

OR in the South African Chemical Industry the early 1970s



Dave Evans, AECI 1971 - 1997
(and what he looked like in the
early 1970s...)

Background

- Jim Buttery; 'technical' visit to ICI, late 1970
- Harry North – ICI man on secondment – production director
- John Hudson, Dave Bromley, Alan Hawcroft, Brian Fuller, Geoff Knights, James Grant, me
- Reg Crane – ammonia plant specialist

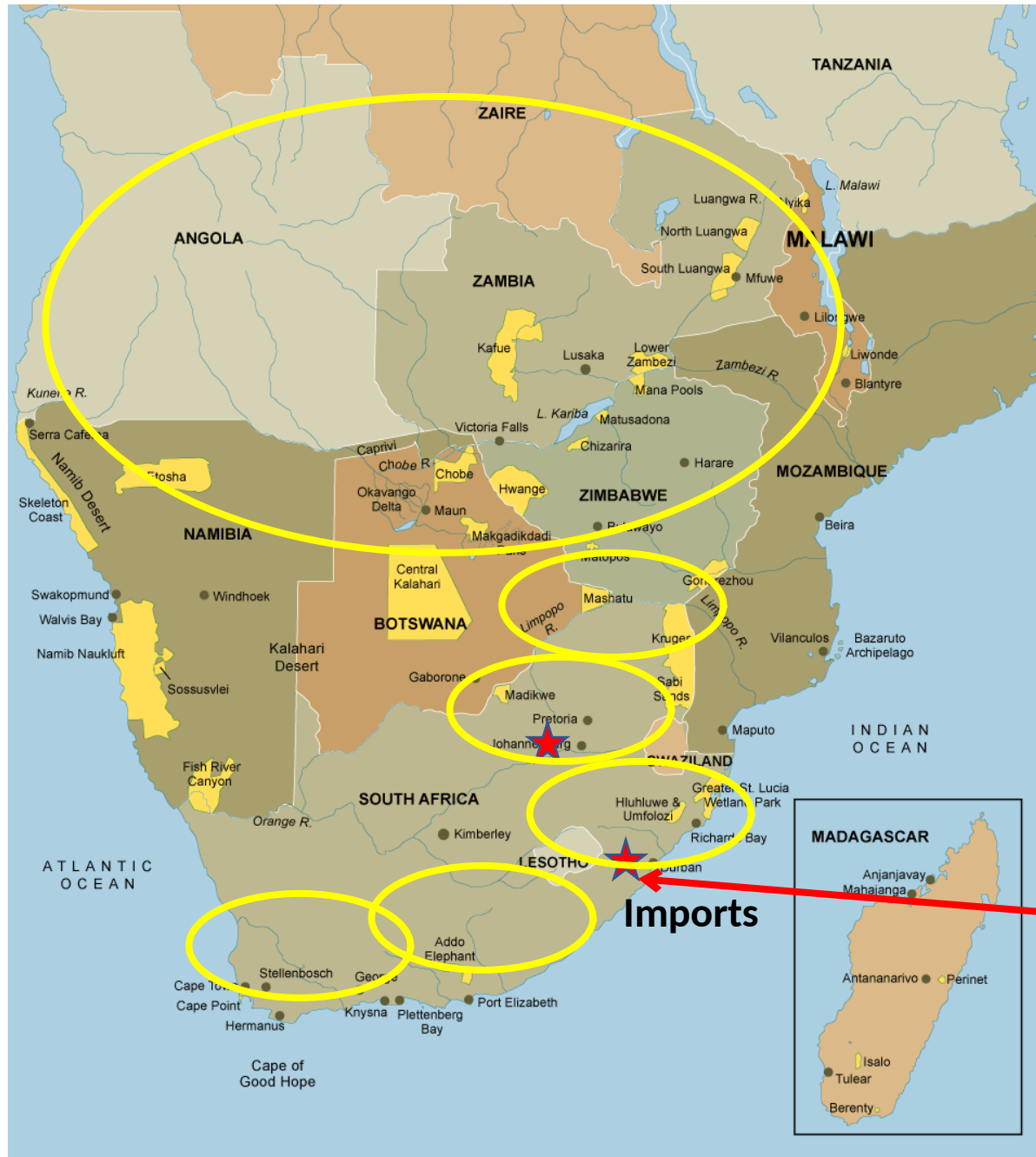
Linear Programming

- Simplex algorithm developed in the 1940s and 50s
- Constrained by computing capacity in the early days
- Anglo-American's Dedicated Data Centre
 - largest computer in Africa in 1971: half megabyte core memory
- Largest LP it could take: 800 variables, 600 equations;
 - typically took the whole machine for an hour per run...
- Variable cost analysis

AECl's "Halogens" business

- Products based on chlorine and caustic soda
- Revenue ~R5 billion p.a. in current terms
 - 2 factories
 - 25 plants
 - 15 products
 - 6 sales regions
- Models with potentially up to 3 000 equations
- Used for
 - Budgeting (monthly)
 - What Ifs (1 year)
 - Capital investment (12 years)

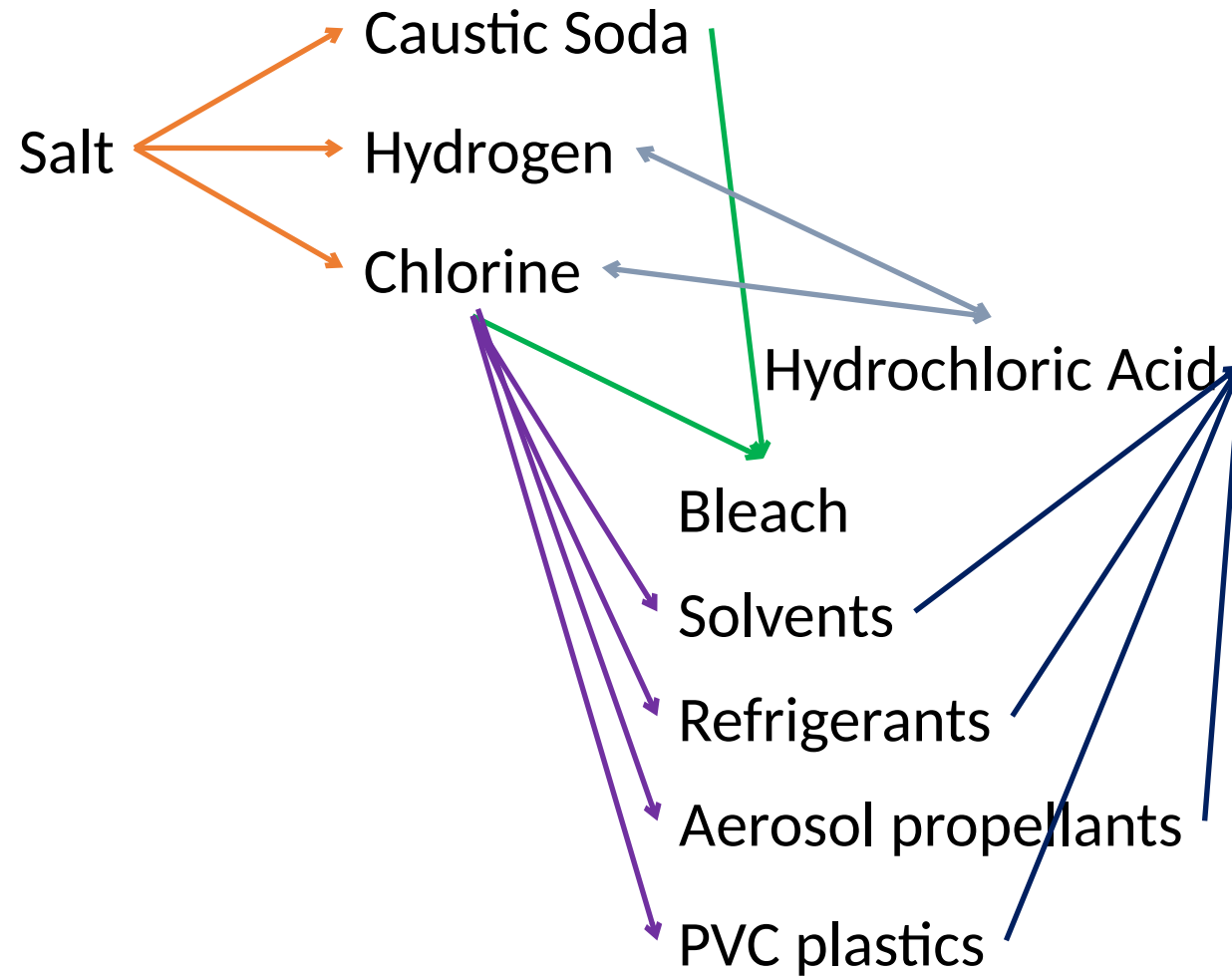
Sales Regions



Exports

Imports

Chemicals



Mass balances...

Typical equations

- Agreed coefficients...
- Plant: Tons manufactured \leq plant capacity
- Sales: Quantity sold \leq Sales demand
Quantity sold \leq amount available
- Intermediates: amount used \leq amount available
- Objective function: Maximise:
 \sum (Tons sold x Selling price)
– \sum Distribution Costs
– \sum ('Tons' raw materials x purchase price)
- Only variable costs; linear over realistic ranges
- Manufacturing costs on plants largely fixed

Outputs

- Economics – money!
 - Test different assumptions about input data
- Mass Balances (every time)
- Reduced costs, Dual activities
 - Transfer pricing
- Sensitivities, ‘What Ifs’
- Ranges

Maximise – ‘profit’: contribution

Minimise – ‘cost’, pollution, energy consumption, global warming

Uses

- Annual Budgets
 - Optimised mass balance
 - What ifs
- What ifs during year
 - Imports
 - Exports
 - Changes in market demands, prices
 - 'Annual' shutdowns
 - Plant breakdowns (Explosions...)
- Long term what ifs
 - Increase plant capacity; electrolysis at Sasolburg
 - Capital investment projects; 'Coalplex' – a project to triple the PVC output at the Sasolburg complex.

Uses

- Tanker to move chlorine between factories – totally a consequence of marginal costs in the model
- Caustic imports: huge potential source evaluated by model
- New titanium dioxide plant near Richards Bay; potential huge new HCl demand also evaluated by model
- Fluorine constraint; customers processing food could only receive acid from the Durban factory

Multi time period models

- Effectively four, ten or twelve models 'hooked together' by stock flows and cash flows
- Shutdown planning; stock build ups for the shutdown
 - Possible import requirements
- Caustic soda model; planning monthly movements among stockpiles around the country, as well as from the factories
- Capital investment analysis; many...

Nitrogen Model

- Conceptually very similar to the Halogens model, but covering the 'ammonia' business
 - Ammonia
 - Ammonium nitrate
 - Urea
 - Explosives...
 - Acids
- Capital investment; the No.4 ammonia plant at Modderfontein – at the time, one of the largest coal based ammonia plants in the world.

Explosives Model

- Development of Nitrogen model
 - Focusing in detail on the explosives business
 - Modderfontein; the free world's largest explosives factory
 - Somerset West – the second largest
 - Manufacturing millions of detonators – a day!
- Production planning – explosives plants occasionally have units blow up...
 - Explosives magazine blew up - implications
 - Import of black powder (gunpowder) when the plant blew up
- Capital investment – the 'R100' project (next slides)

Meta-modeling for capital investment with uncertain returns

Background

- About 45 years ago
- How to tackle an important problem with missing key data
- Useful methodology

South African mining/explosives industry at the time

- Symmetrical 'monopoly'
 - One supplier (AECI Explosives)
 - One customer (Chamber of Mines)
- Anglo American's ambiguous position
- New potential vendor
- Competition Board
- Ten year, cost plus contract; the mining industry will buy from AECI
 - (OR model behind that contract)

Net Present Value Modelling

- Cash flow model covering the time scale required to do discounted cash flow modelling of the various options
- Turned out what was developed was effectively Excel in Fortran
- Covered a wide range of contract structures

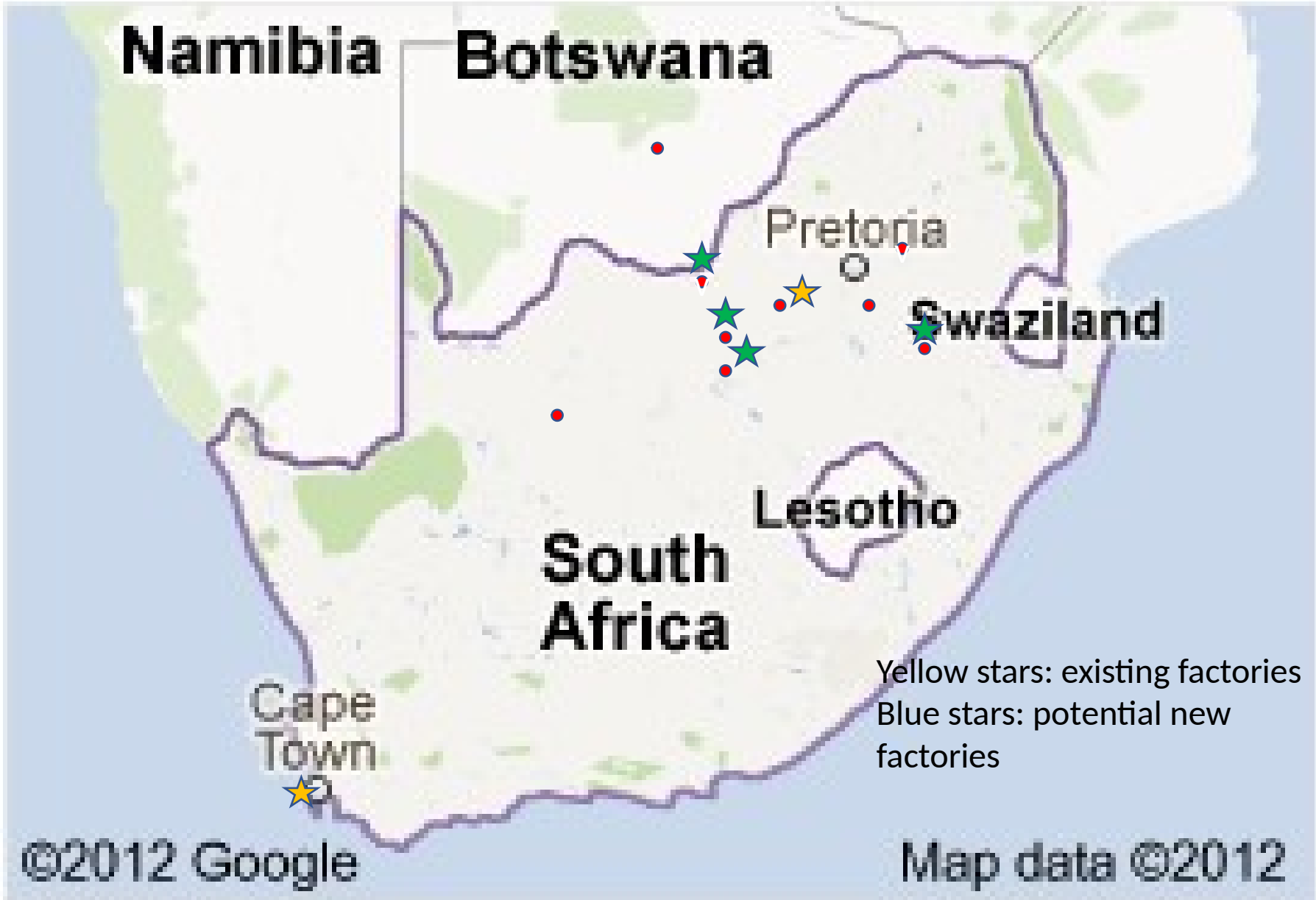
Going forward

- AECI will lose market share
- What will be the impact?
- What options does AECI have?
- What should AECI do?
 - What happens if they stick with the old manufacturing and supply model?
 - What will the ROI be for a new model?
 - Decentralised shaft-head deliveries
- Marketing staff had no ideas of the implications of either

Alternatives

- Existing situation
 - Two factories, one very remote from most markets
 - Expensive inflexible distribution infrastructure
 - Weekly/fortnightly rail deliveries to mines
 - Each mine had extensive explosives storage facilities
 - Legislation
- Possible new approach
 - New factories/distribution sites closer to customers
 - Shaft-head deliveries by AECl
 - Lower cost to customers
 - More difficult for new entrants to compete
 - Legislation - implications

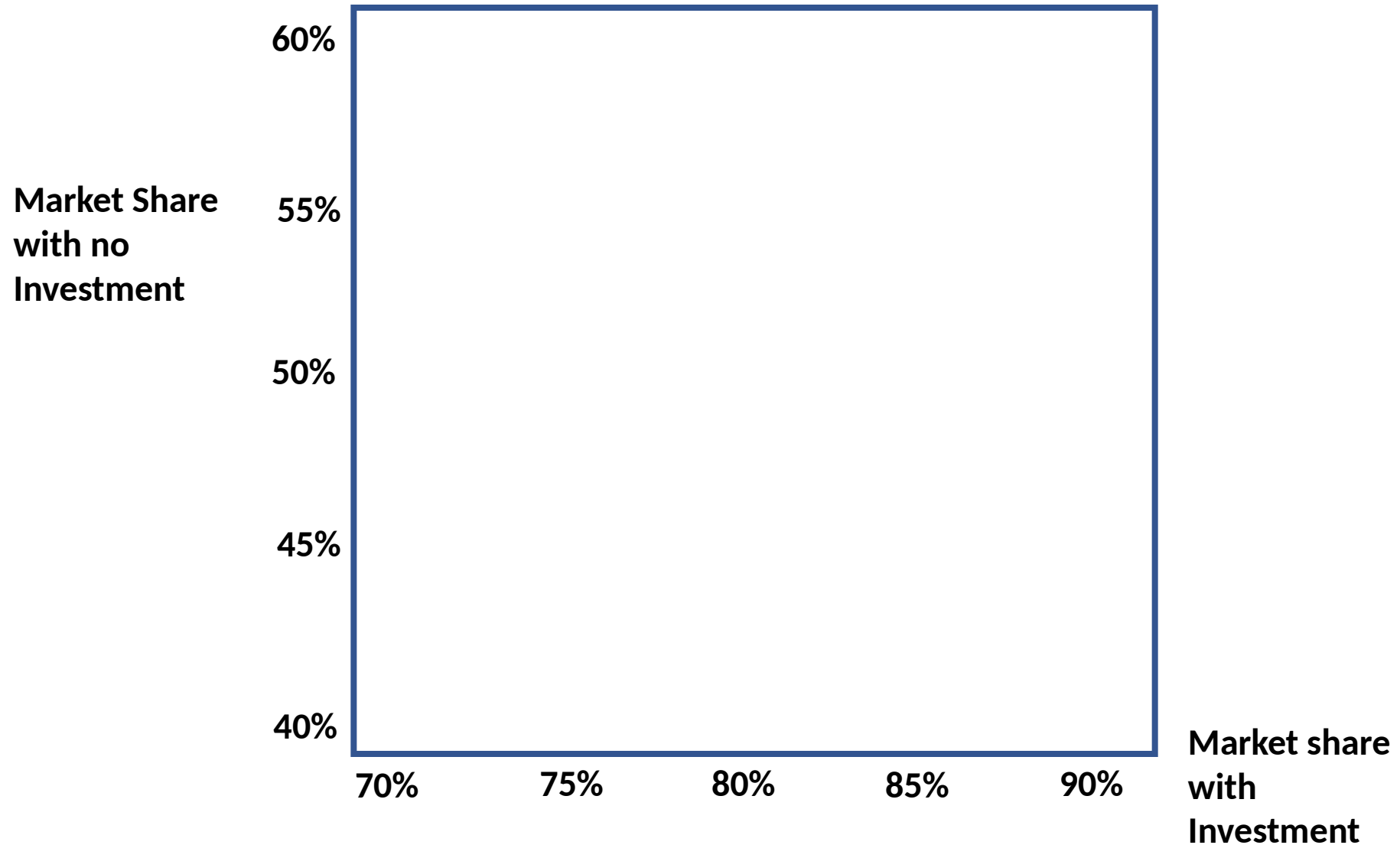




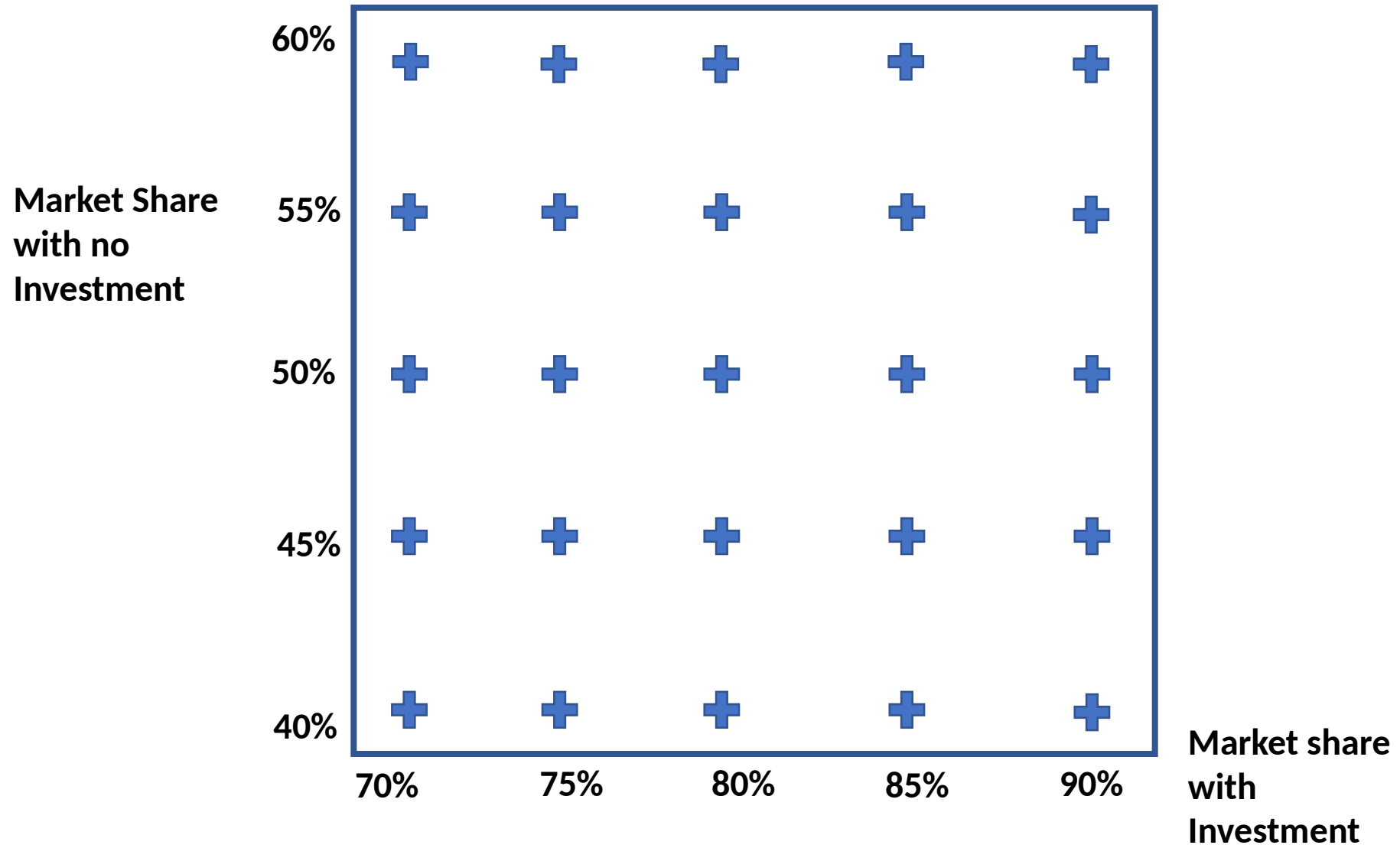
Return on Investment

- Costs of existing model?
 - Known
- Costs of new model?
 - Reasonable estimates
 - Additional R105 m capex (R1 bn in 2012 money)
 - Opex
- Market share going forward if existing model retained?
 - Who knows...
- Market share of new approach?
 - Ditto...

Space for LP model evaluations

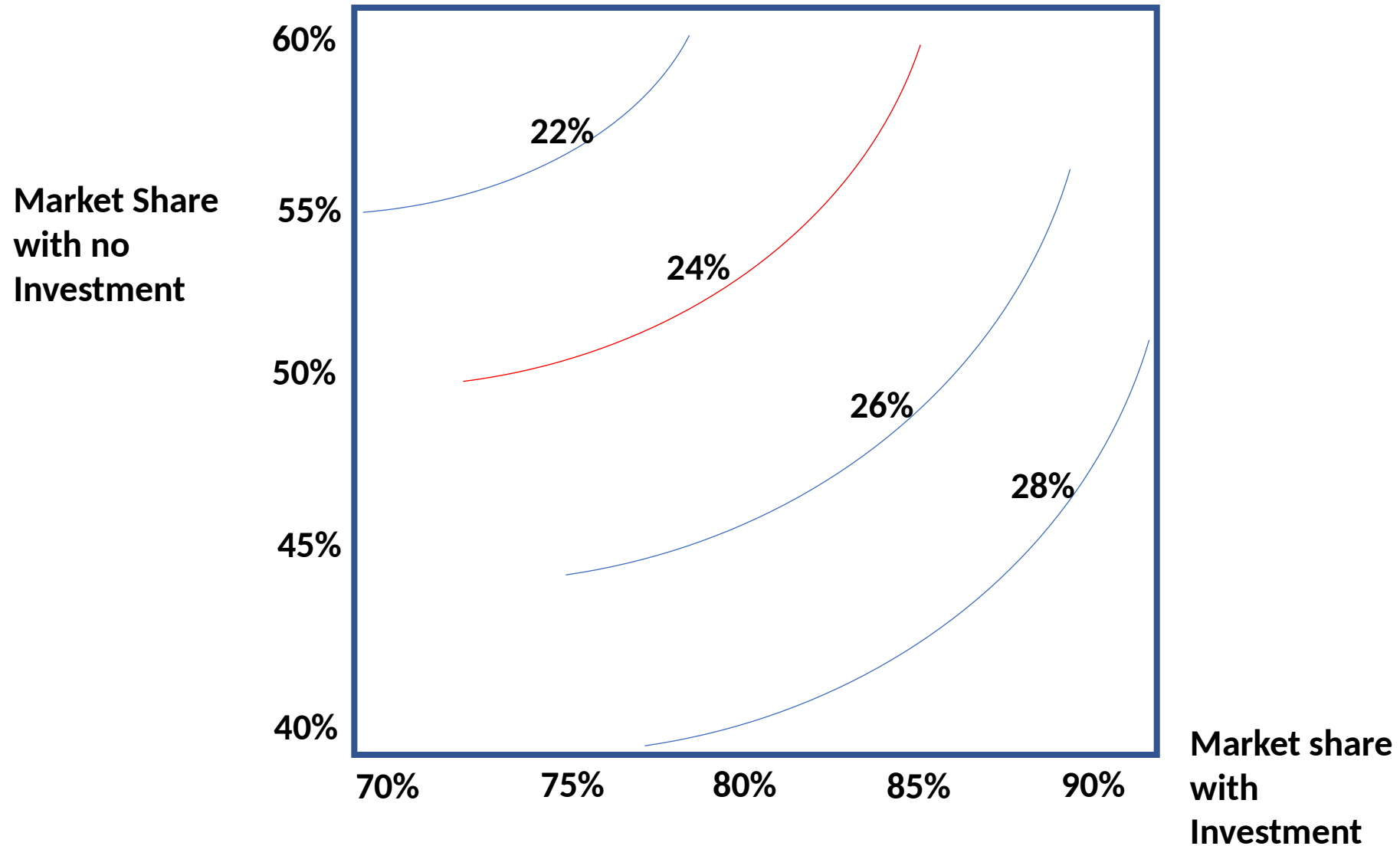


Comparisons to evaluate

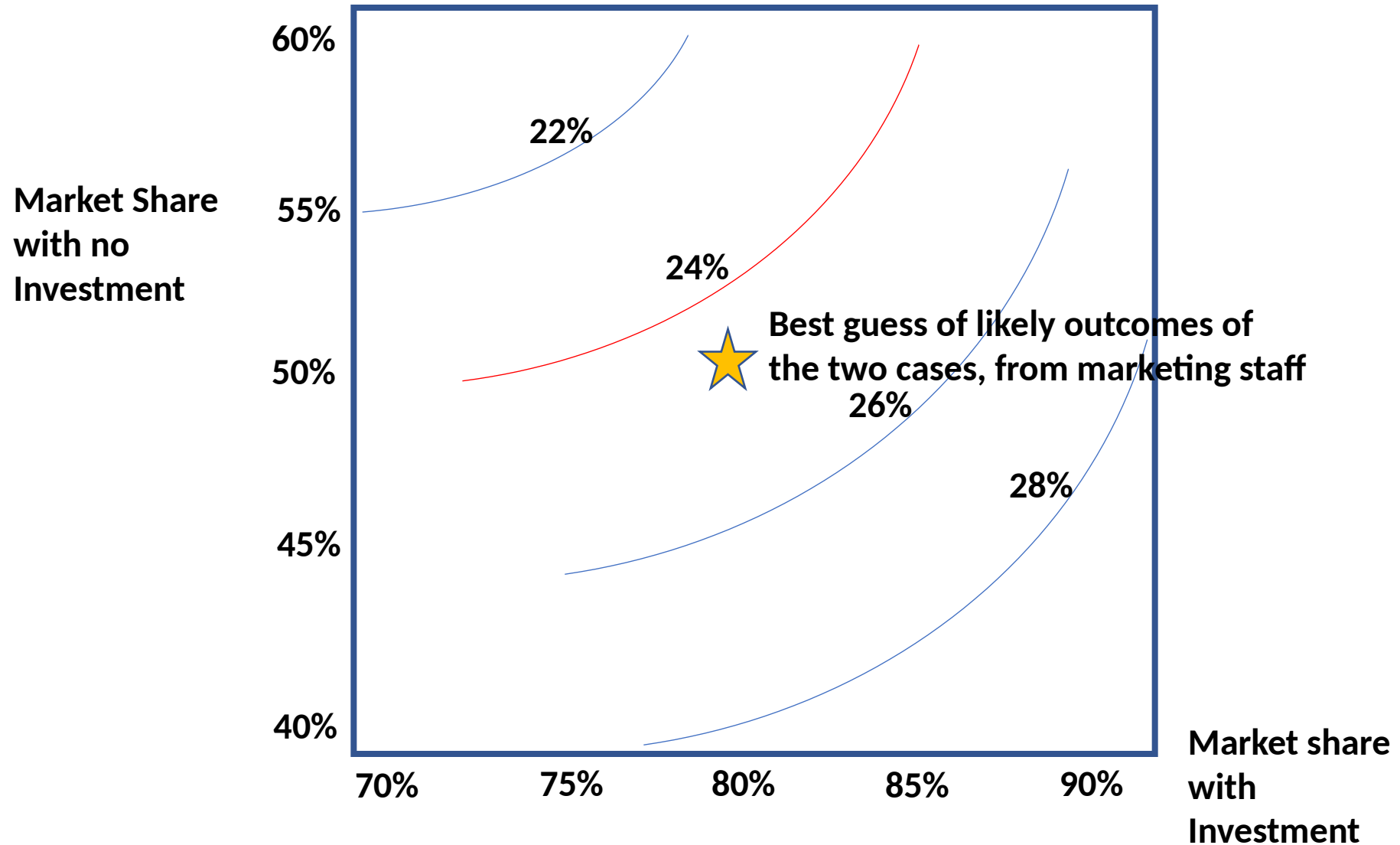


Iso-profit lines for ROI/IRR

Calculated from the model runs by difference between the various cases



Iso-profit lines for ROI



Conclusions

- The investment went ahead
- 40 years later, AECI Explosives is still in business
- Were we right?
 - Who knows?
- The work provided 'decision support'
 - Without it, a decision would have been largely guesswork
 - With it, the decision was better informed.

Simulations

- IBM software
 - GPSS – General Purpose Simulation Software (Discrete Event)
 - CSMP – Continuous Systems Modelling Package (differential equations)
 - Composed into Fortran, then Assembler
 - (Metabolism of a dog)
- Coalplex – interplant storage (CSMP) Before the new plants, the stock tanks had proved too small – how big should they all be in the new investments
- Fertiliser bagging plant (GPSS)
 - Continuous production of AN
 - Bagging plant didn't work weekends
 - What reductions on AN plant so no need to shut down over weekend?
 - Down to a level of detail that included tea breaks!
- When the first PCs became available, how many would we need

Users

- Relationships with planners in divisions vital
- They started to anticipate results...