Lucerne University of
Applied Sciences and Arts

HOCHSCHULE
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Engineering & Architecture

Planning applications

Where the real challenges are

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EFQM
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Agenda

- A planning system used by millions of people every day …

- How easy is it to apply a state-of-the-art planner?

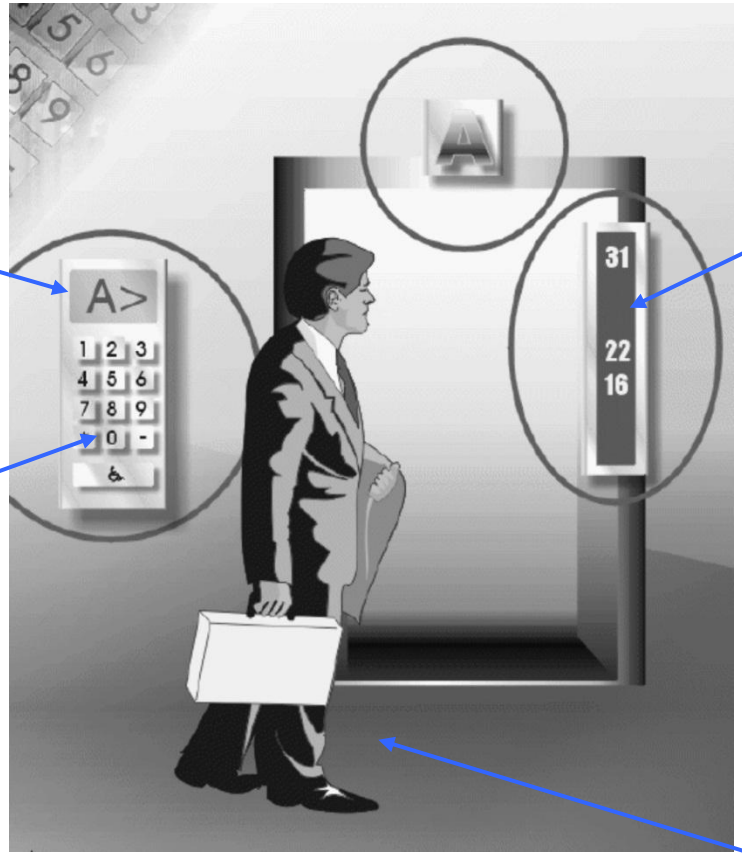
Conventional Elevator Control

1. Outside the cabin:
One or two buttons to call elevator

2. Inside the cabin:
One button per floor

1998 - 2001

Alternative: Destination Control



terminal indicates best elevator **2.**

1. passenger enters destination floor

4. destination indicator in door frame
no buttons inside cabin

3. passenger walks to elevator

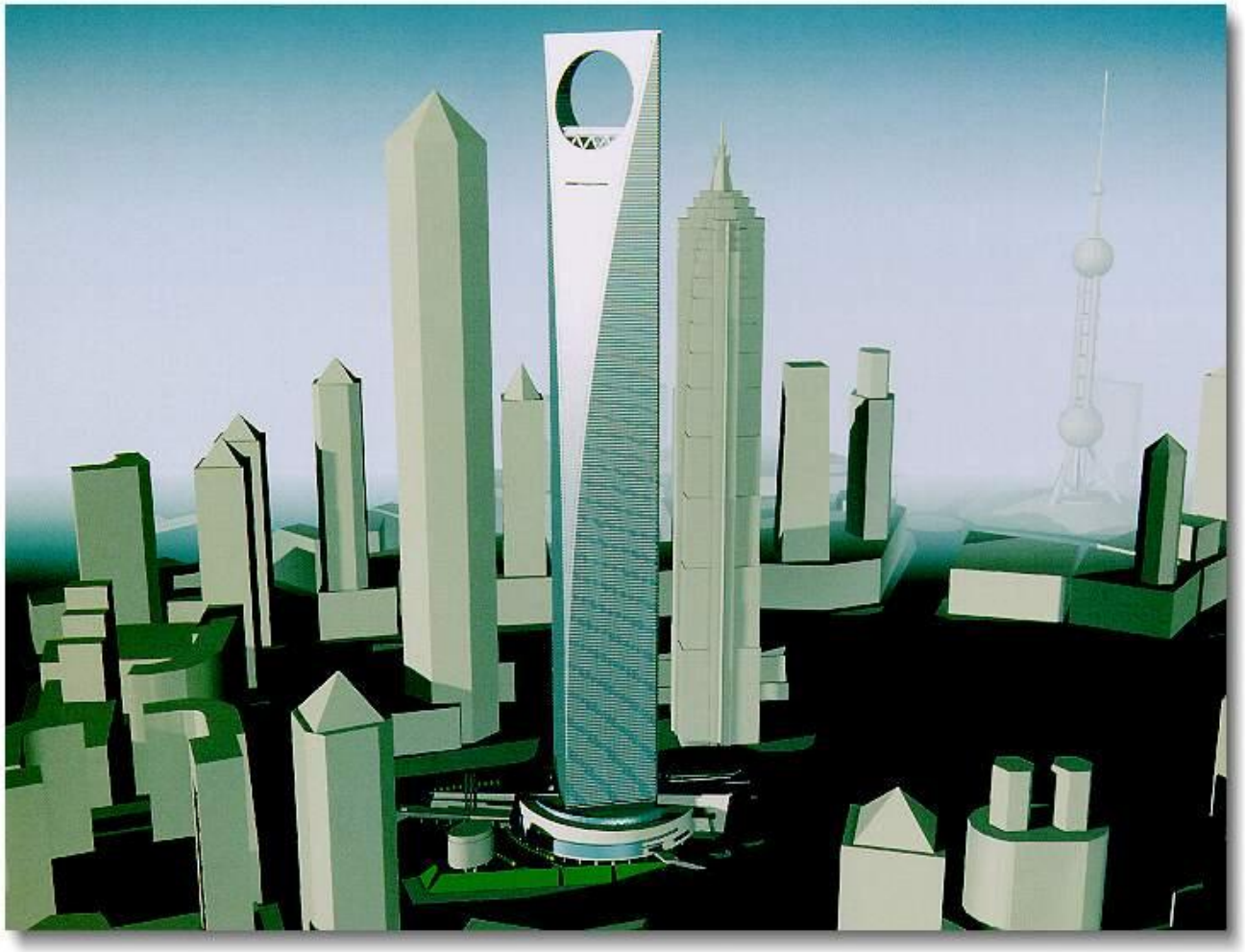
Conventional vs. Destination Control

- Press twice
- Jump on the first elevator that stops
- Conglomerate of passengers

- Press once
- Walk to designated elevator
- Separation of passengers by destination

Main Driver 1: Mixed Usage of Buildings

94-93	observation
90-61	hotel
79-56	office
55-49	hotel
55-6	office
3	shops
2	hotel lobby
1	office lobby
-1 to -3	parking

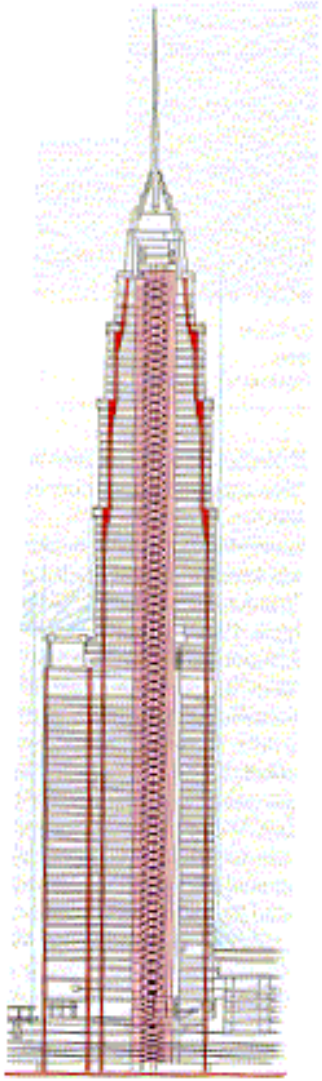


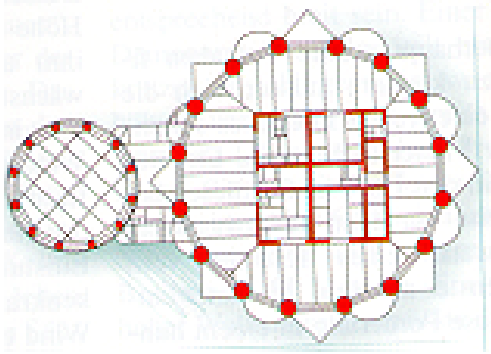
WTB

Shanghai World Financial Center
Illustration: Mori Building Co. Ltd., Japan

Main Driver 2: Increase Customer Value

- Less space
- Less energy costs
- Higher performance
  - Less waiting time
  - Faster traveling
  - More direct travels
- Diversification of products
  - New services
  - Customization





New User Interfaces

Schindler LIFTLOC®
Lift Security Systems

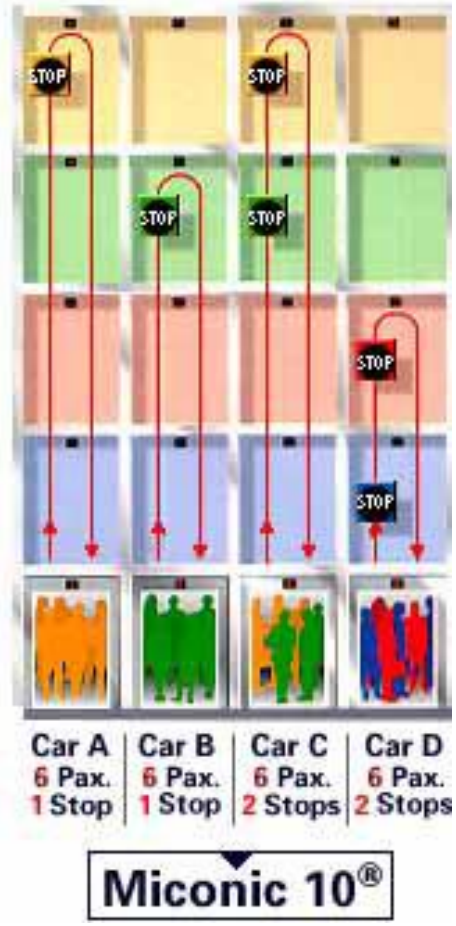
New Products

- Individual **space requirements**
- Desired **travel direction**
- **VIP service** depending on status and traffic situation
- **Access restrictions** to zones in building
- **Separation** of passenger groups
- **Multi-deck** elevators

Schindler's First Destination Control Algorithm

- Each elevator submits an offer
  - Serve new passenger as early as possible
  - Rule-based allocation scheme
- Terminal selects "less-disturbed" car

- **Impossible to add new services**



The Problem

- **Simple rule-based allocations fail**

☞ Transportation performance decreases heavily

☞ Rule set becomes complicated and incomprehensible

☞ State space explodes, impossible to enumerate it explicitly

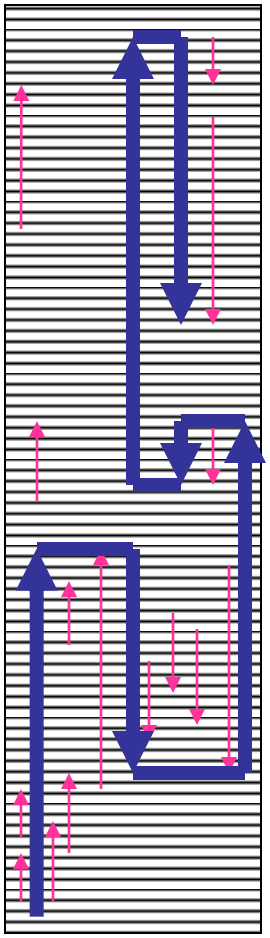
- **New solution should be configuration free**

☞ Varying hardware configurations and frequently changing customer needs

☞ Develop modular software architecture

☞ Do not program control in advance, but compute it online

«Aktions» of Elevators



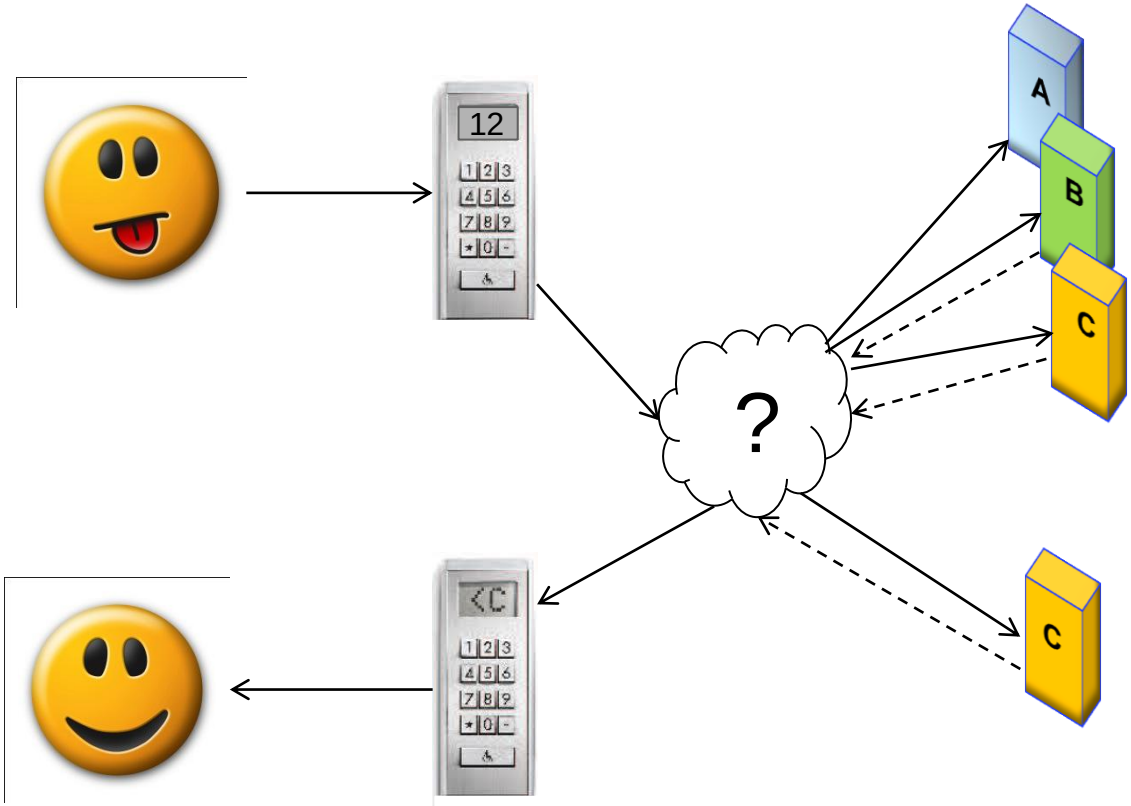
- Stop at floor
- Open door
- Close door
- Move up/down (2 – 10 meters/s)

- 0 - 3 - 5 - 7 - 4 - 9 …

- 10^{10} - 10^{12} states
- Find optimal sequence in <100 ms
  - Minimal waiting and traveling times
  - Guarantee additional constraints

How does it Work?

Technology 1: Run an auction
Technology 2: Search for an optimal sequence of stops



Ask car planners for offers and compare

Select best car and request confirmation

A Behavioral Model of Passengers

- Waiting passengers enter as soon as the elevator reaches their entry floor

- Boarded passengers leave as soon as the elevator reaches their destination floor
  - Behavior of passengers cannot be planned
    - ☞ Non-selective boarding!
    - ☞ Boarding and leaving of passengers as side-effects of elevator behavior

- Algorithm enumerates possible actions of the elevator and determines their impact on passengers according to the behavioral model

The Planning Offline Problem

initial state:

set of destination calls with status information
“<31,5,Waiting>”, “<15,2,Boarded>”

position of car

goal:

carry all passengers to their destination

actions:

stop at floors, open/close doors, move up/down

☞ wanted: optimal sequence of stops

☞NP-hard, TSP-variant, feedback vertex set, point-to-point pairwise connection

The Search Algorithm

- Systematic, depth-first search
  - Branch-and-bound
  - Optimization criteria encoded in heuristic function
  - Forward checking to propagate constraints over non-expanded states
  - Domain-specific state space encoding (“tuned” data structures)

- 200.000 states per second can be expanded when all constraints need to be checked

- State size: 10^{10} - 10^{12} states
  - Practice: 1000 -2000 states explored until optimum found
  - Chess: 10^{40} possible positions, Go: 200^{300}

The Online Problem

- Planner solves a static traffic problem given at a certain moment in time

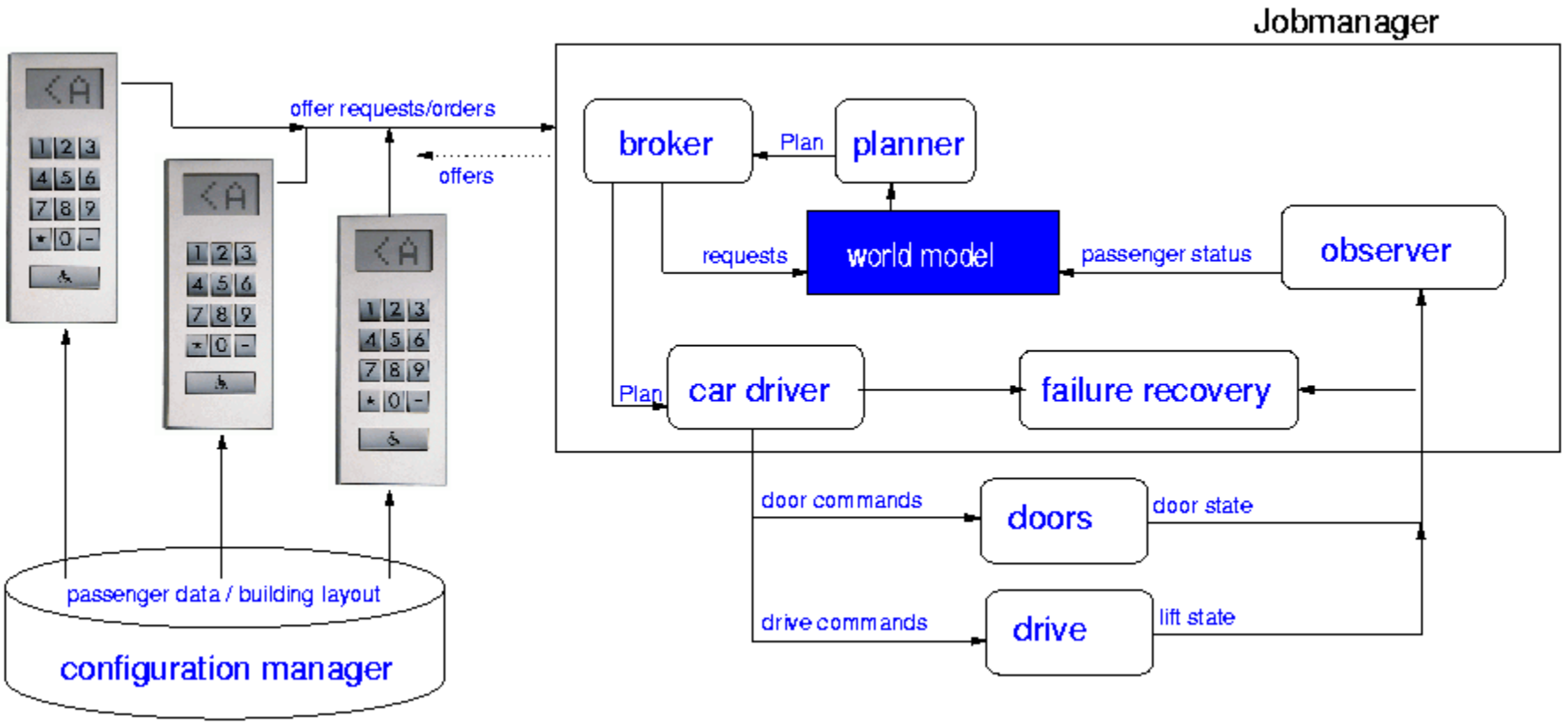
- Planning problem changes frequently
  - New passengers call
  - Passengers ‘misbehave’ (block doors, don’t register call)
  - Hardware failures can occur

☞ Each new call needs to be allocated to the ‘best’ car

☞ Plan execution needs to respond to external or planned changes

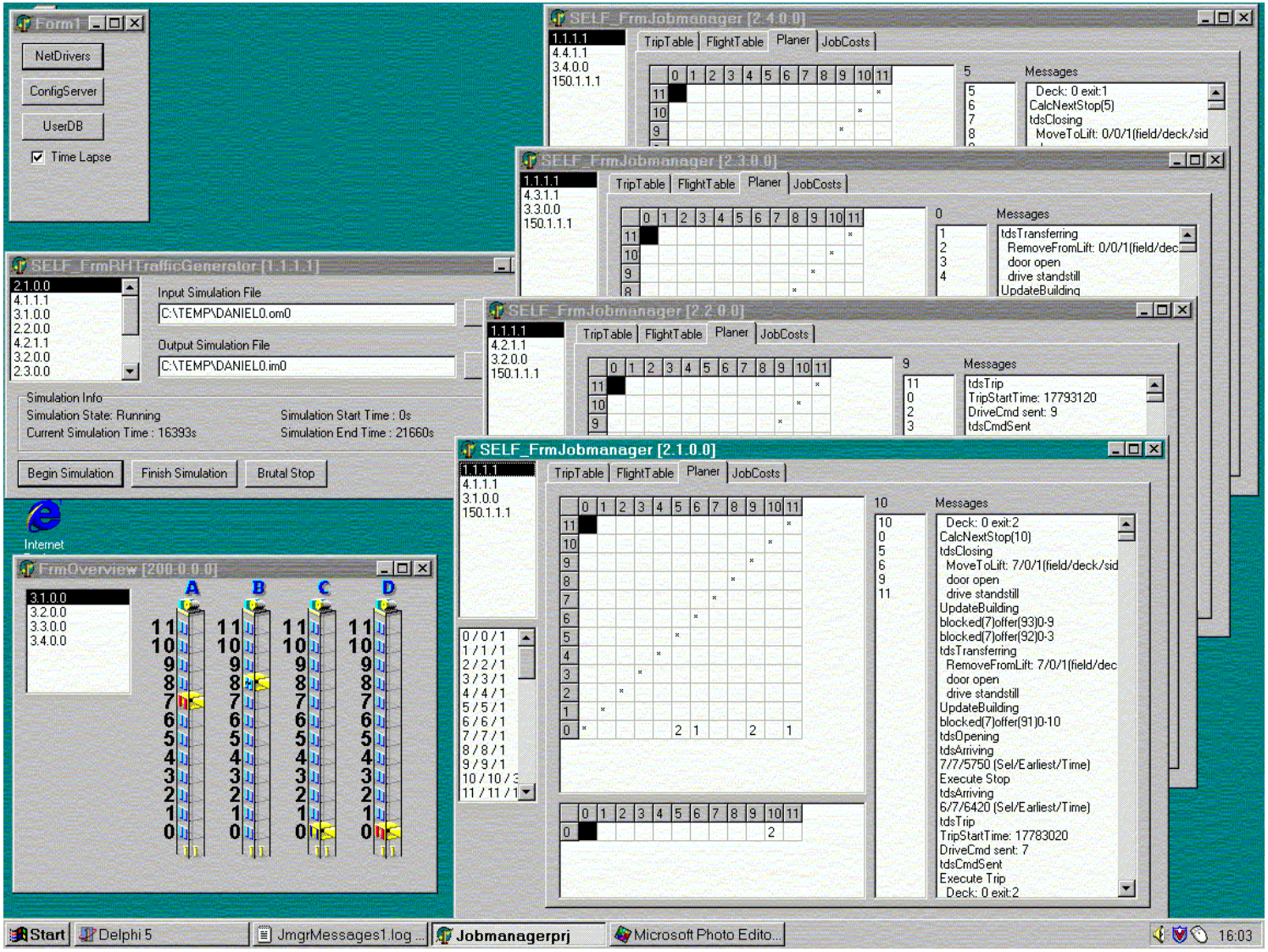
  ☞ Graceful degradation in case of technical failures

Distributed Architecture (Multi-Agent System / SOA)

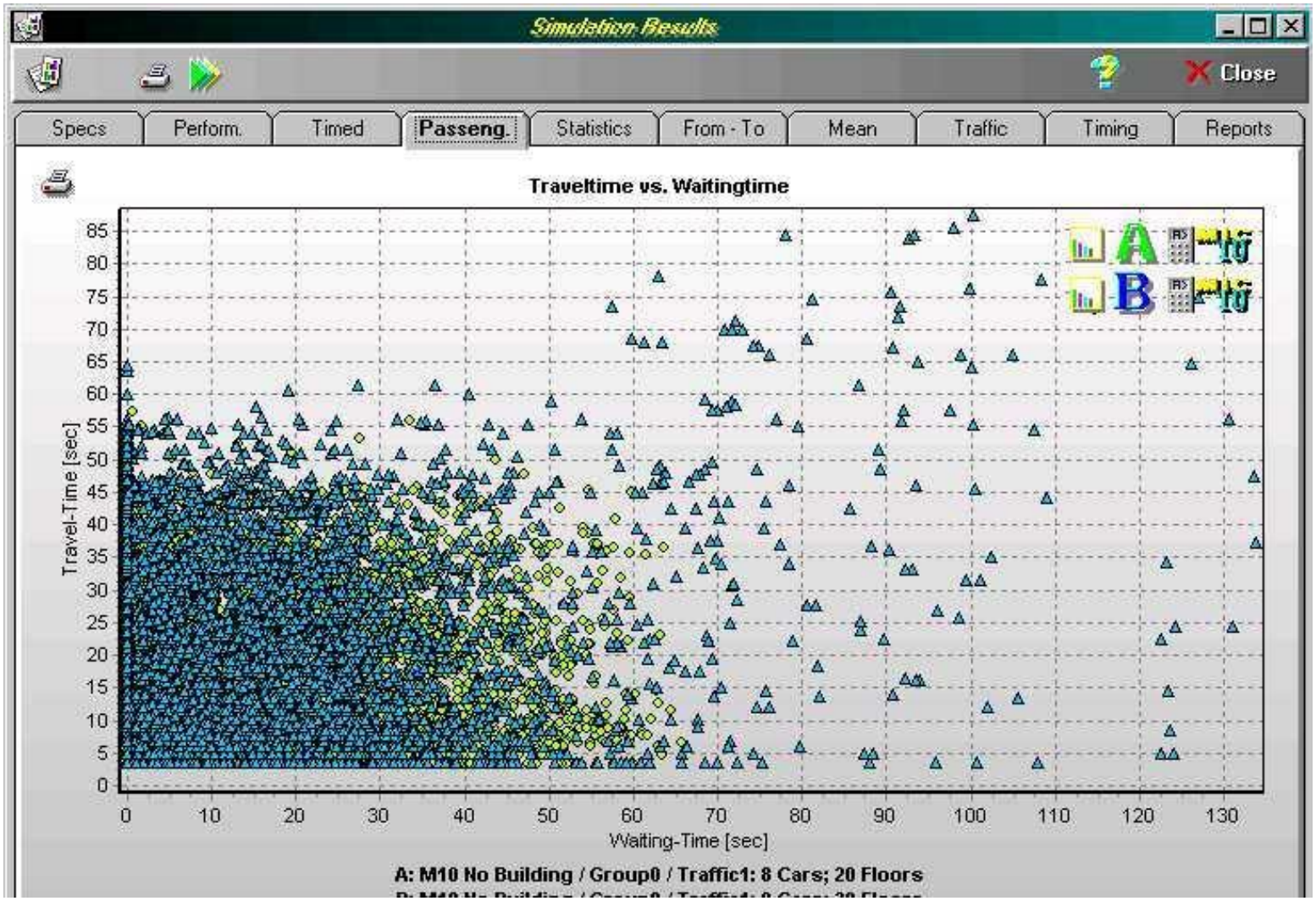


☞communication via asynchronous messaging with publish/subscribe
☞ support of adhoc networking

The Testing Environment

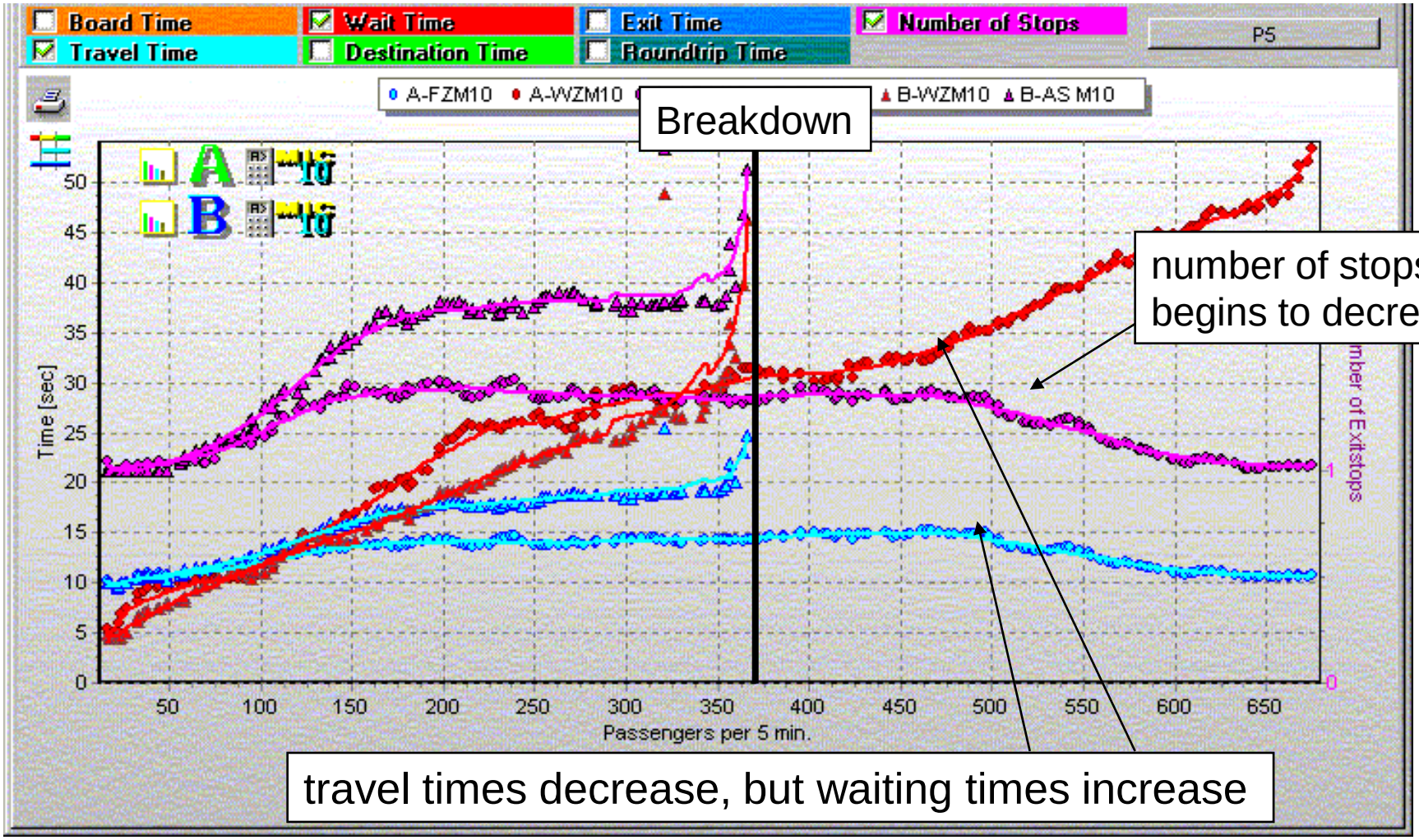


50 % Reduction of Waiting Times during Up-Peak

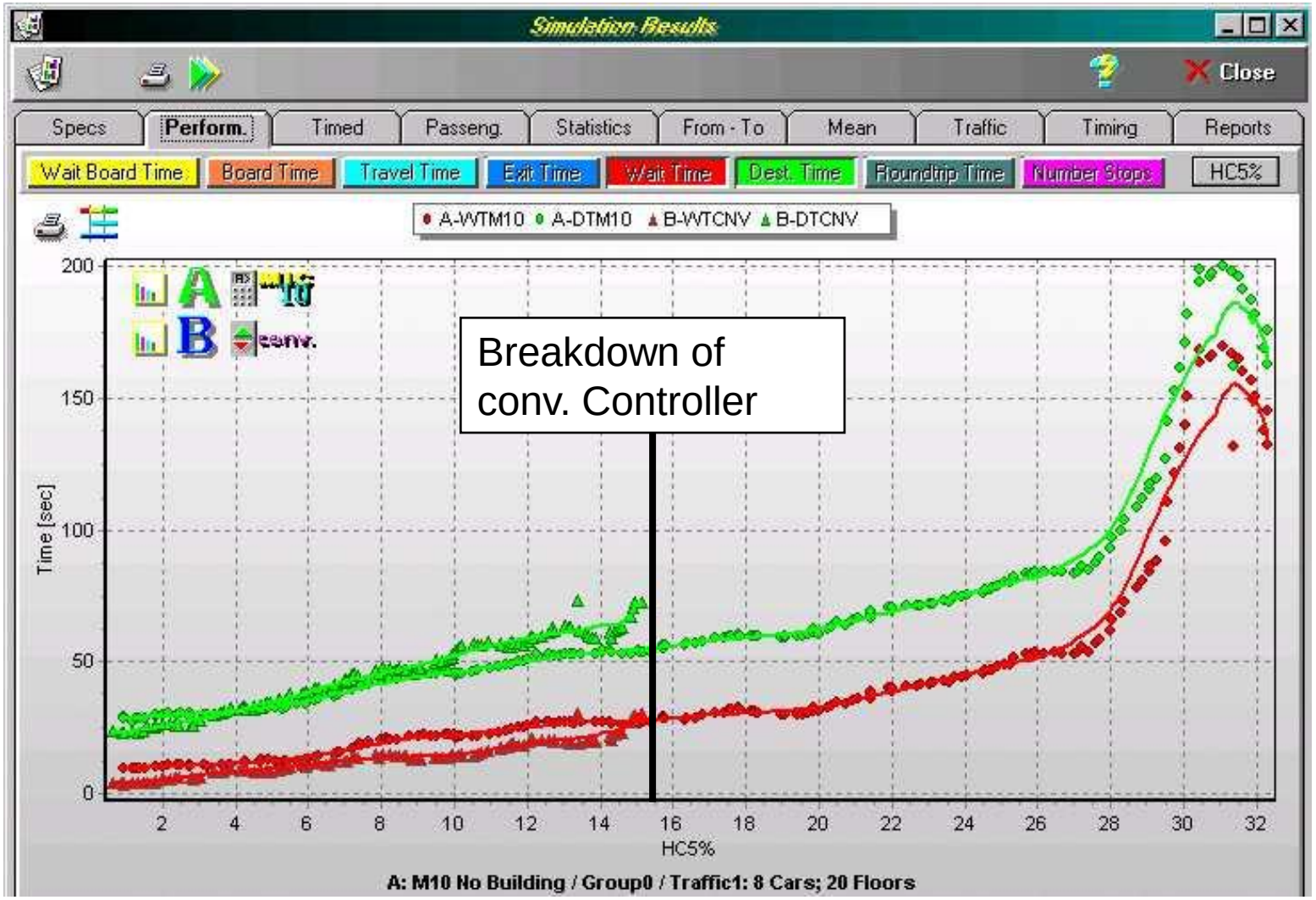


Flexible Response to High Traffic Volumes

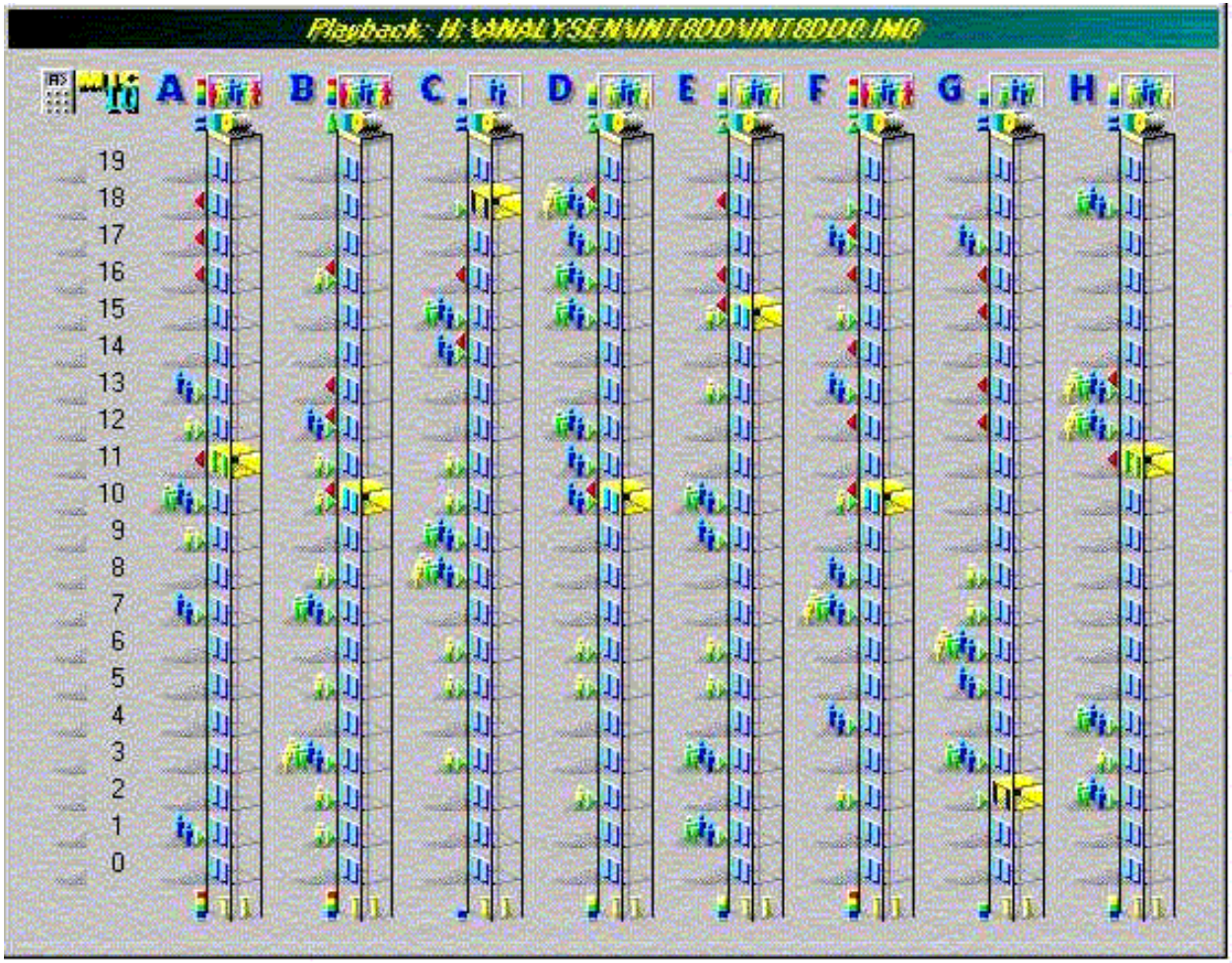
From Collecting Passengers to Shuttle Service



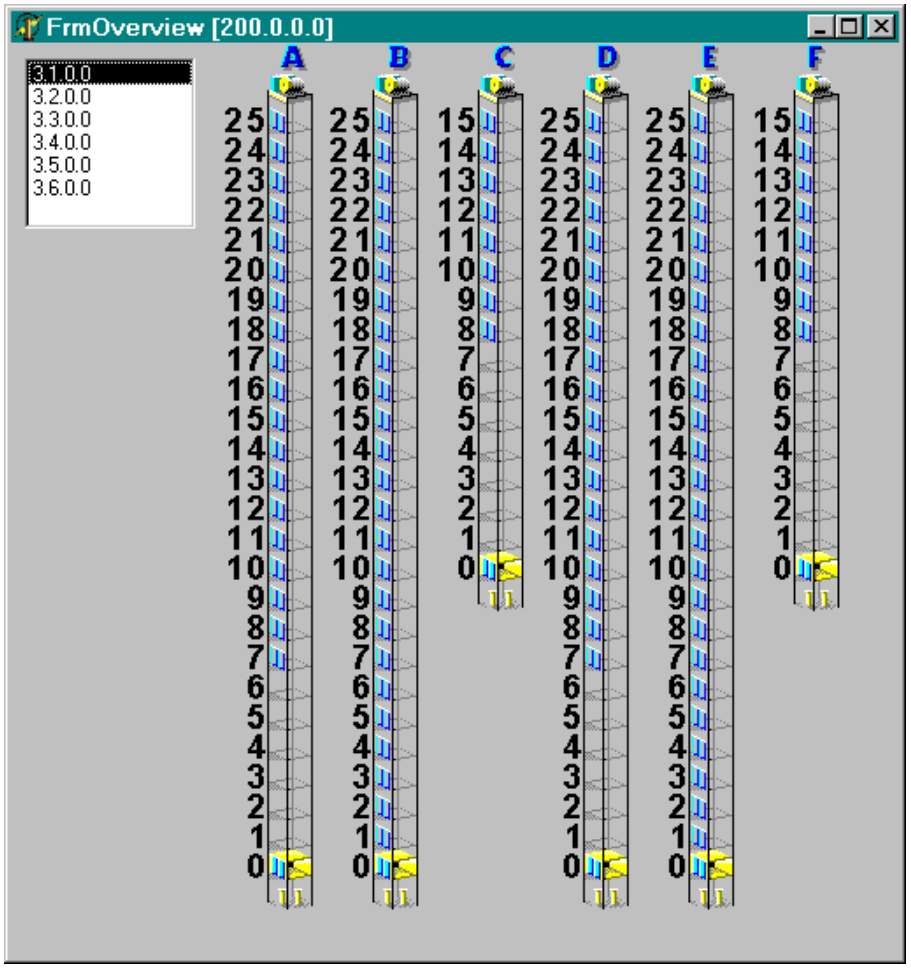
50 % Increased Capacity during an Up-Peak Pattern



Simulation Environment



AIA Tower Hongkong



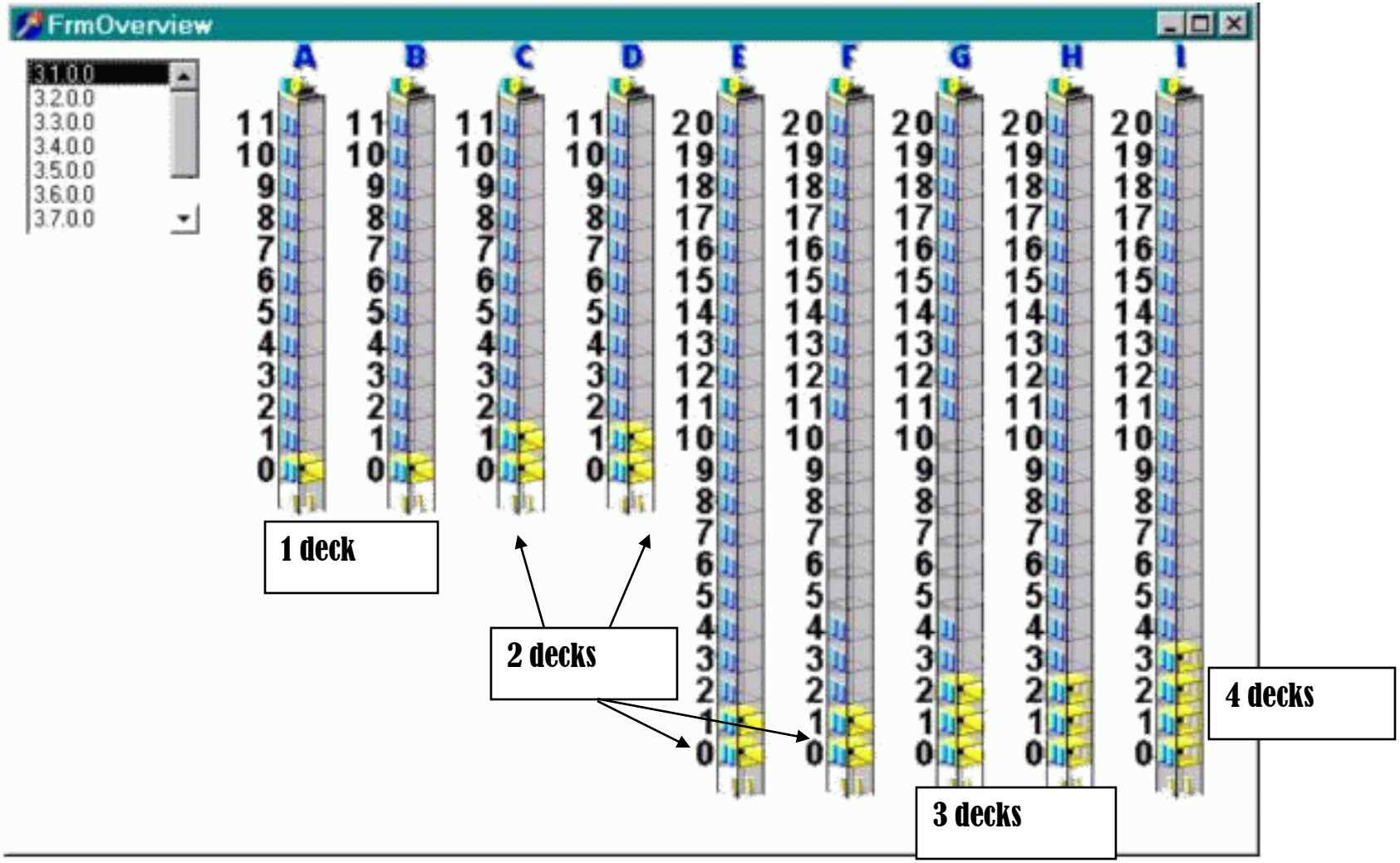
Friday, April 28, 2000

25197 calls
Peak: 1 call/s

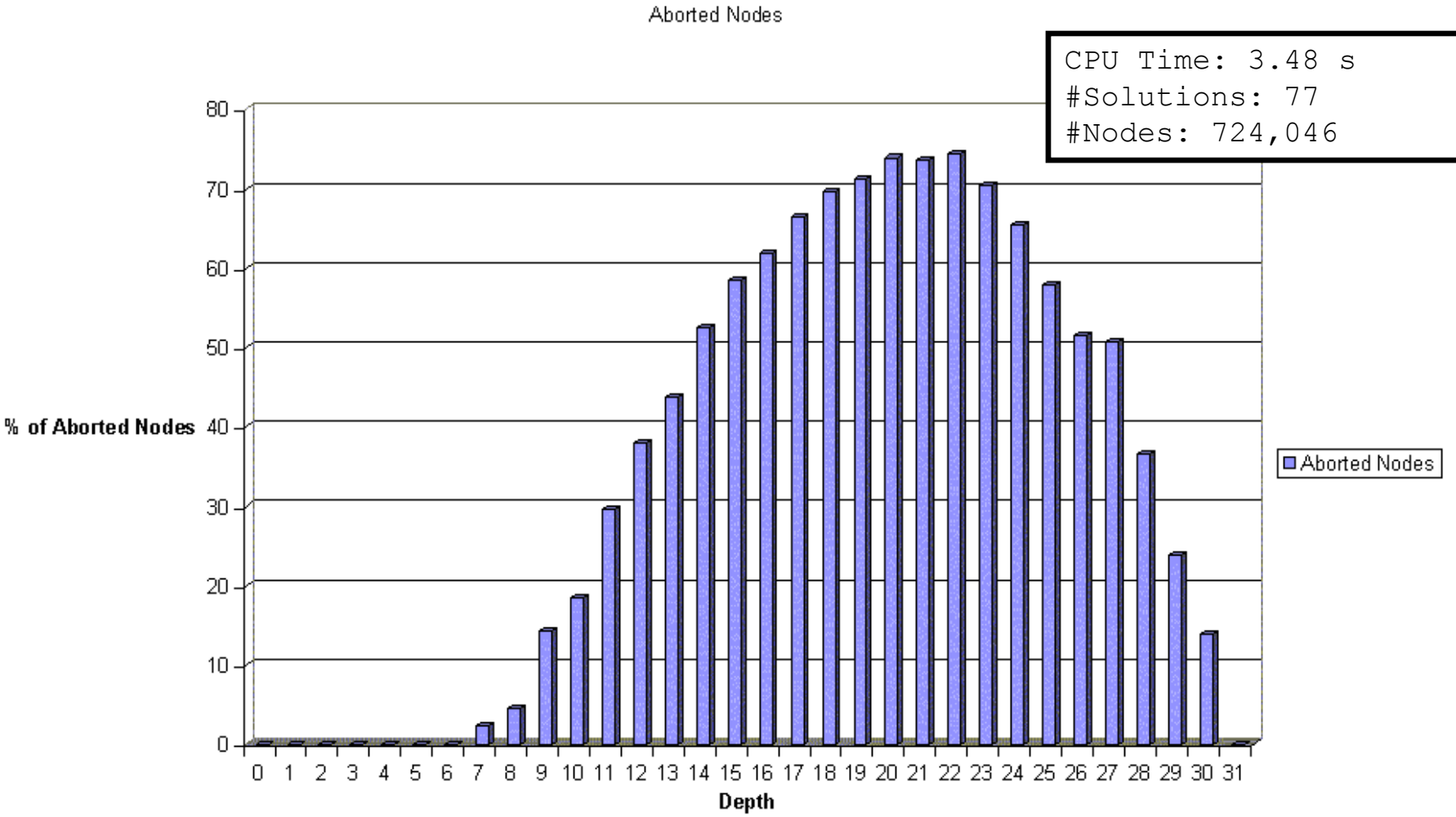
Avg.waiting time = 88.75
Avg. estination time = 144.93

new approach
Avg. waiting time = 52.06
- 58%
Avg. destination time = 87.2
- 60%

Heterogeneous Multi Decker Group

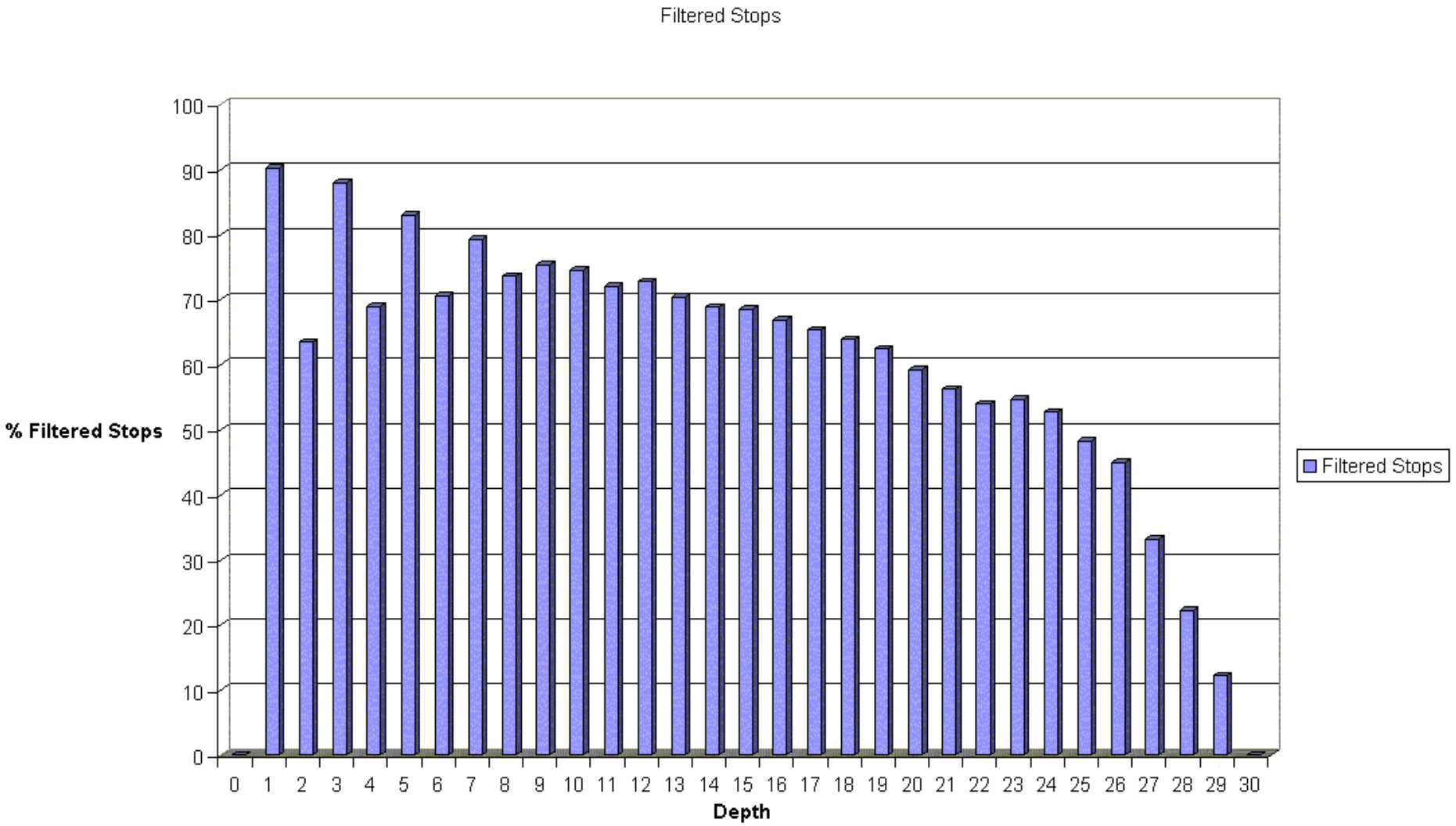


Effectiveness of the Heuristic Function



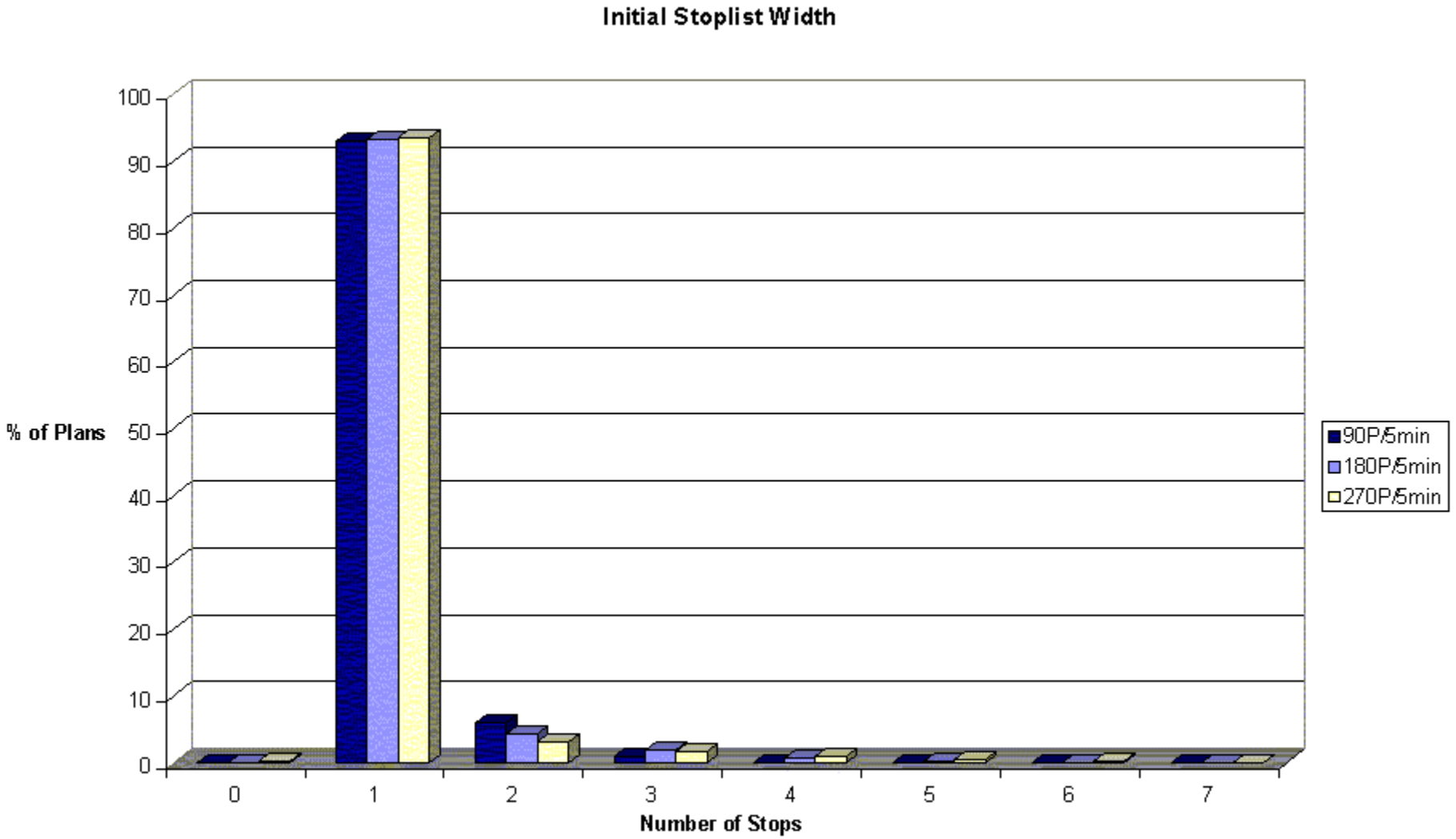
65,332 nodes out of 105,617 nodes at depth 16 (61.86 %)

Forward Checking - Travel Direction+Space

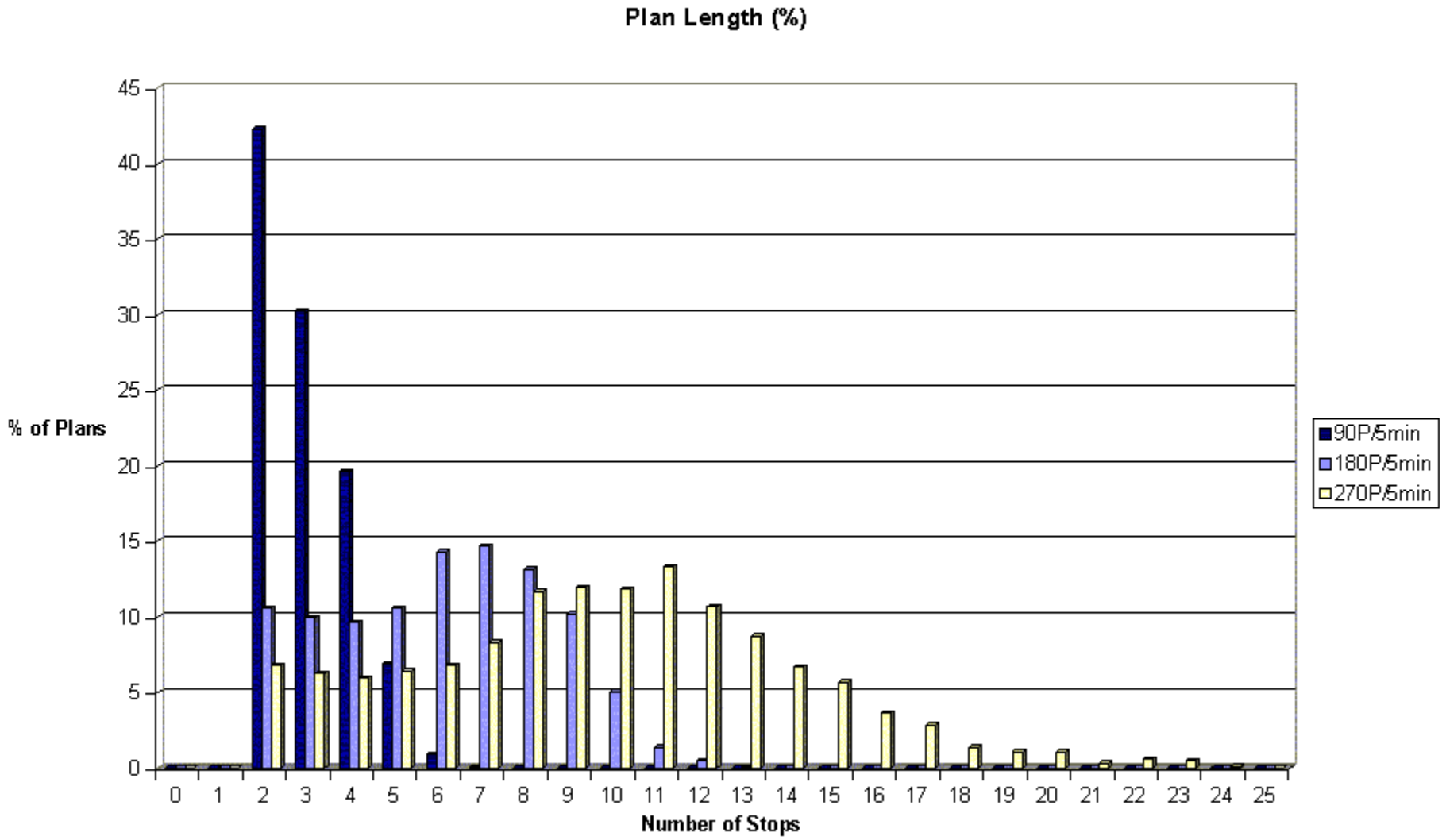


231,732 nodes out of of 336,937 nodes at depth 14 (68.78 %)

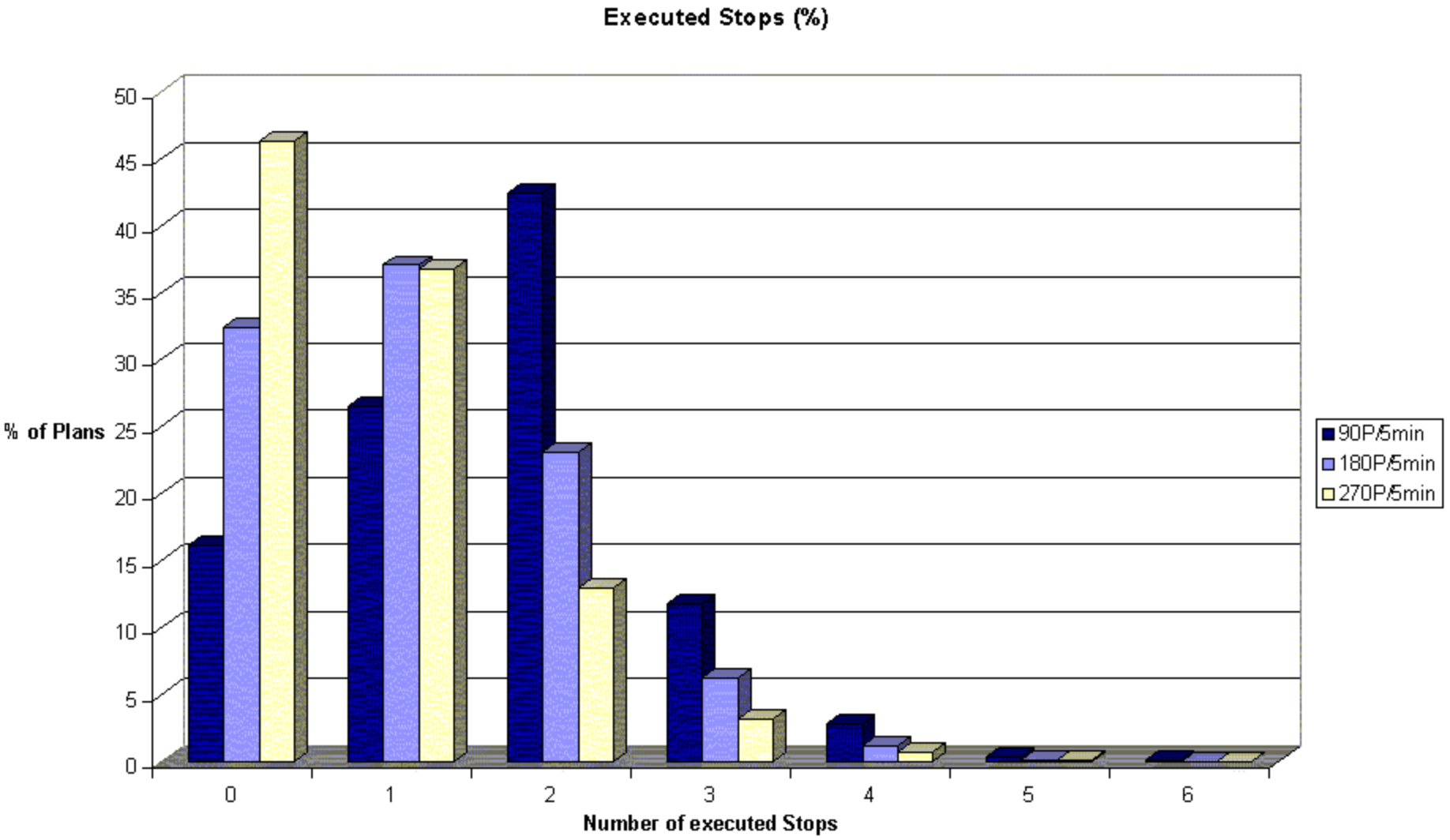
Branching Factor at the Root



Length of Plans by Traffic Intensity



Execution of Plans



Communication in 2000

SchindlerID™

SchindlerID™
- the next generation of Miconic10™

SchindlerID is an enhanced user interface paired with a control overlay, which provides access control as a core service. The basic utilization of SchindlerID follows a generic scheme:

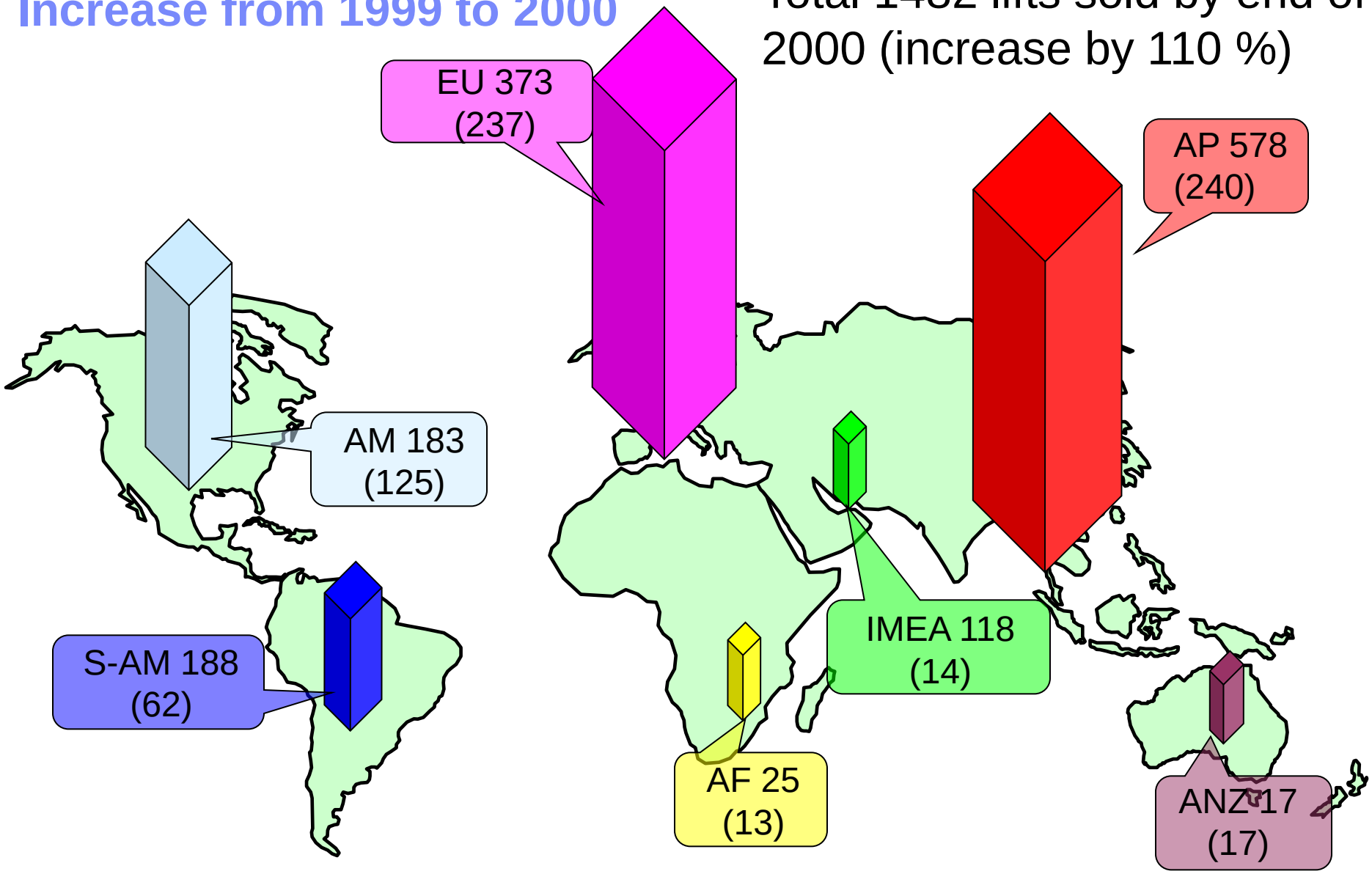
1. The passenger is identified by his identification medium or personal PIN code at a SchindlerID terminal in front of the elevator.
2. The planning algorithm checks the passenger's access rights and assigns a car (A, B, C,…) to the passenger. In doing so, the algorithm takes account of the following criteria:
   - overall traffic capacity
   - individual traveling time
   - security restrictions
   - attributes such as space required, handicapped passengers, preferences, privileges (VIP), or grouping
3. The passenger walks directly to the assigned car and will be transported to his destination without any need for further interaction.

SchindlerID™ terminal

Intended as a platform, SchindlerID allows the integration of a variety of methods and services. For example,

Increase from 1999 to 2000

Total 1482 lifts sold by end of 2000 (increase by 110 %)



In Switzerland …

Basel

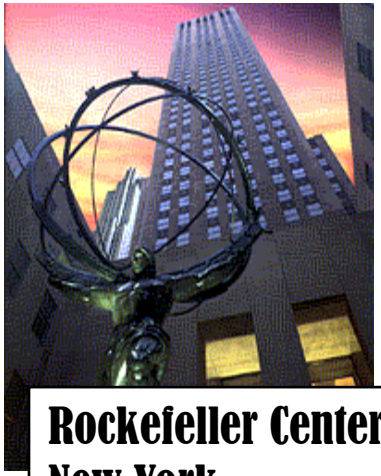
Zurich

Luzern

Other Countries

- groups of 3-8 elevators
- high populations
- new security standards
- “traffic peaks”

Metropolitan Tower
Ho Chi Minh City



Rockefeller Center
New York

Eurotheum Frankfurt

Coeur Defense Paris

Millennium Tower Vienna

Lessons Learned

- Getting the initial 1-2 actions right would be sufficient
- Sense – Plan – Execute
  - RESPOND IMMEDIATELY
  - Problem size is BOUNDED
- Each domain needs its own heuristic function
  - BUT likely also its own state representation

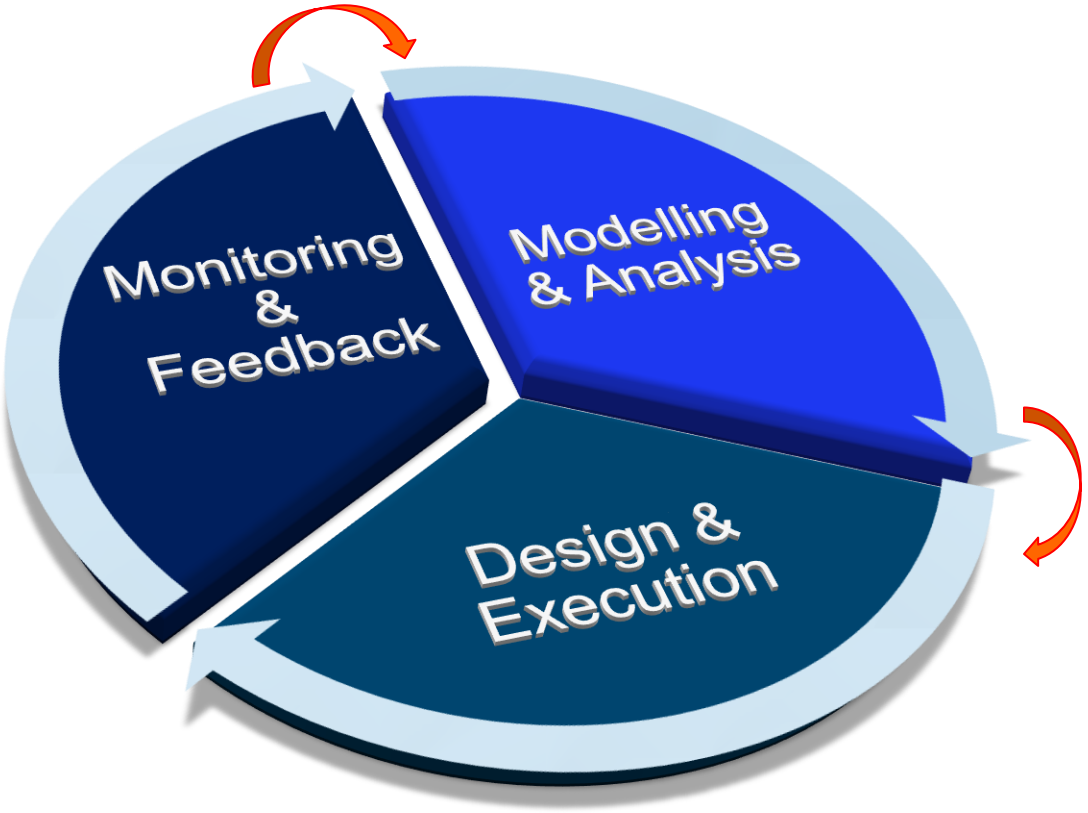
- Open system boundaries - need to integrate flexibly
- Embedding the AI component is critical to success
  - 6 months developing time for search algorithm
  - 1.5 years for the surrounding controller

10 Years Later …

How easy is it to embedd a state-of-the-art planner?

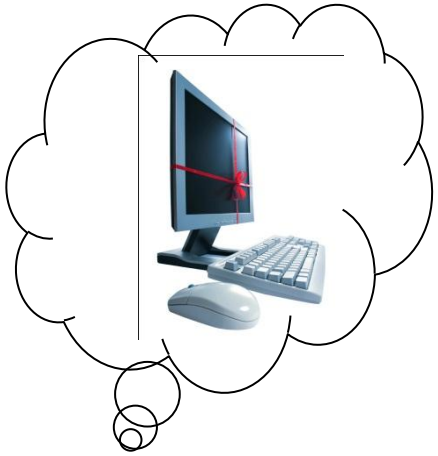
Business Prozess Management

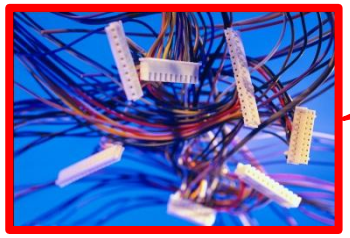
Business Intelligence



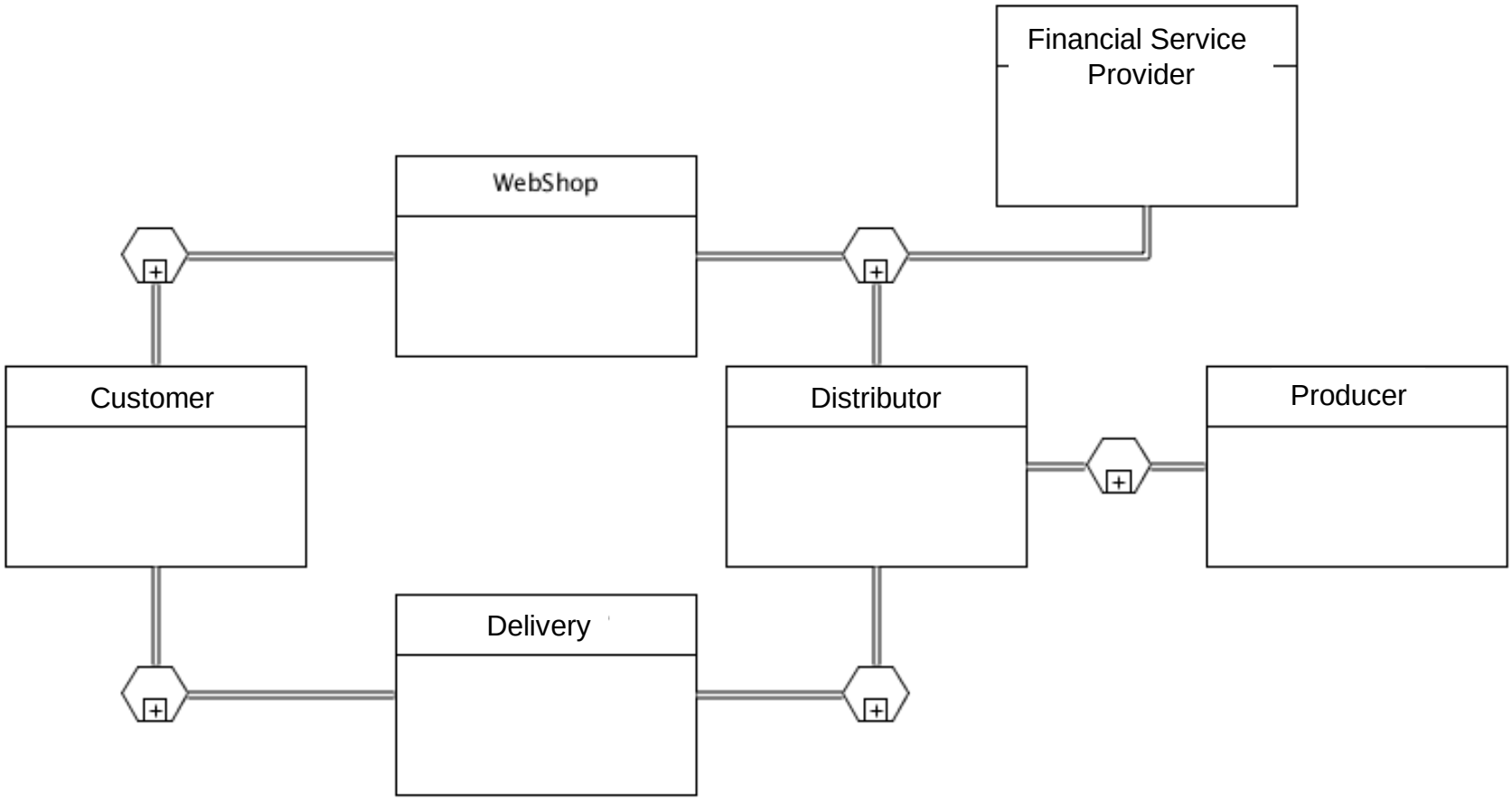
Model-Driven Software Development

An Internet Order

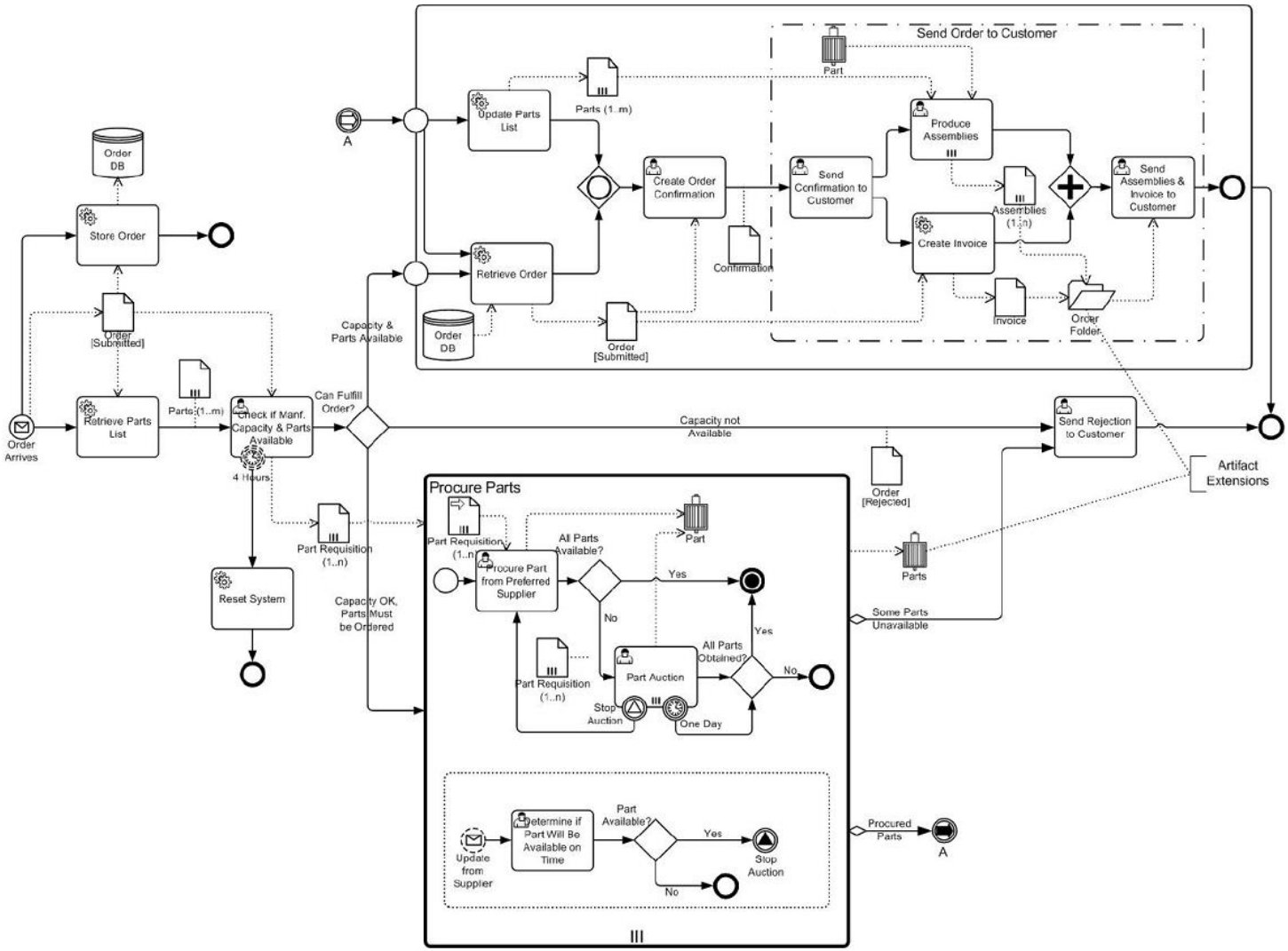




Choreography Model of Partners

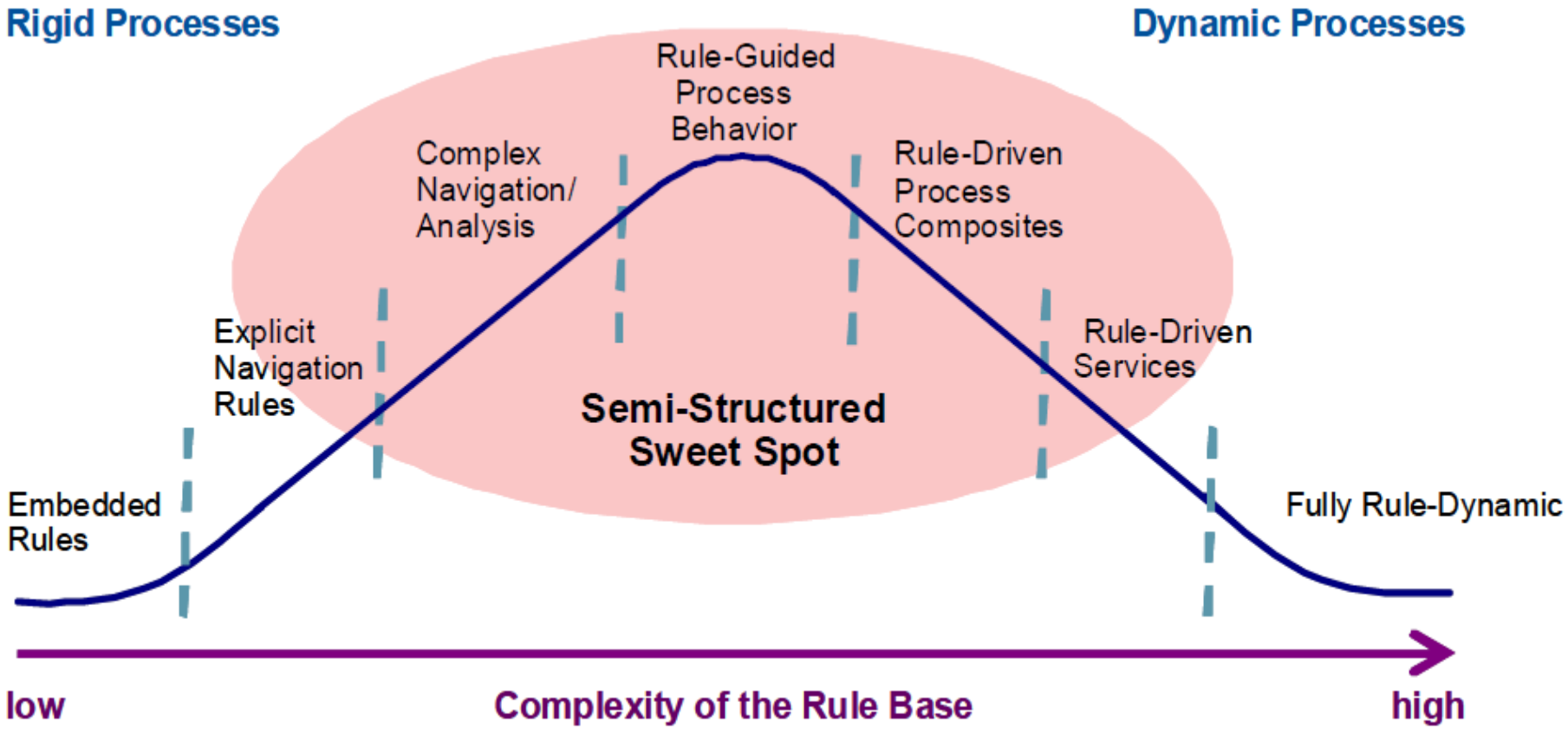


Possible Process of the Webshops



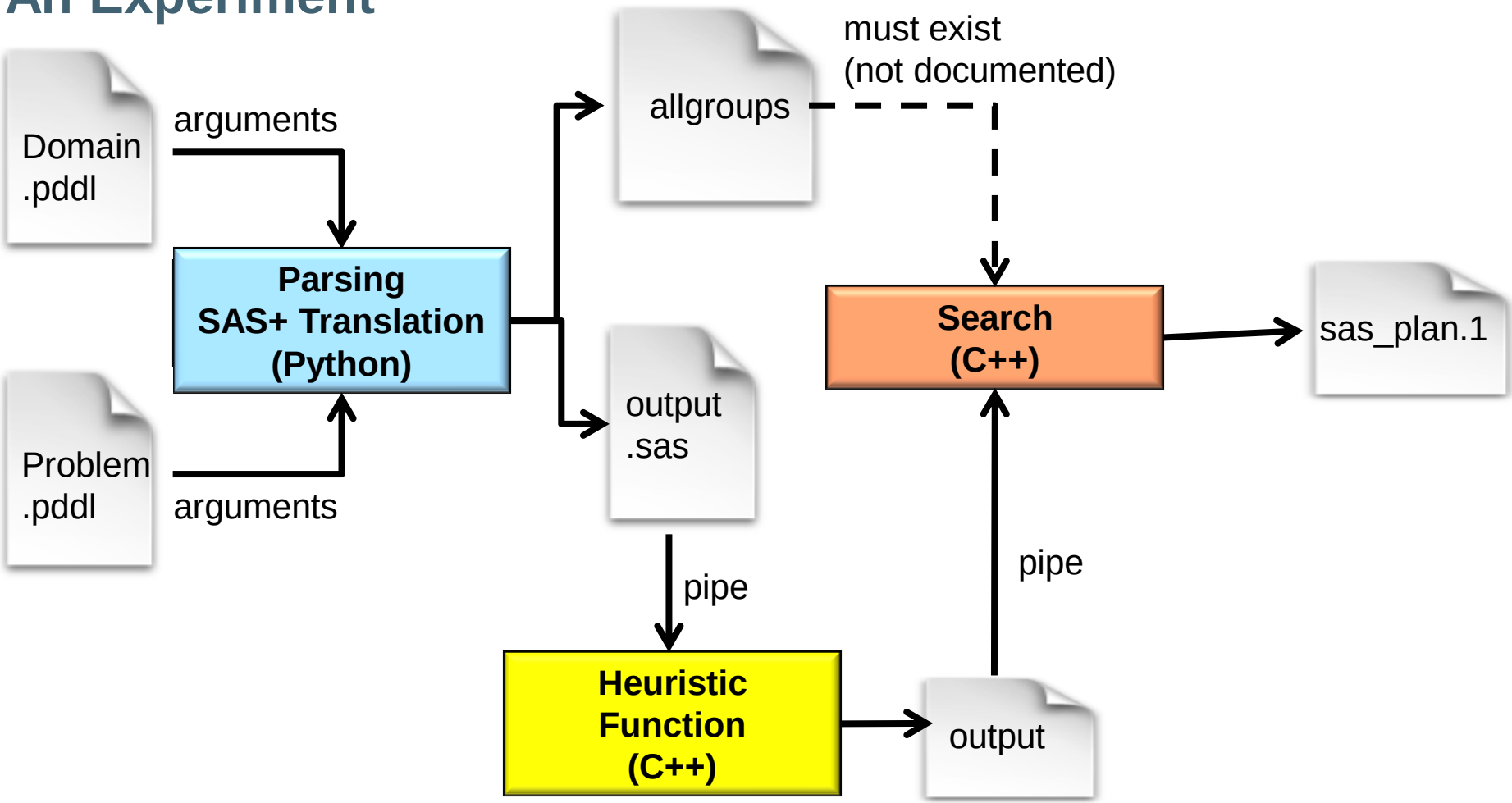
BPMN – Business Process Modell and Notation 2.0

Rules can dynamically orchestrate combinations of process components – the process becomes goal-directed



Source: Gartner (March 2009)

An Experiment



File Transfer as the integration pattern
Code mostly platform-independent

Observations

- Runtimes on IPC8-SeqSat Problems
  - Approx. 700 ms, but 52 – 60 % of time in first two modules
  - Cybersecurity: 8000 ms (95%) preprocessing vs. 400 ms search
- No API, not so easy to configure
- Need more modular architecture
  - Well-defined interfaces (eliminate file transfer, define API)
  - Clean separation of interfaces from implementation
  - Modern input/output data representations, e.g. XML would eliminate hand-written parsers

Would you Receive Academic Merit?

- Approx. 120 citations for 3 elevator publications
  - Miconic domain (Bacchus, 2001)

IBM DeveloperWorks Article on Process Anti-patterns

Date: 28 Feb 2007
Level: Intermediate
Also available in: Chinese

Activity: 10245 views
Comments: 0 (View | Add comment - Sign in)

Average rating (18 votes)
Rate this article

Compare to only 24 citations

Essential for WebSphere Process Runtime
BPM paper (LNCS) not in Harzing PoP
Extended DKE paper 34 citations
Simpler ICSOC paper 114 citations

Conclusions

- Doing real applications is fun
- Not much overlap with academic value system
- Technology transfer mostly focused on software engineering
- Does not necessarily make you rich