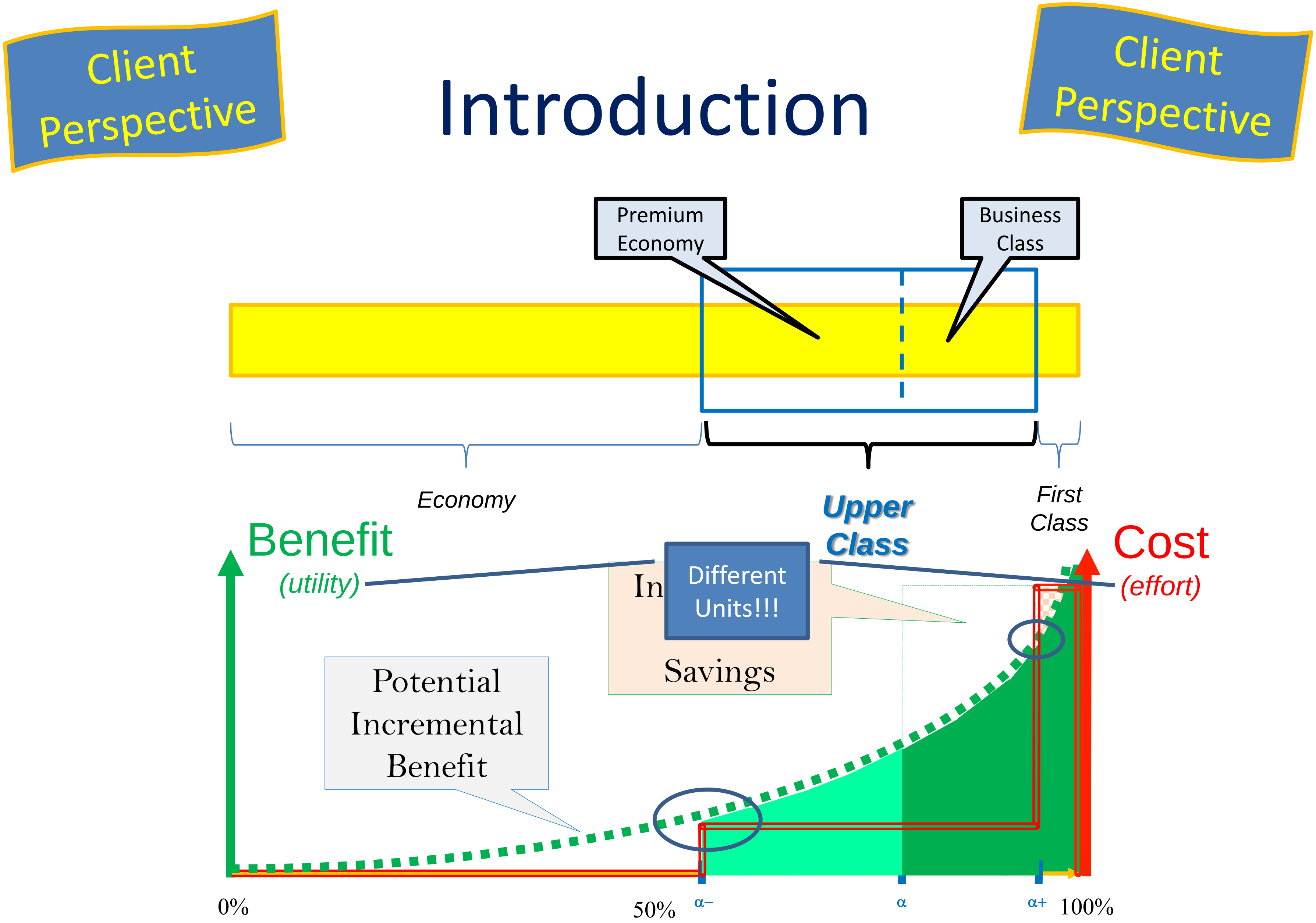

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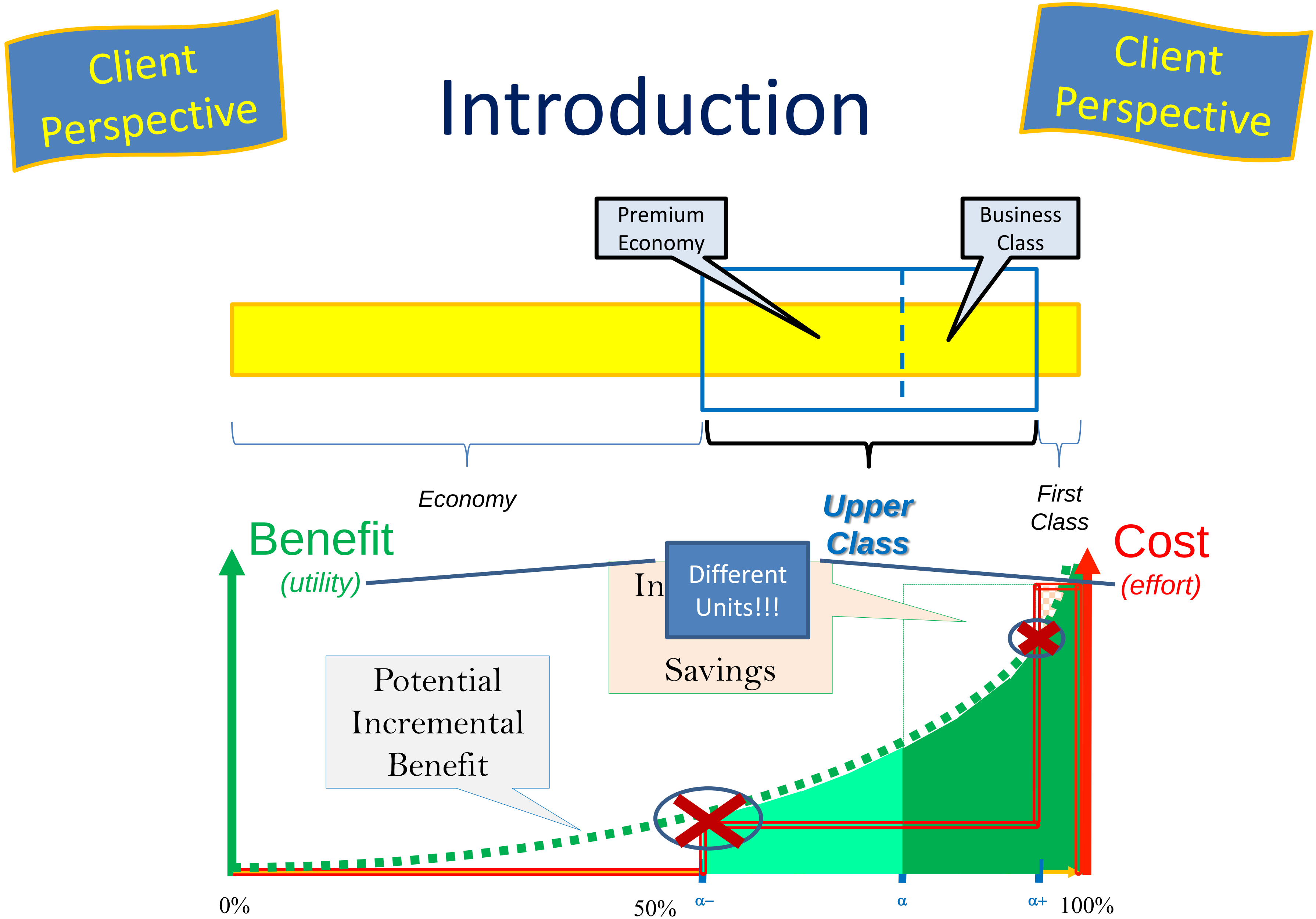

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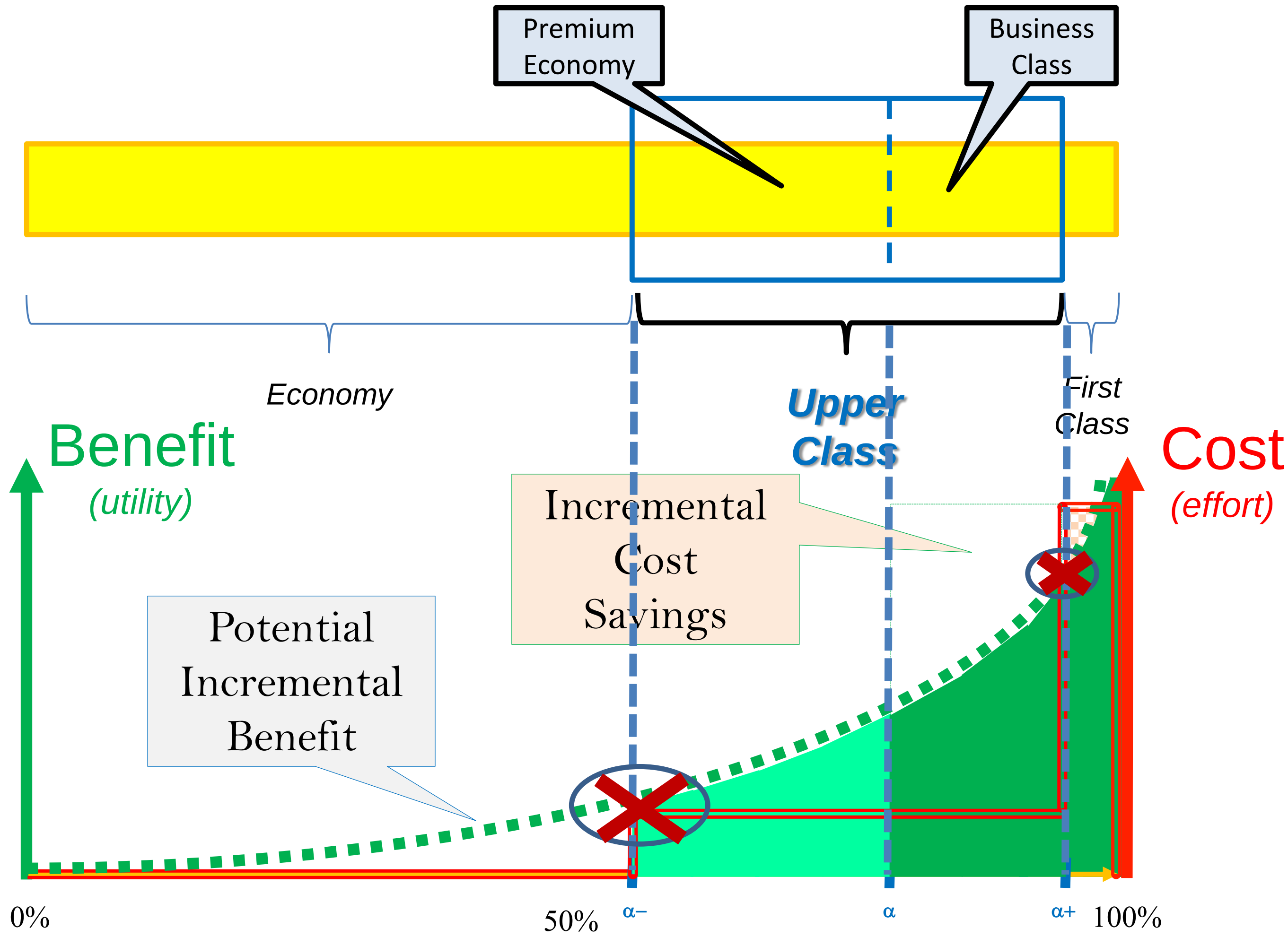

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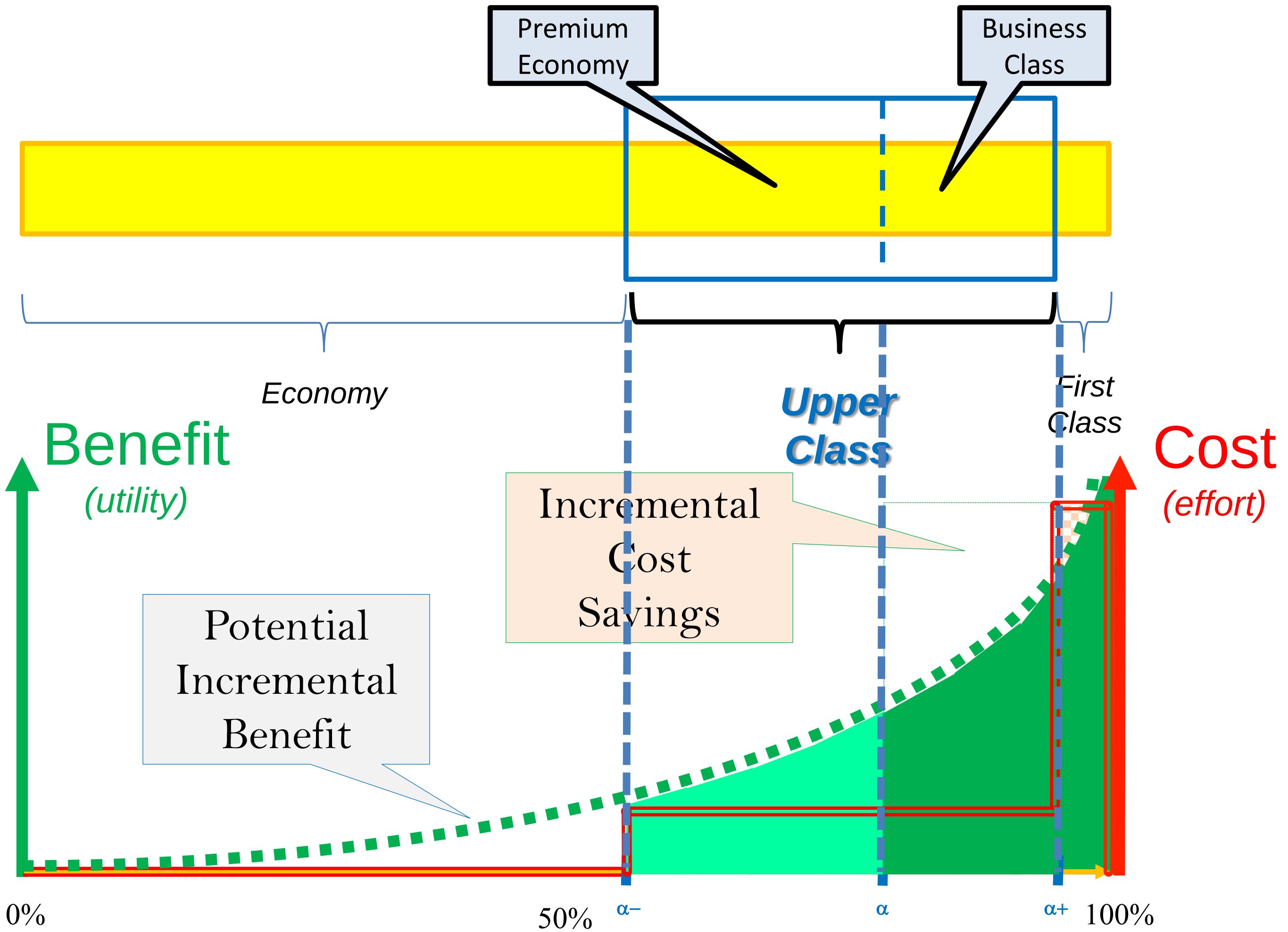

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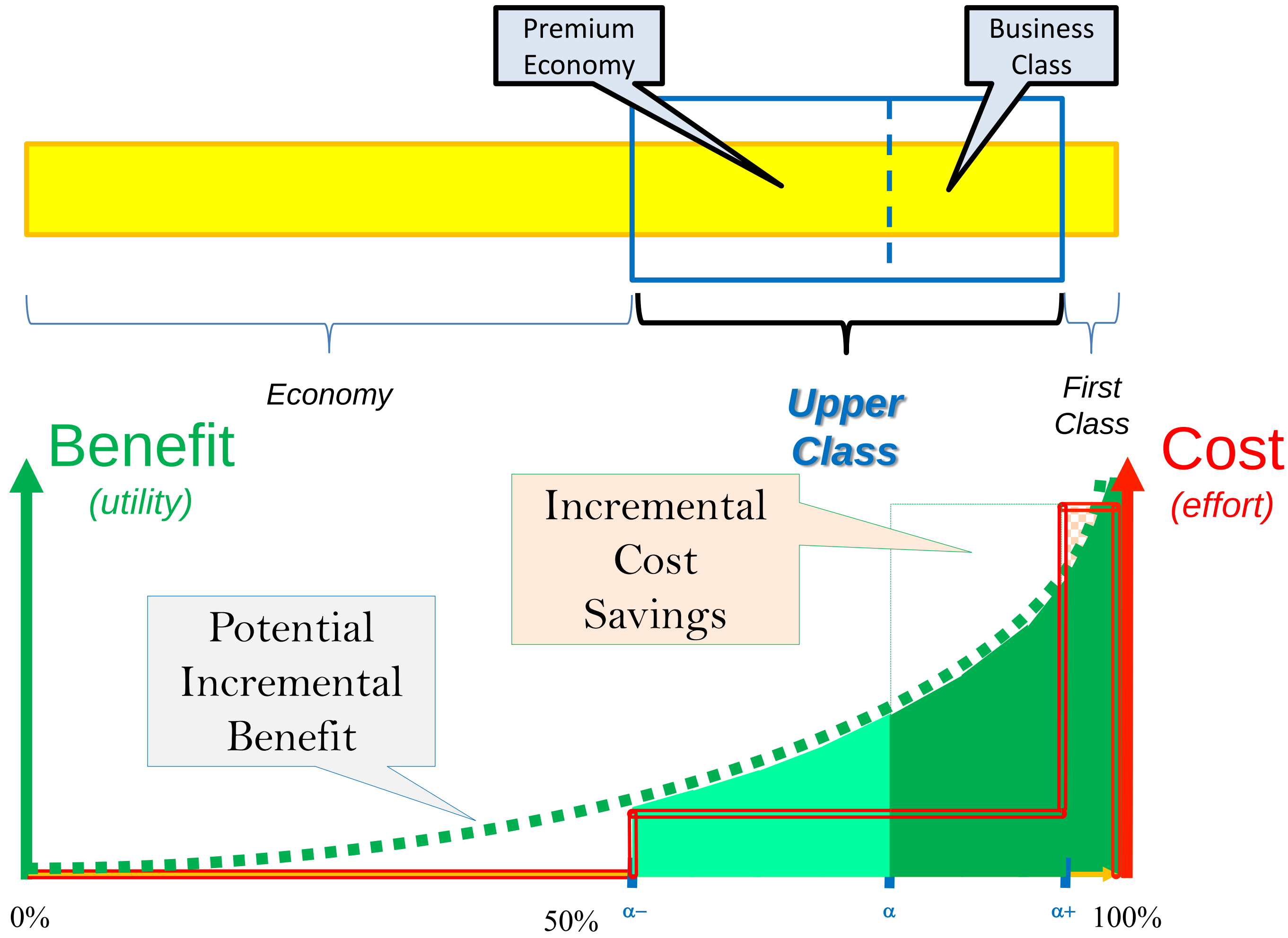

Introduction

Which airline do you think I fly most often?

- Delta Airlines (DA)
- Lufthansa (L)
- United Airlines (UA)
- *American Airlines (AA)*
- British Airways (BA)

Introduction

Which airline do you think I fly most often?

- Delta Airlines (DA)
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- United Airlines (UA)
- *American Airlines (AA)*[*]
- British Airways (BA)

[*]And I use their *American Advantage (AA)* credit card!

Introduction

Which airline do you think I fly most often?

- Delta Airlines (DA)
- Lufthansa (L)
- United Airlines (UA)
- *American Airlines (AA)**
- British Airways (BA)

*And I use their *American Advantage (AA)* credit card!

(Consider this talk an *AA* meeting)

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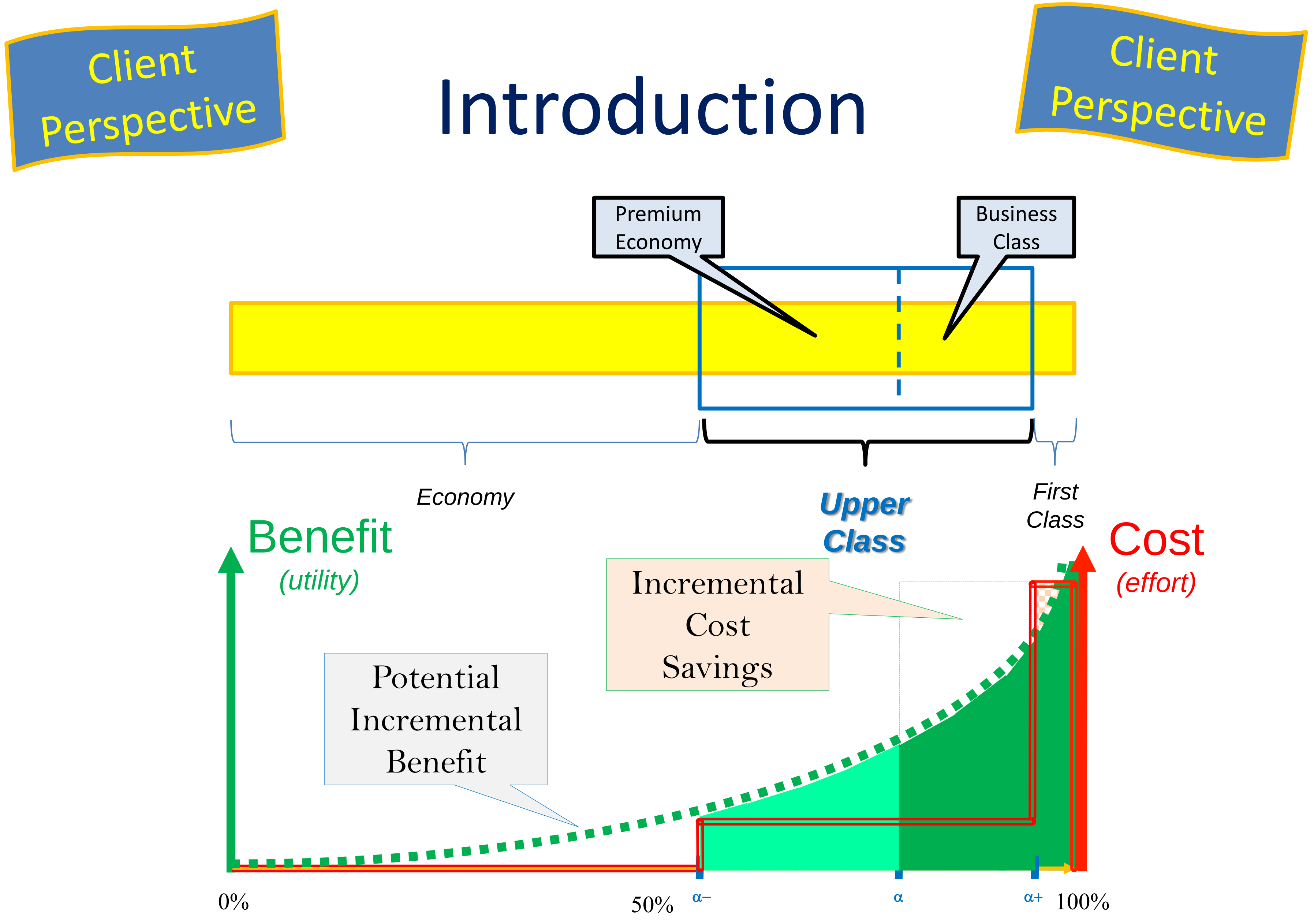
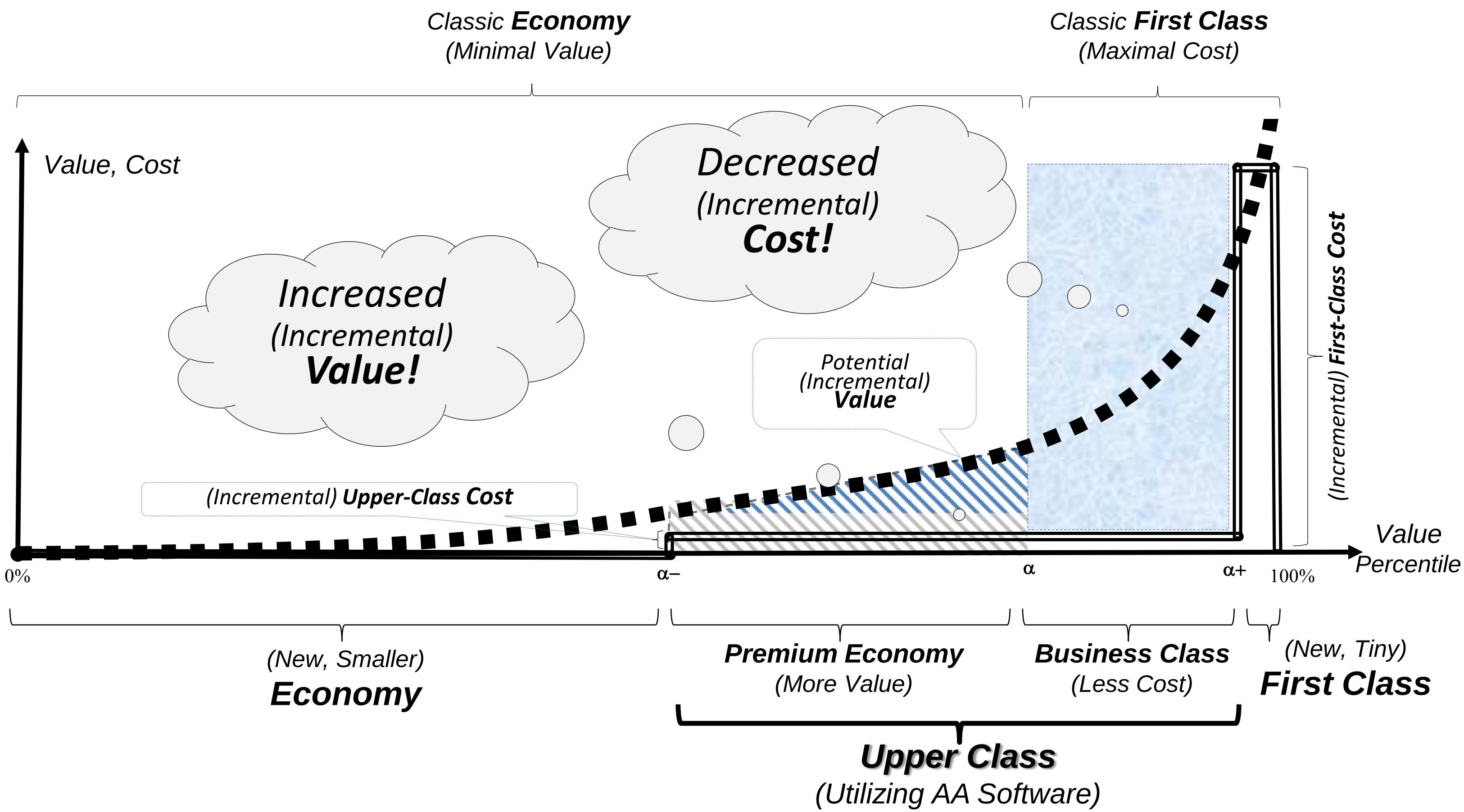


Introduction

Cost/Benefit of Utilizing Allocator-Aware (AA) Software



End of Section

Discussion?

End of Section

Questions?

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Style Alternatives

TIMTOWTDI (Pronounced “*Tim Toady*”)

- Three models
  - C++11
  - PMR (a.k.a. C++17)
  - BB20V
- Four interface styles
  - C++11
  - BDE and C++17/PMR
  - BB20V

C++11-Style [HIGH-COST]

Compile-time centric:

- Pros:
  - Zero overhead (runtime/space): default allocator
  - Allows non-standard addressing: shared memory
- Cons:
  - Forces clients to be templates
  - Raises interoperability issues
  - Complex and difficult (extremely) to implement
  - Not widely used except default; *very* widely disliked

BDE-Style [MODERATE-COST]

Runtime Centric (Doesn't Invade Object's Type):

- Pros:
  - Client's of *AA* objects need not be templated
  - Enhanced Interoperability (e.g., vocabulary types)
  - Reduced implementation cost (can be automated)
- Cons:
  - Non-zero runtime and spatial overhead
  - Significant implementation and maintenance costs

PMR-style [MODERATE-COST]

PMR-style (a.k.a. C++17 Style)

- Based on same Model as BDE style
- Small syntactic difference:
  - base-class pointer is wrapped in a C++11-style-compliant object
- Expected to supplant BDE-style at Bloomberg
  - E.g., BDE 4.0

2. Style for *Allocator-Aware (AA)* Software

BB20V-style [LOW-COST]

Language support for PMR-style allocators

- Some annotation will denote a class as *AA.*
- Compiler does (almost) all of the “plumbing”...

  … compiler-generated constructors too!
- Allocators are injected independently of the constructor signatures…

  ... vaguely similar to installing a VTAB PTR.

Style Alternatives

No matter what the *AA* style …

- Near same performance as bespoke solutions
- Much lower cost
- Important additional collateral benefits

End of Section

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3. Performance Benefits

Considerations

- Performance gains arise from:
  1. Faster allocator/deallocation calls
  2. Improved memory access (locality)
- Which dominates?
  - Short-running programs: *faster allocation calls*
  - Long-running programs: *improved memory access*

3. Performance Benefits

Allocation/Deallocation

Common Usage Pattern 1:

- Build up data structures (few or no deletes), access them (briefly), then tear them down.
- ***Monotonic*** **allocator**:
  - Deallocation is a no-op
  - Memory returned when allocator destroyed
  - Typically used from within a single thread

Allocation/Deallocation

Common Usage Pattern 2:

- Repeatedly allocate/deallocate blocks of a few distinct sizes.
- ***Multipool* allocator**:
  - Dynamically growing pools of fixed-size blocks based on usage
  - Deallocated blocks are retained for re-allocation
  - Two variants: Thread-safe or not

Allocation/Deallocation

Common Usage Pattern 3:

- Need to destroy many objects *en masse,* **and** objects own no resources except memory
- ***Managed*** **allocator**:
  - Has method that releases all memory for reuse
  - Object destructors are **not** called
  - Supported by both ***monotonic*** and ***multipool***
  - Most local allocators are naturally *managed* ones

3. Performance Benefits

Memory Locality

Locality of data in time/space is important.

- Multi-level hardware caching most effective when related data is physically close.
- Long-running programs that repeatedly allocate and deallocate can *diffuse* initially localized data.
- Loss in locality often dominates (“pwnz”) runtime performance of allocate/deallocate.
- Local (arena) allocators attenuate *diffusion*.

3. Performance Benefits

Thread Locality

Local memory allocators facilitate threading

- If distinct threads have their own allocators, synchronization (e.g., using mutexes) can often be avoided or drastically reduced.
- If distinct threads use separate arena allocators, accidental cache-line contention (a.k.a. *destructive interference*, *false sharing*) is naturally avoided.

Maximizing Performance

Achieving maximum performance requires

- Global knowledge of the application
- Solid understanding of different allocator characteristics

3. Performance Benefits

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Creating and Exploiting *AA*

Two different kinds of costs

1. <u>Up-front costs</u> **creating** (and maintaining) *AA*SI

   E.g., "Plumbing" constructors to propagate user-supplied allocators to all the various subobjects

   - ➢ Borne (mostly) by library/infrastructure developers

2. <u>Incremental costs</u> exploiting (or ignoring) *AA*SI

   E.g, Ongoing cognitive burden due to increased interface (and contract) complexity; chance for misuse

   - ➢ Borne by many *(most?)* application developers

Up-Front (Library Development) Costs

Converting an allocator-unaware class to *AA*

- For typical* classes, relatively straightforward
  - Add optional trailing allocator to every constructor.
  - Forward the new argument to base classes, data members, and any other managed sub-objects.
  - Denote the type as *AA* using an allocator-trait metafunction.
- *Non-typical classes are more challenging:
  - E.g., Generic, template, and container types

Up-Front (Library Development) Costs

Converting a generic container/template to *AA*

- Template types – e.g., `std::complex`
  - Requires interacting with *AA*-ness of element type
- Container types – e.g., `std::vector`
  - Involves touching methods other than constructors
- Non-allocating templates – e.g., `std::pair`
  - Templated type does not itself allocate memory
- Irregular types – e.g., `std::shared_ptr`
  - Requires domain knowledge of intended purpose

Up-Front (Library Development) Costs

Maintenance burden

- More source code
  - *AA* code is roughly ~10%* [4% – 17%] larger
- More training
  - Learning to write (and properly test) *AA* types
- Opportunity cost
  - Can require a lot of expert library developers' time
  - Other important projects might be delayed

*Measurment made on BDE code base (c 2017).

Up-Front (Library Development) Costs

Mitigating factors

- Readily lends it self to automation
  - `bde_verify`, a currently-available static-analysis tool, catches most common errors.
  - *BB20V* will eliminate *(most?)* manual "plumbing"…
- Developing BB20V technology is itself a substantial one-time up-front cost.
  - Analogous to self-driving car technology… (tbc...)

Incremental (Application-Developer) Costs

Typical cost of *using* *AA*SI is comparatively small*

- Much easier/faster than "rolling your own"
  - Simply supply desired allocator at construction
  - Does (of course) require additional testing effort
- No need for custom memory allocation?
  - Ignore *AA* parameters
  - Use *and test* normally
  - Use is entirely "opt in"

*We'll discuss *modern C++ style* later in this talk.

Incremental (Application-Developer) Costs

Additional cognitive burden

- Users will still see *AA* features
  - Enlarged (programmatic) interface:

    e.g., Trailing allocator argument in every constructor
  - Enlarged (English) contracts (e.g., for constructors):

    e.g., "Optionally specify a basic allocator to supply..."
- Although the net benefit for those who exploit *AA* clear, the overall net user benefit is less so.

Incremental (Application-Developer) Costs

Additional opportunity for client misuse

- Allowing an object to outlive its allocator
  - [rare] by, say, returning a dynamically allocated object, created using a local (e.g., stack) allocator
- Inappropriate use of special-purpose allocator
  - [common] by, say, repeatedly reusing a monotonic allocator created outside of a long-running loop
- Misuse can be catastrophic or simply fail to improve performance – either way it's a cost!

Incremental (Application-Developer) Costs

Incompatibility with some modern C++ features

- *AA* classes require non-trivial CTORs
  - Compiler-generated copy operations won't work
  - Problem is exacerbated by C++11 move variants
  - Aggregate initialization is not currently* available
- The assertion that "*allocators do not interact well with modern C++ move semantics*" is **false!**
  - We will demonstrate why/how later on in this talk.

*The (language-based) BB20V-style eliminates all such syntactic incompatibilities.

Incremental (Application-Developer) Costs

Lifetime management issues

- The (productive) lifetime of an object must not exceed that of its allocator.
  - Requires additional care by application developers
- Limits applicability of certain standard facilities that manage object lifetimes as they neither track nor extend allocator lifetimes.
  - E.g., `std::shared_ptr` and `std::weak_ptr`

Incremental (Application-Developer) Costs

Education, tools, and governance

- Additional administrative costs of *AA* software
  - Proper training (continuing education)
  - Code reviews (by properly trained reviewers)
  - Developer-facing (e.g., static analysis) tools
  - Company-wide policies (on allocator-usage)
- Not atypical of other powerful paradigms
  - E.g., Multithreading, unit testing, and C++ itself!

4. Costs

Creating and Exploiting *AA*

Bottom line

- Real, substantial costs exist
  – [substantial] Up-front library development costs
  – [modest] Incremental application developer costs
- A credible value proposition remains
  – If we don't have (hierarchically) reusable *AA*SI then some application developers *will* need to write it.
  – All the rest will be forced to do without it.

4. Costs

End of Section

Discussion?

4. Costs

End of Section

Questions?

4. Costs

What Questions Are We Answering?

- What is the % of code that benefits allocators?

Outline

1. Introduction
2. Styles for *Allocator-Aware (AA)* Software
3. Performance Benefits
4. Costs
5. Collateral Benefits
6. "Concerns"

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5. Collateral Benefits

… but Wait! There's More!

Apart from frequent (and sometimes dramatic) performance gains…

- …investing in an *AA*SI provides other benefits
  - rapid prototyping; modularity; (hierarchical) reuse; testing; instrumentation; object placement
- Investment in ultra-performance-tuned, "one-off" data structures are unlikely to provide any of these valuable ***collateral benefits***.

Rapid Prototyping, and Predictability

- Design with AA is low-cost and low-risk.
  1. Select from suite of existing allocation algorithms.
  2. Plug into *AA*SI components in application.
  3. Measure!
  4. Tune.
  5. Repeat, as needed.
- **Deploy immediately!**

Rapid Prototyping, and Predictability

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  2. Plug into *AA*SI components in application.
  3. Measure!
  4. Tune.
  5. Repeat, as needed.
- Deploy immediately! And/or **use as proof-of-concept for custom-data-structure project!**

Modularity and Composition (Reuse)

The BDE-style allocators are *chainable*.

- I.e., One allocator provides some functionality, then goes to its *backing* allocator when additional memory is needed.
- Examples:
  - A “small block” allocator can “fall back” on a “large block” one for big memory chunks as needed.
  - One allocator provides some features (e.g. metrics gathering) and “falls back” to another for memory.

Testing and Instrumentation

Testing: `bslma::TestAllocator`

- Check for memory leaks
  - Log allocate/deallocate calls
  - Match deallocations with known allocations
- Test exception safety
  - Throw **`bsl::bad_alloc`** on cue in tests
- Test for memory-range overwrites (sentinels)
- Non-invasive
  - Works on arbitrarily large-scale code

Testing and Instrumentation

Instrumentation: *Tagged Allocator Store (TAS)*

- Monitor memory usage on an object basis
  - Leverages `bslma::Allocator` vocabulary type
  - Multiply inherits `gtkma::AllocatorStore`
  - Uses `dynamic_cast` to "opt in" to reporting
- Strictly better than other solutions
  - "Opt In" is fine-grained and entirely optional
  - Provides object- as opposed to class-based info
  - Works on arbitrarily large-scale code

5. Collateral Benefits

Whole-Object Placement

Placement of objects in memory is important!

- Allocators facilitate the placement of (entire) objects in “special” memory.
  - (placement `new` is for only the top-level footprint)
- Examples
  - High-bandwidth memory (HBM)
  - Hardware protected (no read and/or write access)
  - Persistent or file-mapped (**`mmap`**) memory
    - The `gmalloc` allocator is but one relevant example

5. Collateral Benefits

Garbage Collection

Sometimes we need to get down to the metal

- Traditional use of managed pointers can be unnecessarily expensive in both time and space.
- Large (many-node) data structures built out of ***raw pointers*** can be summarily "winked out"!
  - The release method of a (managed) allocator will unilaterally reclaims all memory (*w/o destructors).*
  - **Requirement**: The data structures own no resources other than memory from that allocator.

5. Collateral Benefits

Pluggable Customization

The utility of an *AA*SI for realizing performance and other, collateral benefits are open-ended.

- Most (but not all) of these benefits depend largely (albeit indirectly) on the ability to inject allocators into a system ***at runtime.***
- Without having invested in an *AA*SI, the cost of pursuing such benefits would require prohibitive expenditure of time and effort – especially w.r.t. to bespoke data structures.

End of Section

Discussion?

End of Section

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Why the Quotes?

Classical allocators specifications have sucked!

- C++98 allocators didn't work at all!
  - stateless (and completely useless) – Lakos'96
- C++03 allocators had “weasel words”
  - Not portable: allowed but not required to work
- C++11 allocators are a pain in the @SS!
  - Hard to write; invade object type; *very* hard to use
- C++17 allocators are much better
  - Runtime polymorphic; **much** easier to write/use

6. “Concerns”

Why the Quotes?

People *invent* “reasons” for *not* liking allocators

- State-of-the-art allocators are as good or better
- PMR violates the zero-overhead principle (ZOP)
- (Generally) poor *runtime performance* trade-off
- (Unmanageable) verification/testing complexity
- (Gross) incompatibility with modern C++ style
- Don’t play nice w/modern C++ move semantics
- *Object pools* and *factories* are as good or better

6. “Concerns”

State-of-the-Art Global Allocators

“Advances in global memory allocators have led to dramatic performance improvements – especially with respect to real-world multithreaded applications; wouldn’t replacing the compiler-supplied global memory allocator with a newer, “state-of-the-art” one achieve most (if not all) of the real benefits derived from assiduous use of local allocators designed into a program?”

6. “Concerns”

State-of-the-Art Global Allocators

Global allocators are not (cannot be) sufficient.

- General-purpose global allocators are ignorant of application-specific details.
- They cannot achieve the locality that local allocators can.
- They cannot not provide the collateral benefits.

6. “Concerns”

Zero-Overhead-Principle Compliance

“For all but the C++11 model, *AA* objects (1) require maintaining extra state – even for the most common case (i.e., where the default allocator is used) – and (2) necessarily employ virtual-function dispatch when allocating and deallocating memory; isn’t that too inefficient for *AA* software to be viable in C++?”

6. "Concerns"

Zero-Overhead-Principle Compliance

Neither *letter* nor *spirit* of ZOP is violated.

- The needed "extra space" can be addressed
  - Used only upon allocation
  - Stored outside the footprint
  - Elided in common case(s) especially the default
- The virtual-function dispatch "overhead"
  - Can be bound *at compile time* in relevant cases
  - Is invariably negligible compared to added locality
  - Is generally a red herring: allocators boost runtime

6. “Concerns”

Zero-Overhead-Principle Compliance

AA software makes prudent design trade-offs

1. Benefits to some with negligible cost to others
   – Implementation change: O(N) -> O(log N)
2. Solid benefits for a few but small cost to other
   – **`std::list<T>::size()`** must be O(1)
3. Large benefit for expected case but significate cost for others
   – Short-string optimization (SSO)
      • Especially costly for (sparse) vectors of string data

6. “Concerns”

Zero-Overhead-Principle Compliance

AA software makes **<u>these</u>** design trade-offs

1. **Benefits to some with negligible cost to others**
   – Implementation change: O(N) -> O(log N)
2. **Solid benefits for a few but small cost to others**
   – `std::list<T>::size()` must be O(1)

<u>Allocator Tax Analogy</u>

Everyone must buy auto insurance:

Accidents are *<u>unusual</u>* – but not ***rare!***

6. “Concerns”

Verification/Testing Complexity

“Failure to properly annotate types or propagate allocators can undermine the effectiveness of the allocation strategy and can lead to memory leaks, especially when ‘winking out’ memory; aren't the extensive verification, testing, and/or peer review required to avoid such errors impracticable?”

6. “Concerns”

Verification/Testing Complexity

Almost every new library or language feature has a learning curve and requires additional testing.

- Allocators are entirely opt-in (can ignore them)
- Special-purpose allocators do require training
- “Winking out” is inherently for experts only
- Static analysis tools (e.g., `bde_verify`) can help
- `bslma::TestAllocator` (e.g., leak testing)
- BB20V-styled *will* help dramatically!

6. “Concerns”

Compatibility with Modern C++ Style

“C++11 encourages a style of programming where objects are more often passed and returned by value, sometimes relying on rvalue references to move these objects efficiently whereas BDE style relies on passing *AA* objects (by address) as arguments to achieve optimal efficiency and control over the allocator employed; isn't this ‘old-fashioned’ style unjustifiably restrictive?”

Compatibility with Modern C++ Style

Custom allocators do <u>not</u> affect function style

- Returning by value is inherently inefficient
  - The retuned object must be constructed each time
  - Supplying an allocator doesn’t help
- Returning an object by argument is faster
  - Can reuse object to return multiple values
    - E.g., Accumulator Pattern: *tokenizer returning strings*
  - Full control over result allocator in client context
  - Can build returning style on top (but not vice versa)

6. “Concerns”

Move vs. Allocate

“When two objects use different allocators, *move* assignment degenerates to a copy operation and *swap* becomes undefined behavior; doesn’t that imply that local allocators should be avoided to enable such operations?”

6. “Concerns”

Move vs. Allocate

Move assignment is often *not* as efficient as copy!

- Object returned by value are *not* moved
  - They are constructed in place via RVO (or NRVO)
- Moving objects around “mucks” with memory
  i. Locality (cache-lines, caches, pages, etc.)
  ii. Constructive interference (a.k.a. “true sharing”)
  iii. Prefetching
  iv. Optimal N-way-cache/main-memory-bank access
- Moving within a container (or an “arena”) is OK
  - Preserves i and ii (above) but *not necessarily* iii or iv.

6. “Concerns”

Compared to Non-*AA* Alternatives

“Object pools and factories serve to reduce overhead caused by allocating memory; so why aren’t these other approaches as good (if not better) alternatives to allocators?”

6. “Concerns”

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- Memory allocation is reduced, not obviated, and only in certain cases.

6. “Concerns”

Compared to Non-*AA* Alternatives

“Object pools and factories serve to reduce overhead caused by allocating memory; so why aren’t these other approaches as good (if not better) alternatives to allocators?”

- Memory allocation is reduced, not obviated, and only in certain cases.
- Do moving vans eliminate the need for furniture companies?

6. “Concerns”

Compared to Non-*AA* Alternatives

Object pools are ***<u>not</u>*** replacements for allocators.

1. Object pools are not faster than allocators.
2. They are at different levels of abstraction:
   – Object pools minimize construction/destruction
   – Memory pools minimize allocation/deallocation
3. Object pools are created using memory pools
4. Object pools themselves should naturally be *AA*
   – That way they *too* can enjoy the *collateral benefits*!

End of Section

Discussion?

6. “Concerns”

End of Section

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Allocator-Aware Software Infrastructure (*AA*SI):

- Custom memory allocation strategies' impact:
  - Performance
  - Instrumentation
  - Object placement **…**
- Historically, required bespoke data structures:
  - Long delivery time
  - Any collateral benefits cost extra
  - No reuse **…**

Conclusion

*AA*SI has real costs:

- “Fixed” engineering costs (for SI developers)
- Added operational costs
  - Documentation
  - Training
  - Developer-facing tools
  - Risk of misuse
- Resistance based on C++11-style allocators

Conclusion

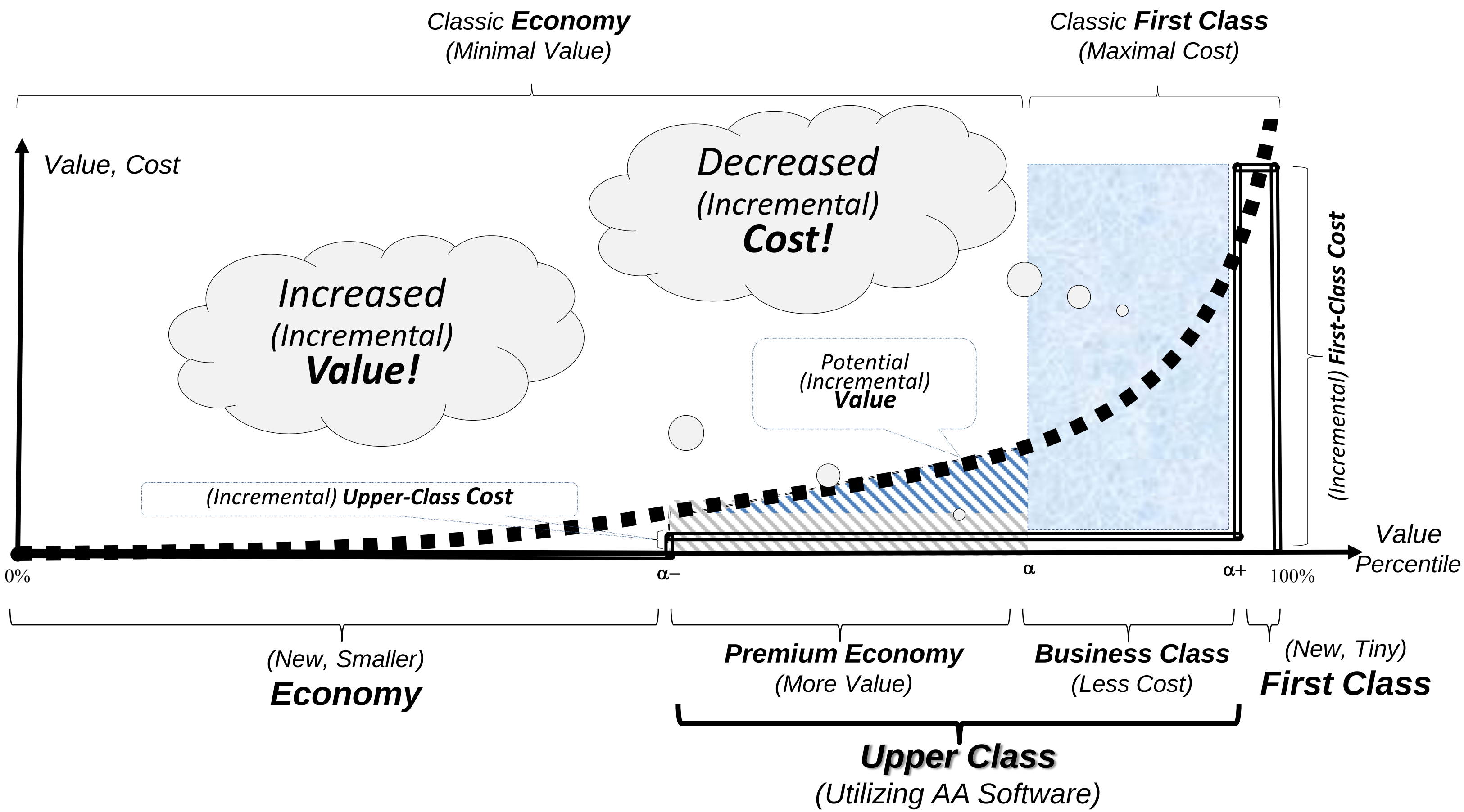
Investing in an *AA*SI is an economic decision:

- Provides nearly same runtime performance
- Lower incremental cost -> used more often
- Requires substantial up-front cost
- Comes with important collateral benefits
- C++11 experience -> “concerns” (F.U.D)

Do the benefits outweigh the costs?

Conclusion

Cost/Benefit of Utilizing Allocator-Aware (AA) Software



Conclusion

WAIT!!

Conclusion

WAIT!!

What if ***BB20V*** could eliminate ***<u>all</u>*** *fixed* costs ***entirely?***

Conclusion

WAIT!!

What if ***BB20V*** could eliminate ***all*** *fixed* costs ***entirely?***

Now what do you say?

Conclusion

Should we (e.g., Bloomberg) invest in *AA*SI?

➔ How can we afford not to?! 🡐

- The user benefits outweigh the costs *<u>now</u>*!

Conclusion

Should we (e.g., Bloomberg) invest in *AA*SI?

➔ **How can we afford not to?!** 🡐

- The user benefits outweigh the costs *now*!

What about BB20V?

- Eliminates (SI-library) “fixed” costs ***entirely!***
  - Analogous to self-driving car technology

Conclusion

Should we (e.g., Bloomberg) invest in *AA*SI?

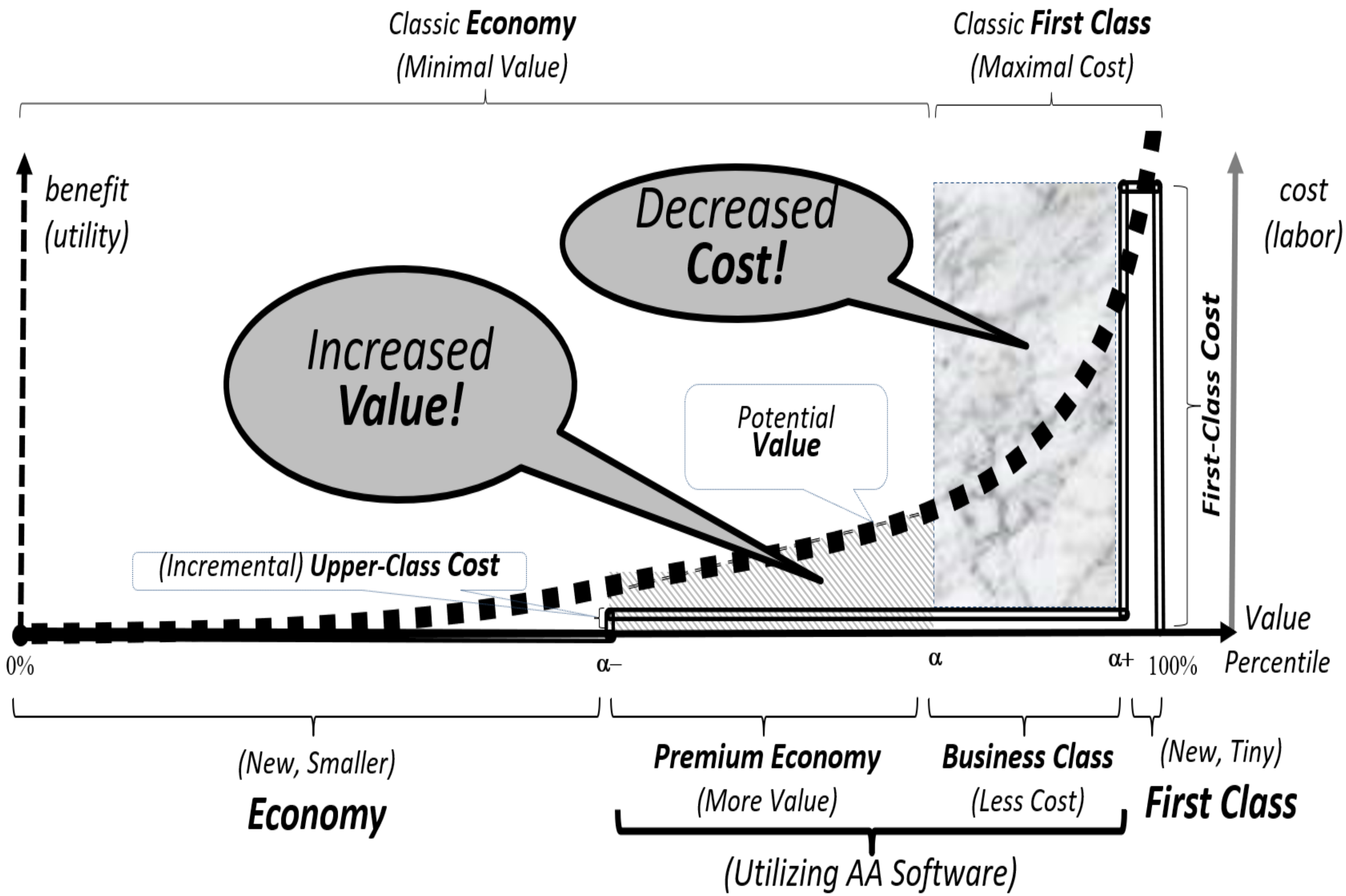
➔ How can we afford not to?! 🡐

- The user benefits outweigh the costs *<u>now</u>*!

What about BB20V?

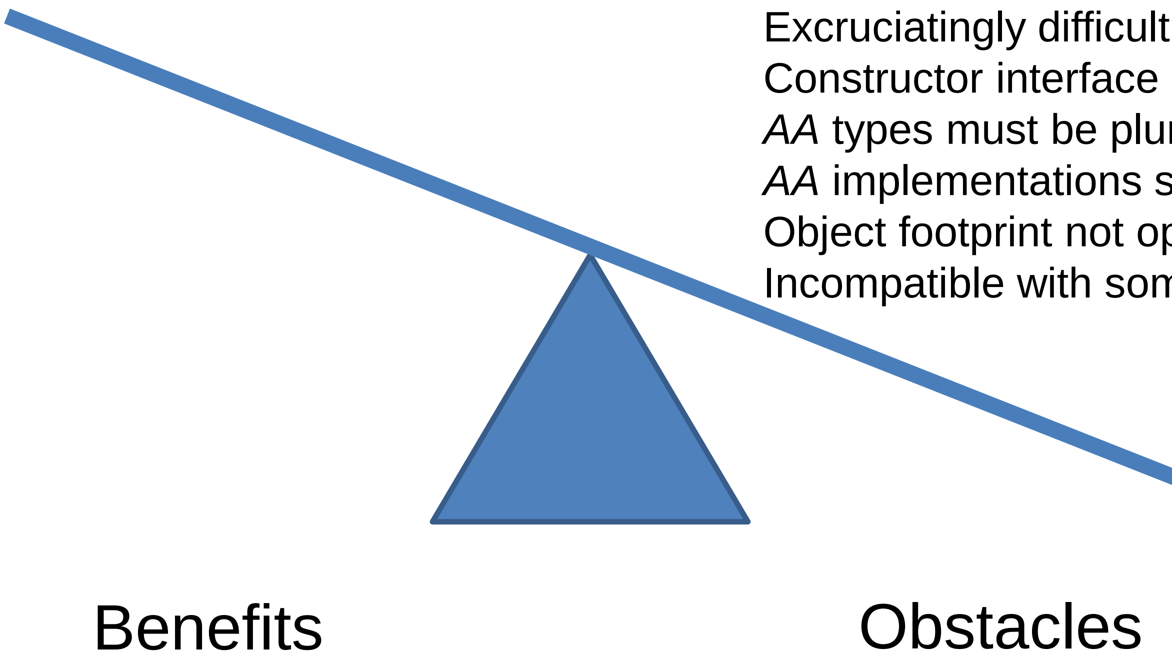
- Eliminates (SI-library) "fixed" costs ***<u>entirely</u>!***
  - Analogous to self-driving car technology
- Reduces (client) "use" costs to ***<u>bare minimum</u>***
  - Akin to using virtual functions in C++ today

Conclusion


Classic **Economy**
(Minimal Value)
Classic **First Class**
(Maximal Cost)
benefit
(utility)
cost
(labor)
Decreased
Cost!
Increased
Value!
Potential
Value
(Incremental) **Upper-Class Cost**
First-Class Cost
Value
Percentile
0%
α–
α
α+
100%
(New, Smaller)
Economy
Premium Economy
(More Value)
Business Class
(Less Cost)
(New, Tiny)
First Class
(Utilizing AA Software)

C++98/03 allocators

Incomplete specification
Non-portable support for stateful allocators
Inadequate interoperability at scale
Excruciatingly difficult to write
Constructor interface bloat
AA types must be plumbed manually
AA implementations subject to human error
Object footprint not optimized by compiler
Incompatible with some C++ features



C++11 allocators

Runtime performance
Scoped allocator model
Localized (“arena”) object memory
Entire-object placement in memory
Per-object metrics/measurement

Inadequate interoperability at scale
Difficult to write
Constructor interface bloat
AA types must be plumbed manually
AA implementations subject to human error
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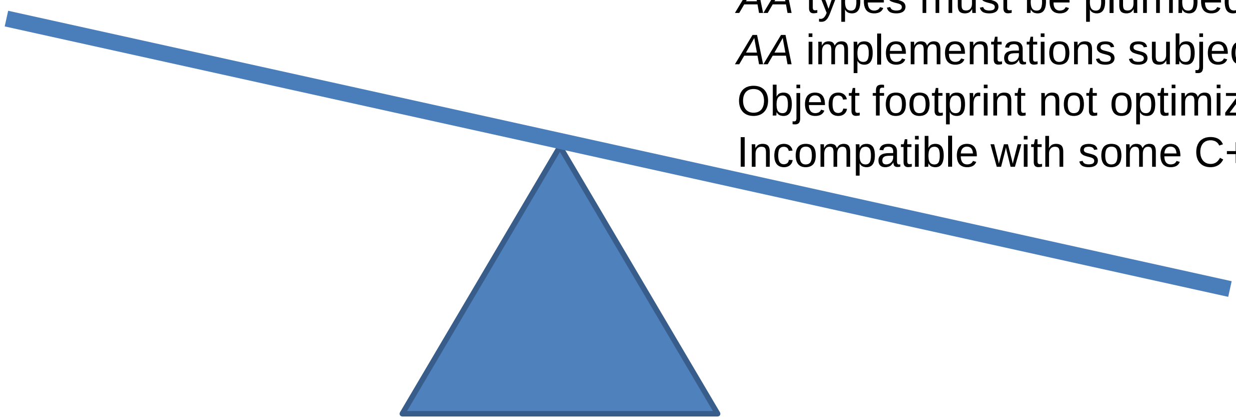

Benefits

Obstacles

C++17/20 allocators

Runtime performance
Scoped allocator model
Localized (“arena”) object memory
Entire-object placement in memory
Per-object metrics/measurement
Ubiquitous vocabulary types (handles)
Simple (to write/use) allocators
Rapid prototyping (e.g., `pmr` containers)
Predefined resources (e.g., `monotonic`)

Constructor interface bloat
AA types must be plumbed manually
AA implementations subject to human error
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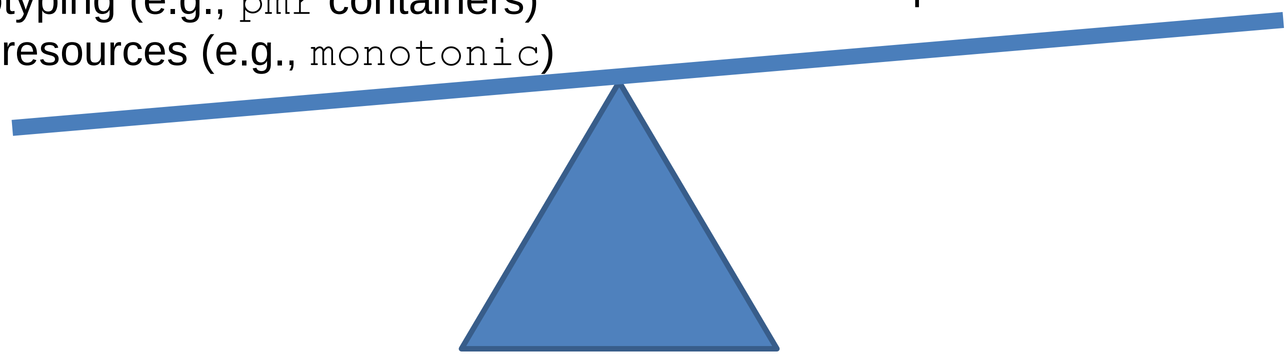


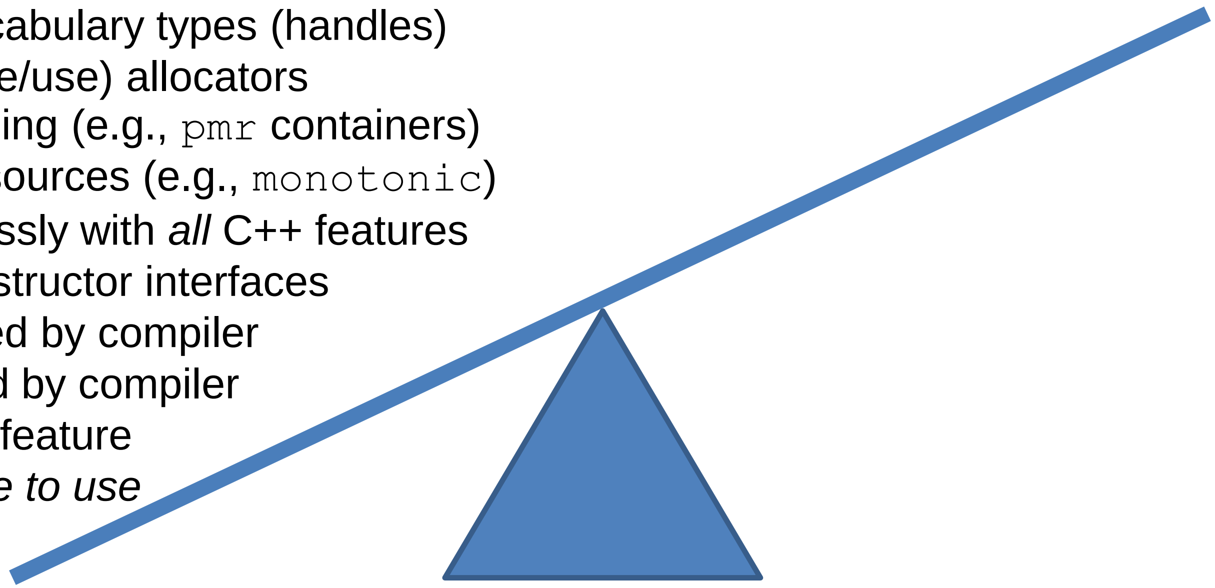
Benefits

Obstacles

Our Goal (Not Yet Realized)

Runtime performance
Scoped allocator model
Localized (“arena”) object memory
Entire-object placement in memory
Per-object metrics/measurement
Ubiquitous vocabulary types (handles)
Simple (to write/use) allocators
Rapid prototyping (e.g., `pmr` containers)
Predefined resources (e.g., `monotonic`)
Works seamlessly with *all* C++ features
Simplified constructor interfaces
Fully automated by compiler
Fully optimized by compiler
Generalizable feature
A true pleasure to use

Not realized yet



Benefits

Obstacles

Conclusion

The End

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Questions?

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