

# My very own experience in solving optimization problems

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# Automated tools vs Optimization

- Shift from “manual” to “automated tool” is seen as the holy grail
  - Underlying problem can be tough
- Optimization seen as cherry on the cake... but the cake is needed first
- Optimization expert needs to educate the customer about “optimization potential/capabilities” for managing expectations
- Very often customers do not know what they want to optimize
  - Possibly conflicting objectives
- Optimization can unleash considerable potential savings
  
- Optimization may threaten jobs. No-optimization may threaten entire companies



# Optimization development phases

## 1. Discovery

- Understanding the revenue and costs drivers, size of the problem
- Define the problem, its constraints, its objective function(s)

30%

## 2. Designing and implementing an optimization model/algorithm

- All models are wrong but some are useful (cit. George Box)
- Understand necessary assumptions/approximations

10%

## 3. Integrating with existing IT system / workflow

- Fetching and preparing input to optimization model/algorithm
- Feeding back the (sub) optimal solution

30%

## 4. Testing – Verifying constraint satisfaction, hypothesis, etc...

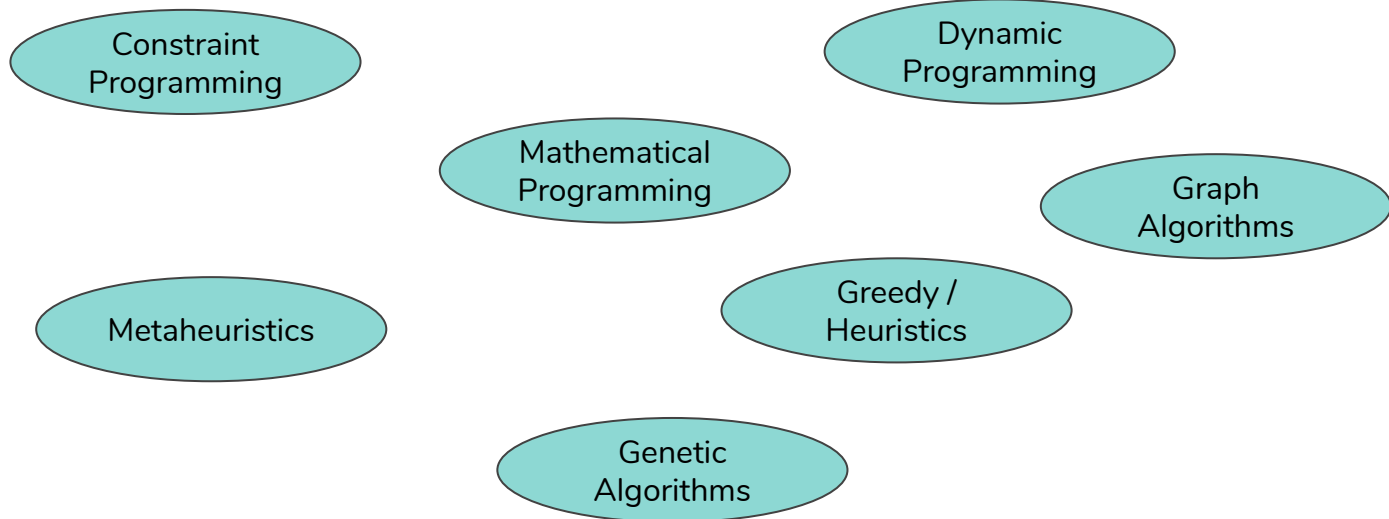
30%

**Business case/model needs to be defined!!!**



# Optimization technologies

An incomplete list for discrete optimization



# E-bus deployment optimization





# Electrical buses - the TOSA case

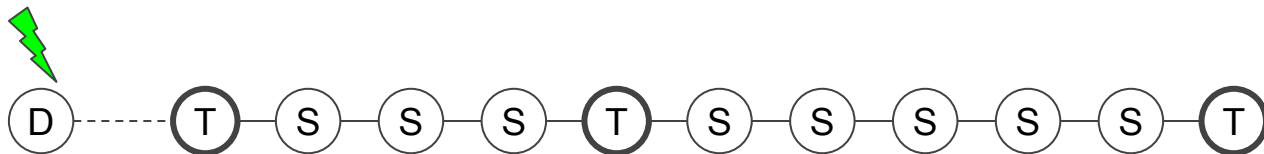




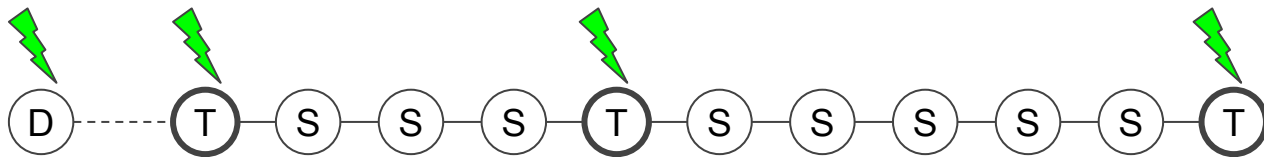
# E-bus technologies



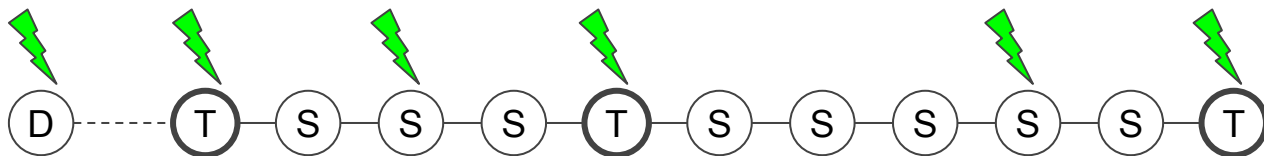
Depot charging



Terminal charging

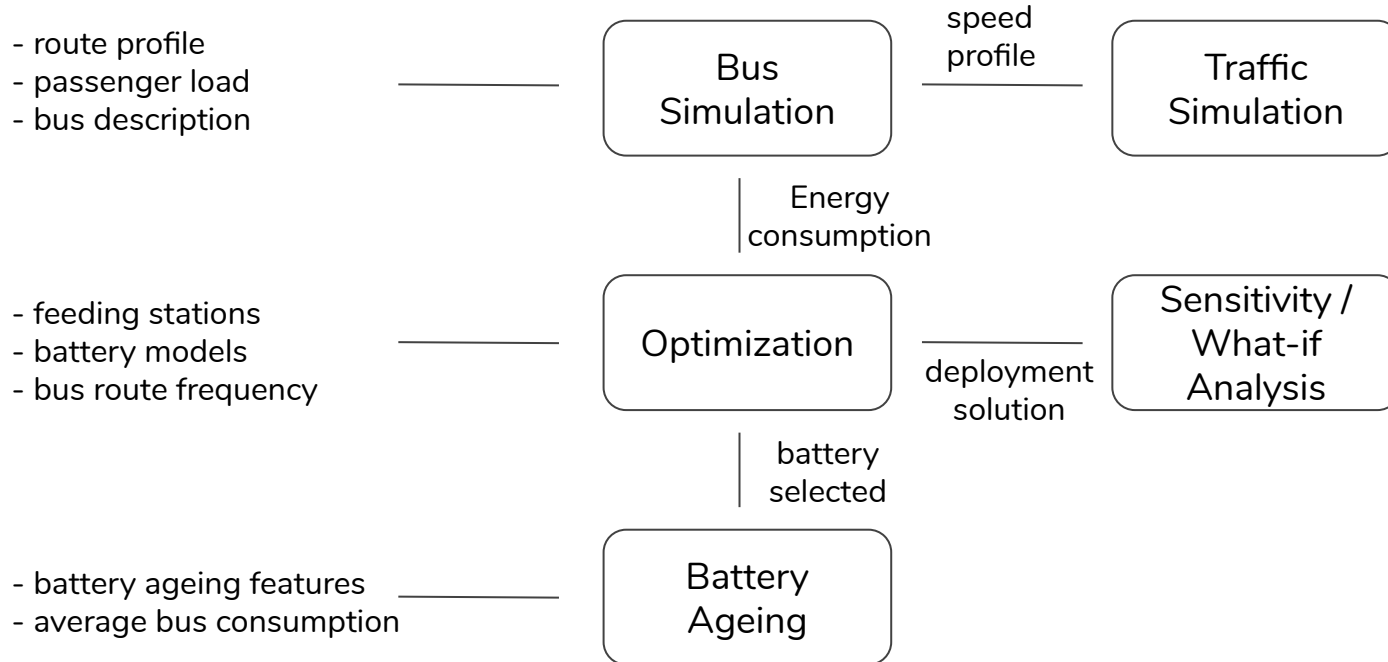


En-route charging





# myTOSA



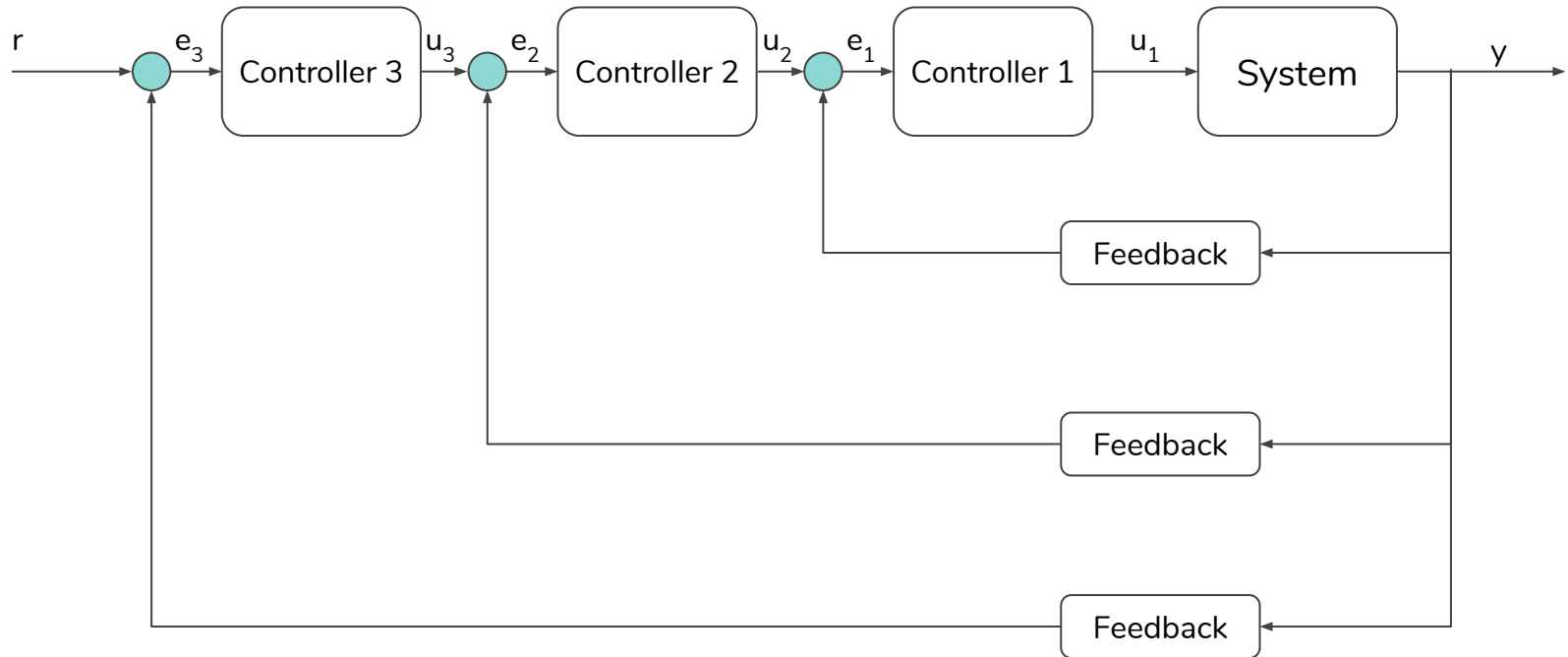


# Optimal deployment of control solutions



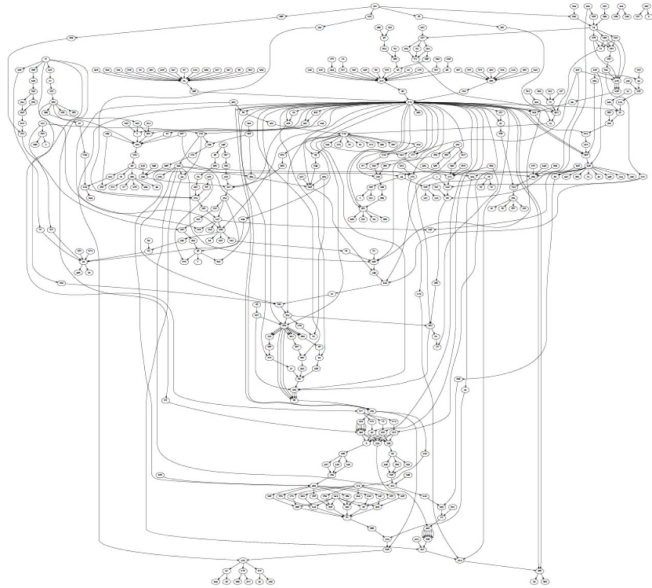


# Multirate control systems





# Context



Hardware

- SoC (2 cores + FPGA)





# Problem Definition

- *Set of homogeneous resources R*
- *Set of cyclic applications*
  - with fixed priority
  - *with different periods*
- *Apps composed from activities*
  - with fixed duration
  - and precedences

$$A = \{a_0, \dots, a_{n-1}\}$$

$$\text{prio}(a_0) > \dots > \text{prio}(a_{n-1})$$

$$\lambda_{i+1} = \eta_i \lambda_i \quad (\lambda_{\max} = \lambda_{n-1})$$

$$V_i = \{x_j^i\}$$

$$d(x_j^i)$$

$$x_j^i < x_k^i$$

Objective function

Minimize makespan of  $a_0$  then  $a_1$  then ...

$$\min \text{lexico}(\text{makespan}(a_0), \dots, \text{makespan}(a_{n-1}))$$



# Experimental evaluation - CP

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	<b>Avg #act</b>	<b>MRC</b>	<b>T&amp;E</b>	<b>DJ</b>
Real 1 ( $\eta_{\text{tot}} = 36$ )	2353	5	521	496
Real 2 ( $\eta_{\text{tot}} = 2000$ )	177646	159	1827187	2468504

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## Solution time (ms)

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	<b>MRC</b>	<b>T&amp;E</b>	<b>DJ</b>
Real 1 ( $\eta_{\text{tot}} = 36$ )	14.9	27.4	29.25
Real 2 ( $\eta_{\text{tot}} = 2000$ )	34.4	1258.3	1253.8

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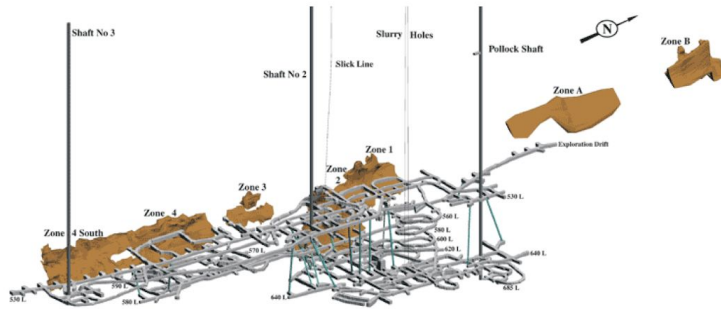
## Memory Consumption (MB)

# Underground mining fleet optimization



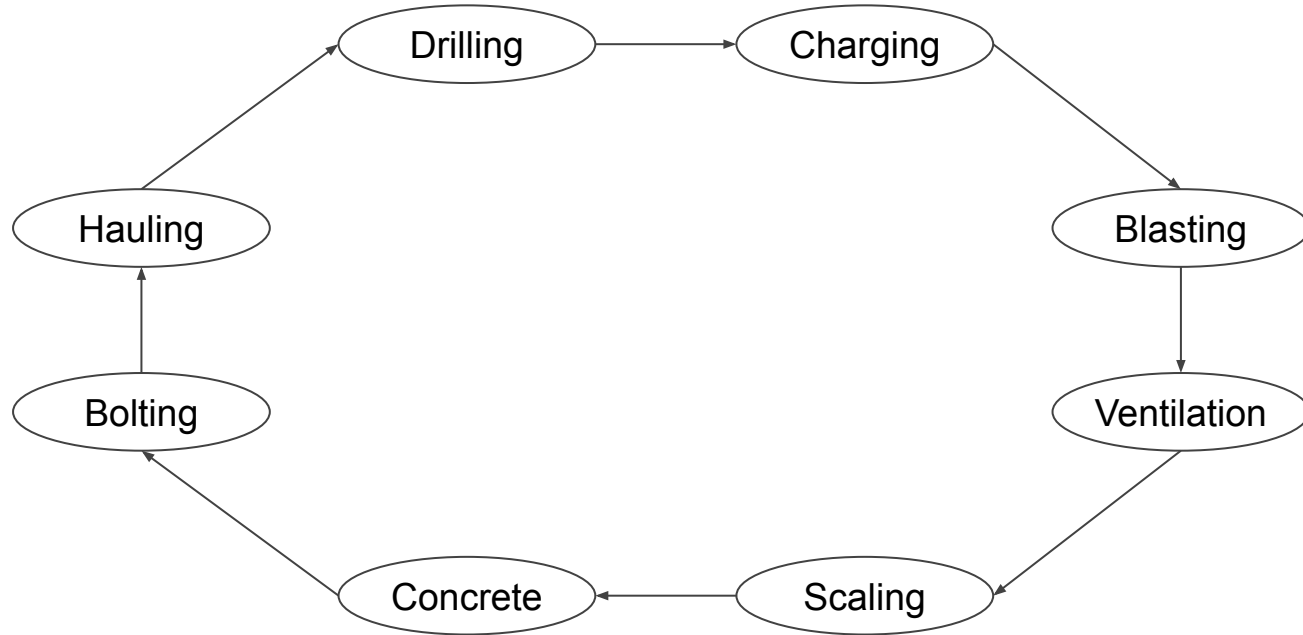


# Underground Mine



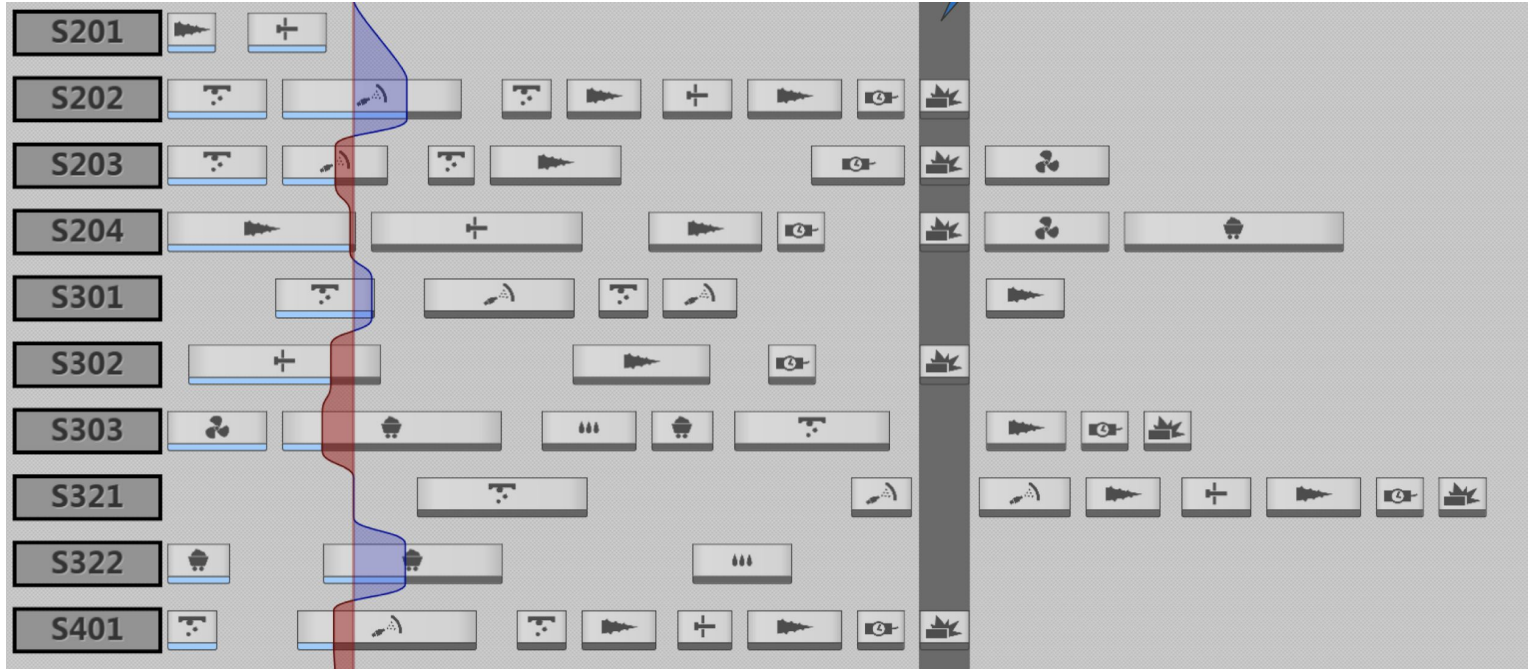


# Undeground mining operations





# Automated Cyclic Scheduling



# Stator Winding Design Optimization



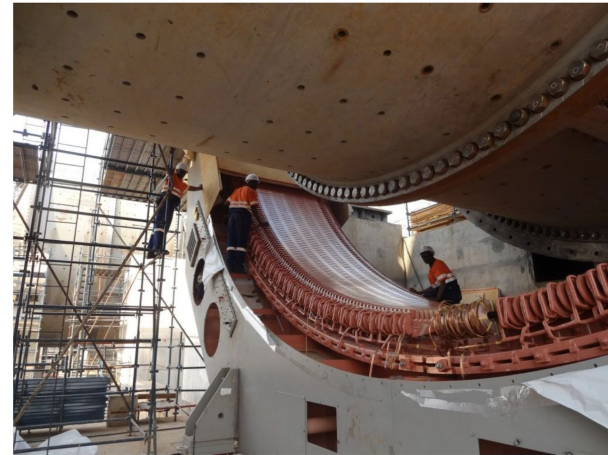
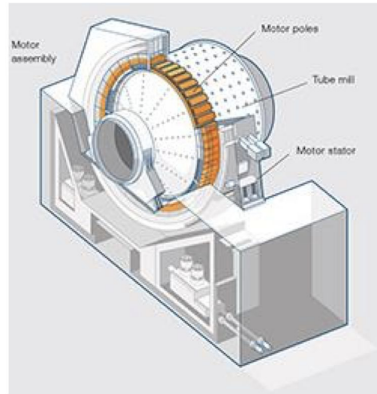


# Gearless Mill Drives





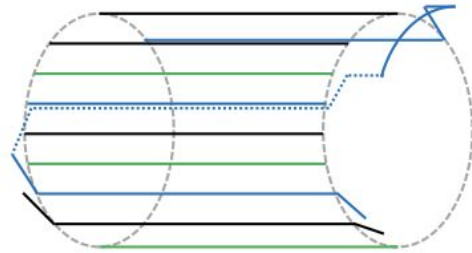
# Stator



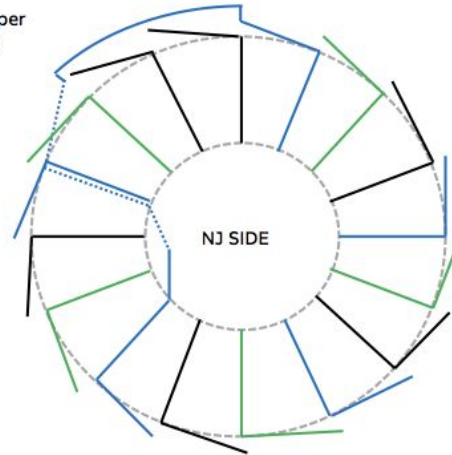


# Main Intuition

No jumper side  
(NJ SIDE)



Jumper  
side





# Different approaches

$n_s$	Decomposed MIP+CP				Decomposed MIP				MIP			
	t ( $\mu$ )	t ( $\sigma$ )	$Obj_{CP}$	%Sol	t ( $\mu$ )	t ( $\sigma$ )	$\frac{Obj}{Obj_{CP}}$	%Sol	t ( $\mu$ )	t ( $\sigma$ )	$\frac{Obj}{Obj_{CP}}$	%Sol
102	4.4	1.0	12.18	100%	2.4	1.2	100.0%	100%	177.6	112.2	98.2%	90%
264	28.6	28.7	23.57	100%	26.0	28.9	100.0%	95%	340.7	2.0	101.7%	5%
384	23.2	19.5	25.39	100%	19.4	19.4	99.9%	95%	342.1	3.2	-	0%
480	42.0	35.6	32.34	100%	38.8	34.8	100.1%	100%	339.8	2.2	-	0%
576	65.0	33.4	43.56	70%	60.4	32.7	99.8%	30%	341.2	2.4	-	0%

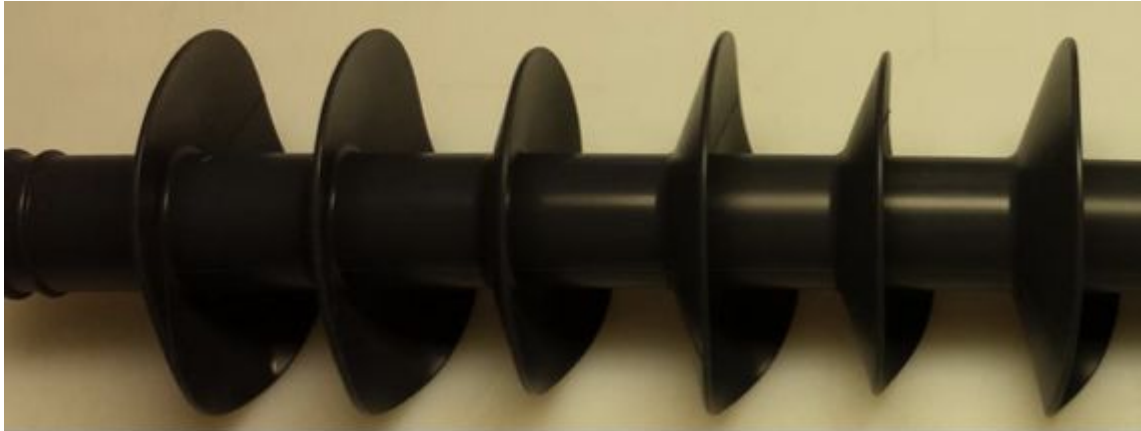
# Optimal Stock Sizing in a Cutting Stock Problem with Stochastic Demands

Case Study 1





# Production of plastic pieces

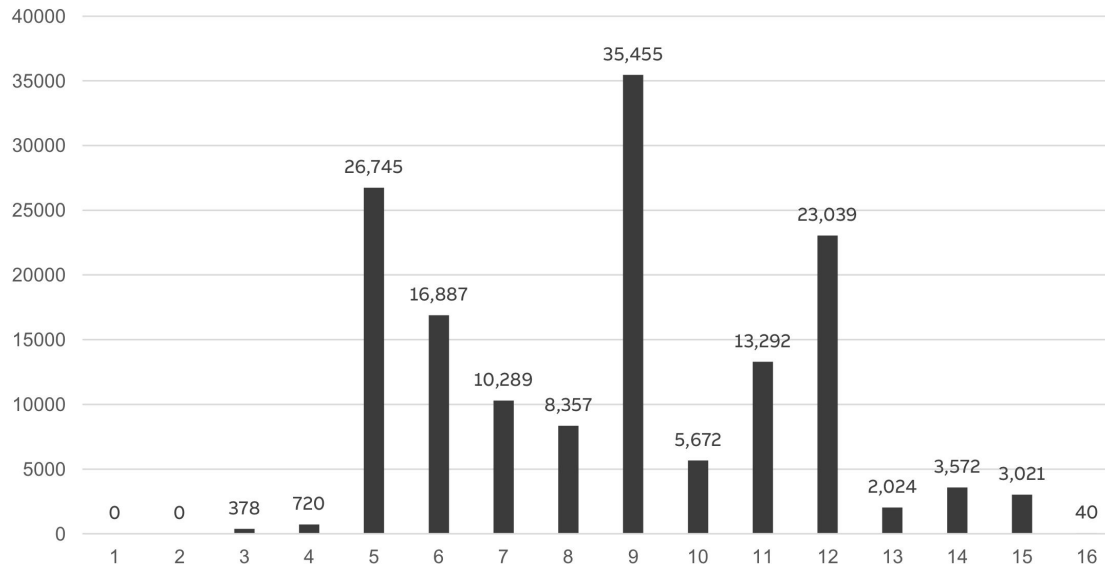






# Initial Input

- A mold creates a piece with 16 discs
- Orders in year 2018





# Discovery Phase

- What are the cost drivers?
  - Total time of production, waste, total plastic used, overproduction, cutting costs
- Is there a possibility to build a new mold?
- Will different molds have the same yield?
- Will different molds have the same throughput?
- Are the production requirements constant or they may vary on subsequent years (i.e. stochastic)?
- Is the yield of the cutting procedure constant?
  
- **Size of the problem?**



# Actual Problem

## Decision variables

- Which investment to build a set of molds to use subject to stochastic production requirements
- Which cutting patterns to use subject to given production requirements

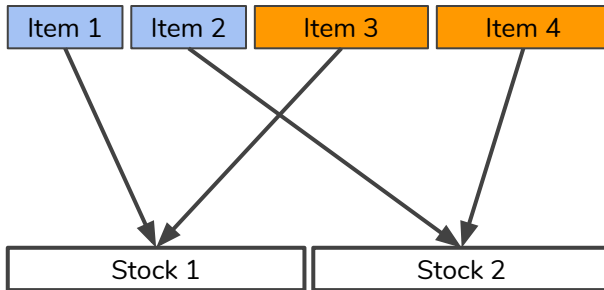
## Objective function

- Minimize: Waste, Over-production, Number of cuts

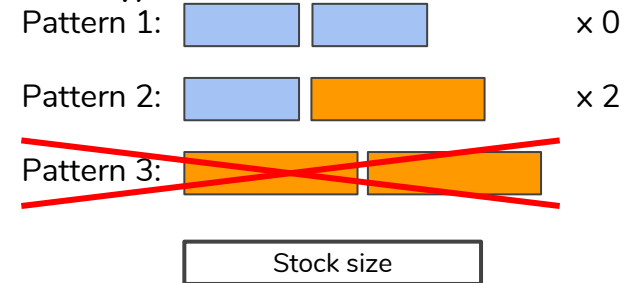


# Models for operational optimization

Item-based formulation (Kantorovich)

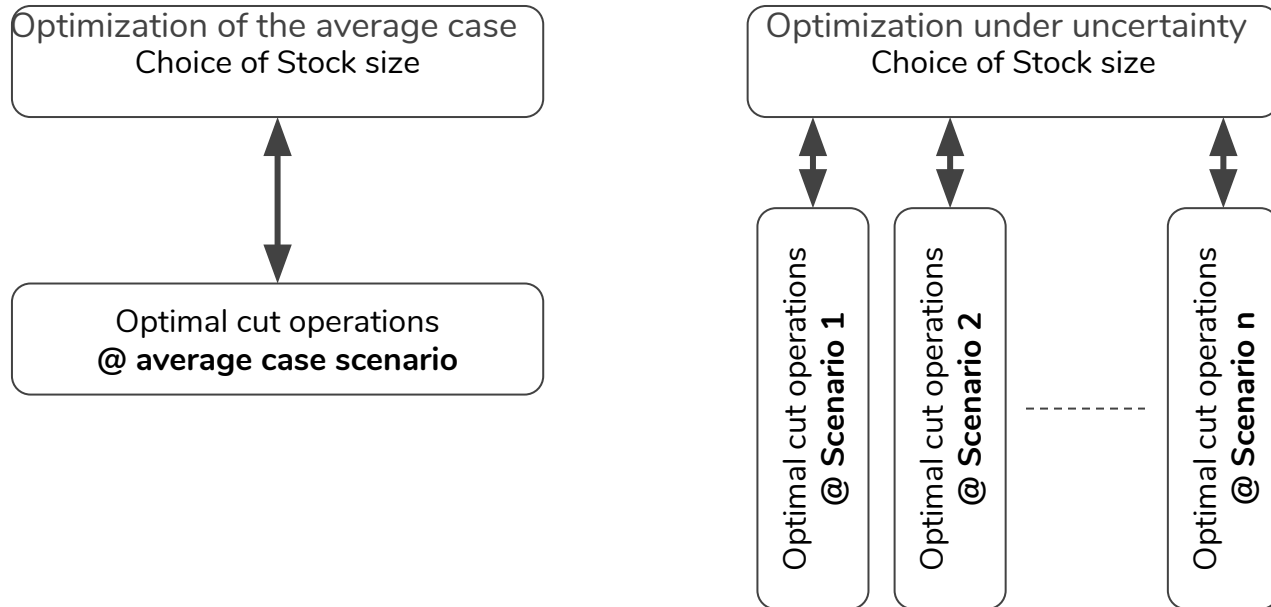


Pattern-based formulation (Gilmore & Gomory)





# High level model for (stochastic) planning



# Container Terminal Optimization

Case Study 2



# Container Terminal

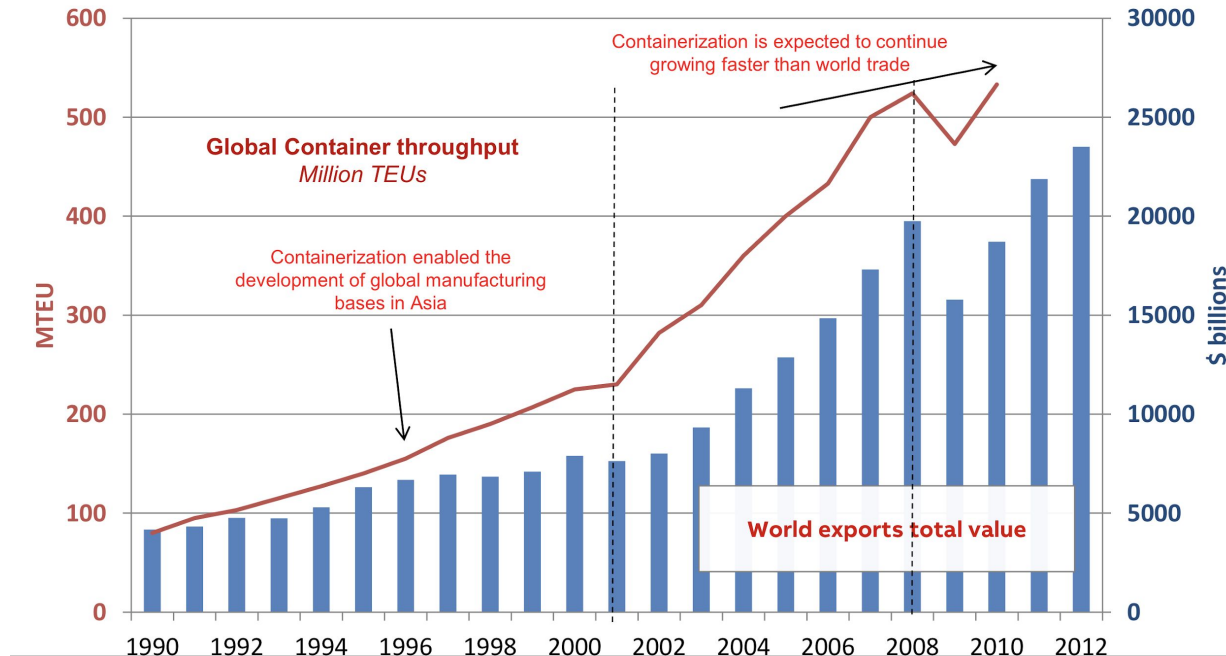




# Container Trade Growth

*Container logistics throughput grows significantly faster than global trade*

*2010 volumes higher than 2008, 2011 increase 6-8%*





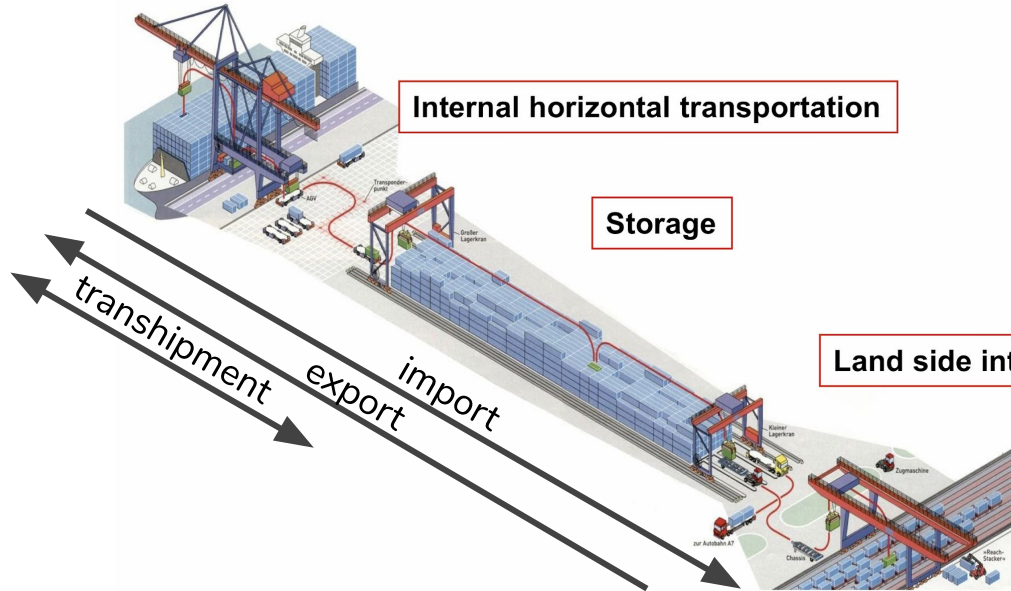
# End-loaded terminal operations

Off-load/load ship

Internal horizontal transportation

Storage

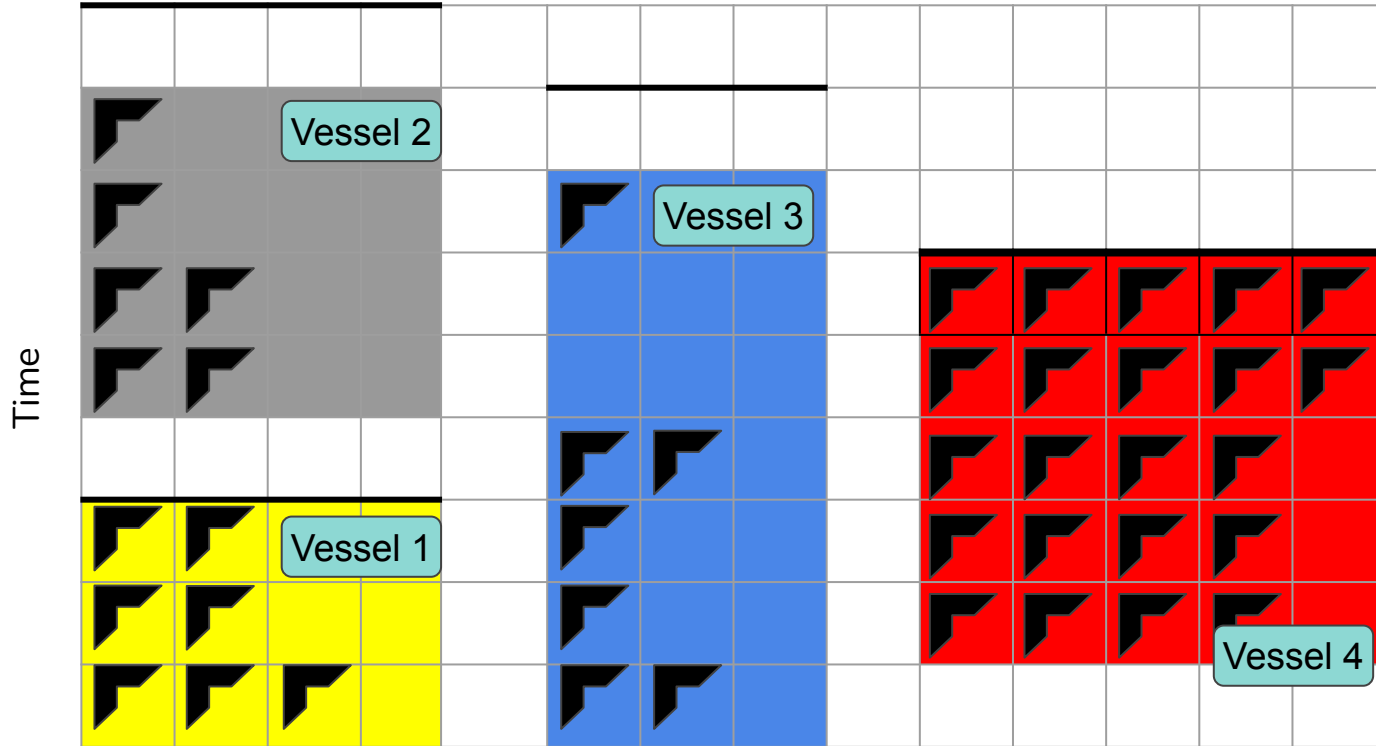
Land side interface



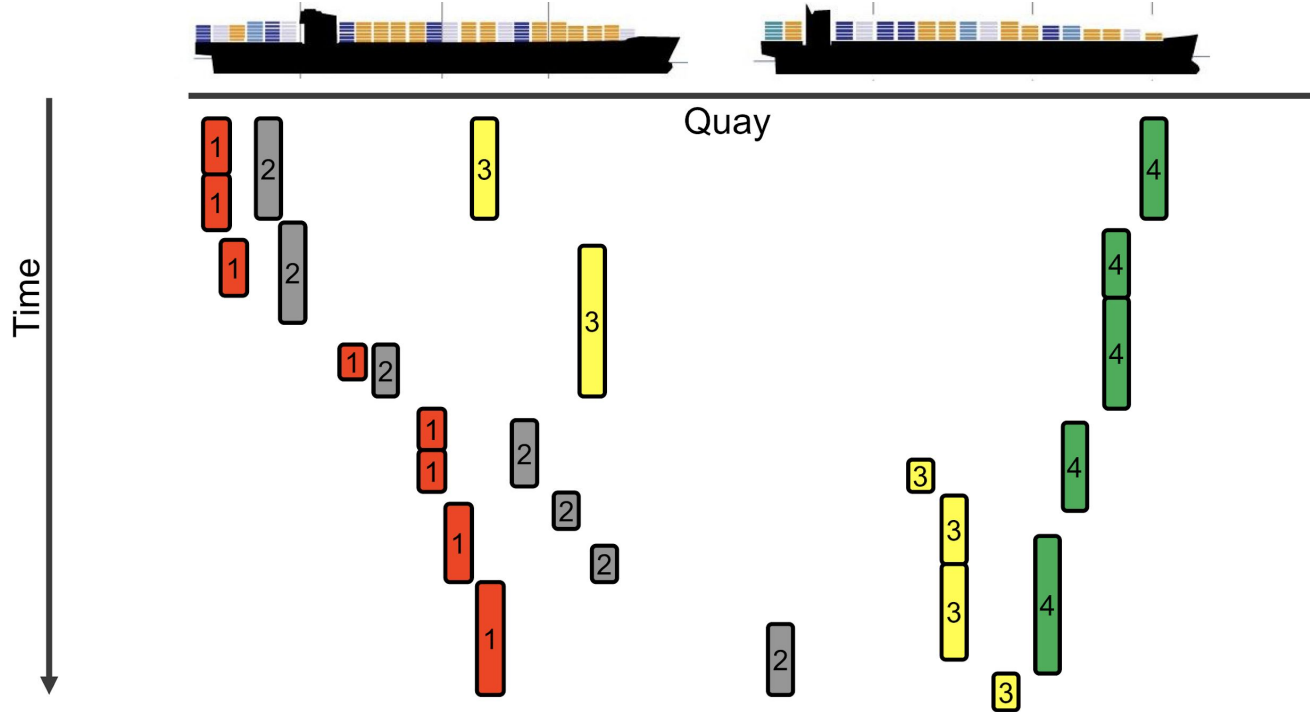


# Discovery Phase

# Berth Crane and Allocation



# Quay Crane Allocation and Scheduling



# Stowing sequence and allocation

The screenshot shows a software interface for managing cargo stowage on a vessel. The main window displays a grid of 20 cargo holds, each with a color-coded stowage plan. A 'Loading Summary (Cargo)' window is open in the bottom left, showing a table of cargo details. A 'Container' window is open in the bottom right, showing details for container WHLU1406314.

**Loading Summary (Cargo)**

	TTL	OAK	LGB	ZLO	BLB	YSB	MAA	CHS	MMK
20	195	26	36	2	0	9	13	2	3
40	288	71	97	4	11	4	8	0	2
60	55	19	22	1		7	10		1
20	MAA	8	2	1	1	1	3		
40	CPA	1							
60	TR	19		5					
VE	17	5	7			1		2	2
DC	59	32	21	2		1	1	2	1
MA	17	6	9	1					
TR	38	1	23		1	4	1		4
TR	61		12		4	1			4

**Container**

Container: WHLU1406314  
 Pos.: 220510  
 Yard: 20

Equipment Spec. - Port  
 Size: 40 L.P. YOK  
 Type: FR D.P. HKG  
 Mgt: 86 BST  
 Liner: WNL POR  
 T.Wgt: PLW  
 Max.G.W.:  
 G.Wgt: 17.1 ton 2nd Val  
 Material: 2nd D.P.

Cargo Type - Other Description  
 9500 (80) Recv.  
 LBL (80) Delv.  
 (80) Svc.  
 Sound Insp.Dt  
 Other

# Yard Management / Planning

The screenshot displays the 'Terminal Operational Package - topX-Expert - TOPX' interface. The main window, titled 'Y91 - BirdseyeView Window', shows a 3D perspective of a container yard with various stacks and cranes. The interface includes a menu bar (Vessel, Rail, Yard, Equipment Control, Utilities, Management, Statistics, System References, Window, Active Tool) and a toolbar with icons for Show Allocation Filters, Refresh, Show/Hide, Colouring Mode, Open Set, Copy Set, Activate New Filter Set, Show All Working RTG, Display All RTG Working Ranges, Show Colour Dialog, Set Print Mode, and Chat Mode.

On the right, a 'G25 - Tracking Container' window shows details for container KHOX0358592, including a 3D model, height (8.6), and a list of attributes:

ISO	22RE	Grwt	3.0
Tare	3.0	Cat	S
LOP	MSK	ODP	
LPD	JPLKB	POD	MYTPP
LLPOD	MYTPP	FPOD	
Temp.		Grade	
Cont'd			
ArrCar	V	KHOA081114	
DepCar	V	702 05110512	
Loadrat.			
Seal No.			
SpringI			
ArrTm			
ArrTm			
EMT-1			

Below the main view, a summary panel displays statistics:

Total 20'	5947	Total 40'	7855	Total 45'	127	Total Other	0	Total TEUs	13900	Working CHes	0
??MNS:	1	??MYP:	26	AEABU:	11	AUBBN:	1	AUMEL:	3	AUSYD:	1
CNDLN:	11	CNFQJ:	1	CNHKO:	3	CNLYG:	56	CNGB:	117	CNNP:	1

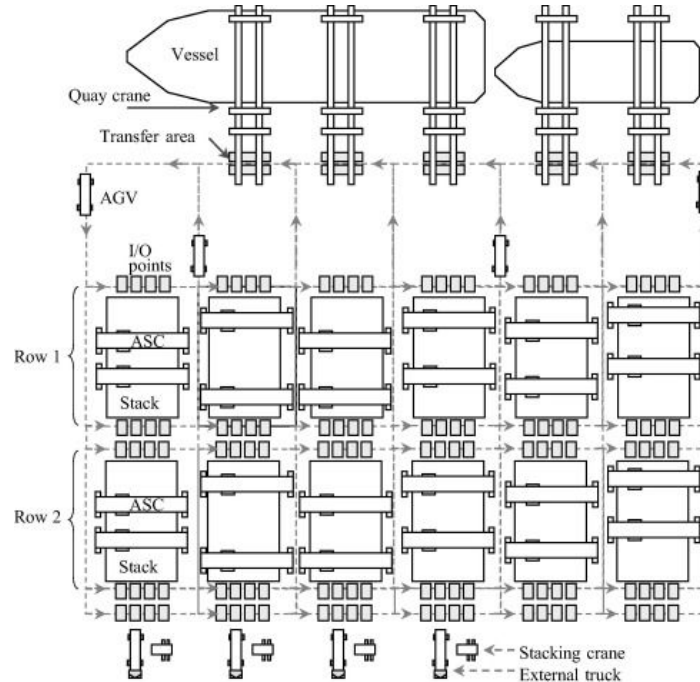
At the bottom, a 'Containers Search Filter' table is visible:

Filter Name	Field Name	Condition	Value1	Value2
FILTER_KiBuye				
INYARD_40 F				
INYARD_40_E_Z=>4				

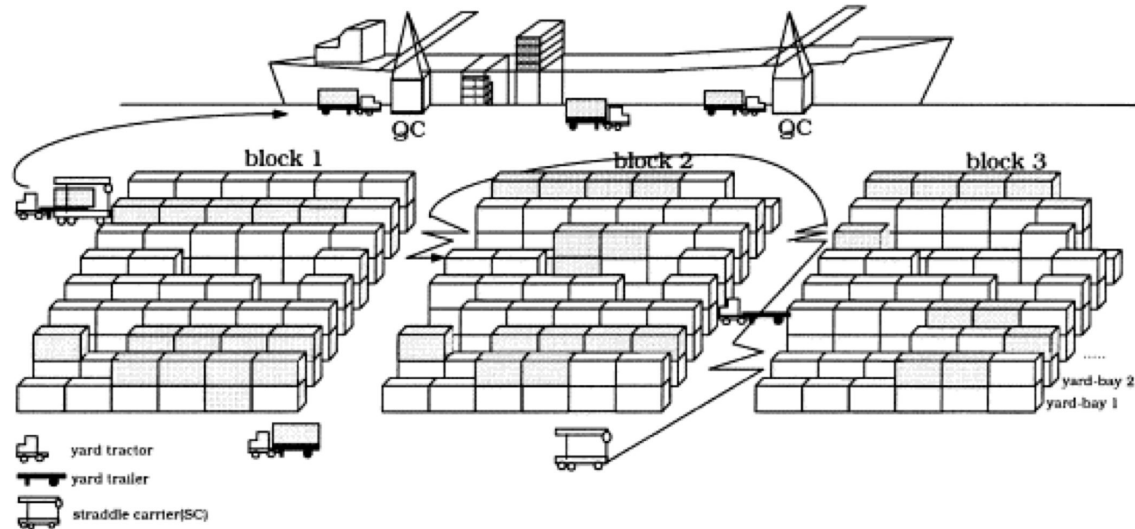
The bottom status bar shows: 'Y91 - BirdseyeView Window | Global Command | EC Mode: Manual | No Vessel | Colour Scheme: Disch. Port | Scheme1 | Move Reason: |'



# Automated Stacking Cranes



# Horizontal Transportation





# Conclusions





# Conclusions

- Real challenge is understanding domain-specific knowledge and translate it into abstractions and mathematical formulations
- Getting access to data is key
  - Baseline for comparing optimized solution vs current solution
  - Understanding problem features and size
- Educate the customer about
  - Optimization potentials (setting expectations right)
  - Trade-off between performance vs quality
- Fail fast
  - Short feedback cycle with customer
  - Post-processing tool for verifying solution (better if customer developed)
- Technology mastery is required to understand strengths and weaknesses of each technology and figure out which technology is suited for which problem