

# Constraint Programming Methodology

Helmut Simonis

ACP Winterschool 2024

# Licence

This work is licensed under the Creative Commons Attribution-Noncommercial-Share Alike 3.0 Unported License. To view a copy of this license, visit <http://creativecommons.org/licenses/by-nc-sa/3.0/> or send a letter to Creative Commons, 171 Second Street, Suite 300, San Francisco, California, 94105, USA.



# Acknowledgments

This publication has emanated from research conducted with the financial support of Science Foundation Ireland under Grant number 12/RC/2289-P2 at Insight the SFI Research Centre for Data Analytics at UCC, which is co-funded under the European Regional Development Fund.

A version of this material was developed as part of the ECLIPSe ELearning course:

<https://eclipseclp.org/ELearning/index.html>.

Support from Cisco Systems and the Silicon Valley Community Foundation is gratefully acknowledged.

# What we want to introduce

- How does a Constraint Model fit into a bigger system
- Interaction with stakeholders
- You define what the problem is
- 12 Steps to success

# Outline

## The Bigger Picture

12 Steps to Success

Constraints in an Uncertain World

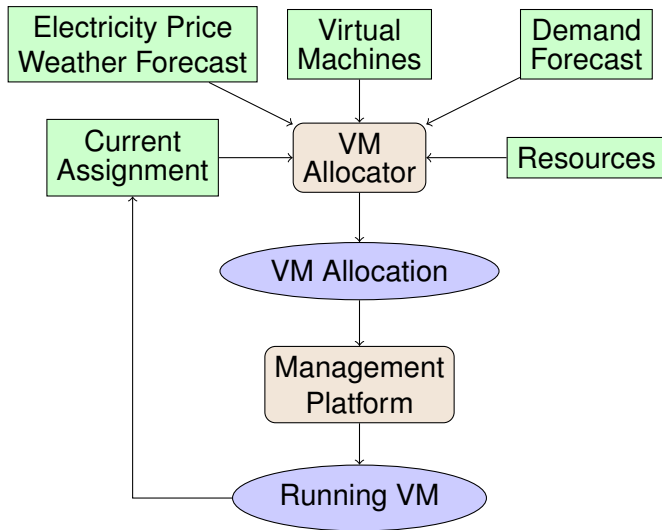
There is no “The Model”

Conclusion

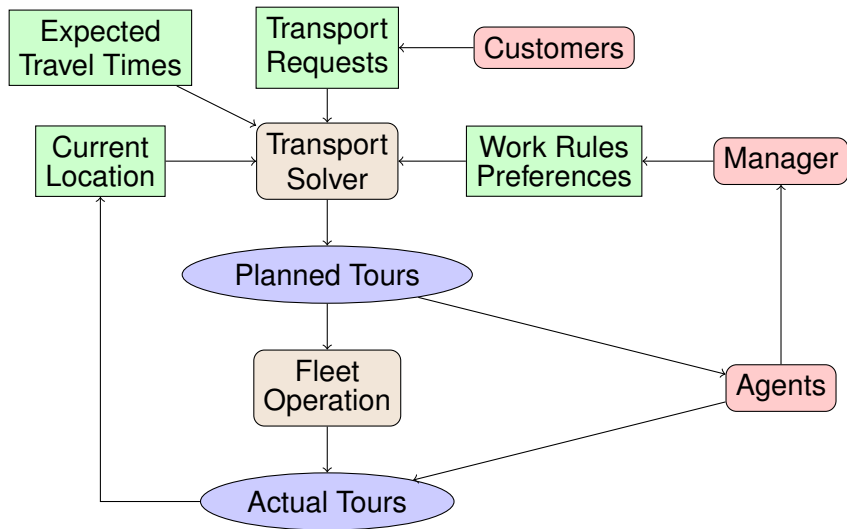
# CP Model is Part of a Larger System

- Where do data come from?
- Control over data
- Generated plan
- Externalized representation of constraints
- Implementation of plan
- Feedback from previous runs

# Example: Datacenter Management

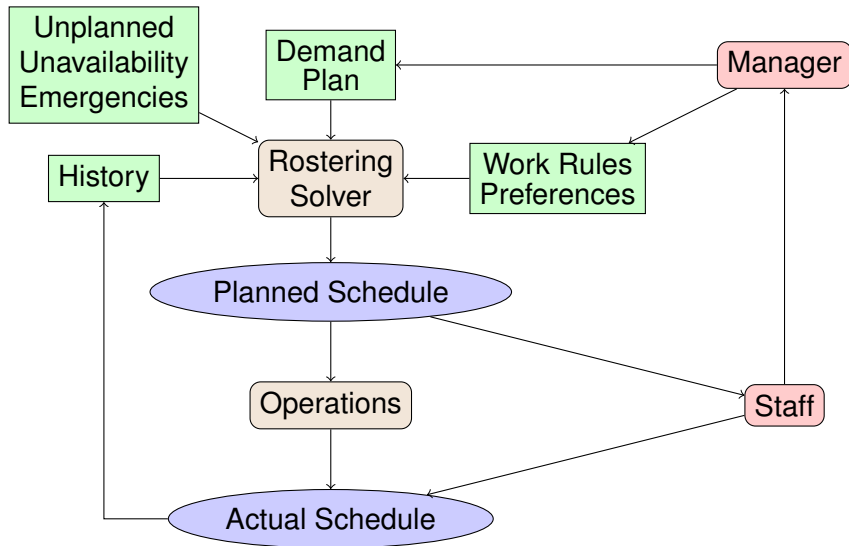


# Example: Transport

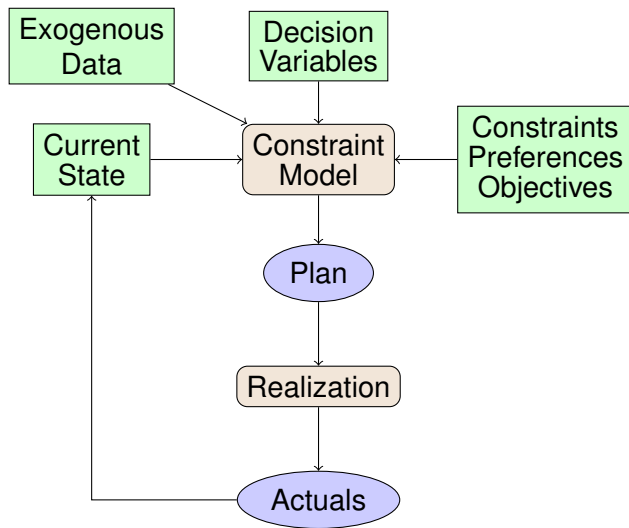




# Example: Personnel Rostering



# The General Scheme



# Key Questions: How? Who? When? Where?

- (How is work done?)
- Who performs work?
- When is it performed?
- (Where is it performed?)

# Outline

The Bigger Picture

**12 Steps to Success**

Constraints in an Uncertain World

There is no “The Model”

Conclusion

# Step 1: Literature Review

- Which problem are other people solving?
- What are the favourite techniques, why?
- What tools are used?
- Learn the domain specific language

## Step 2: Description of Problem

- Clearly defined use cases, ranked by importance
- Textual description of problem before math
- Important: Involve all stakeholders
- Important: Identify champions and their benefits
- State what is outside the scope

## Step 3: Example Data and Solution

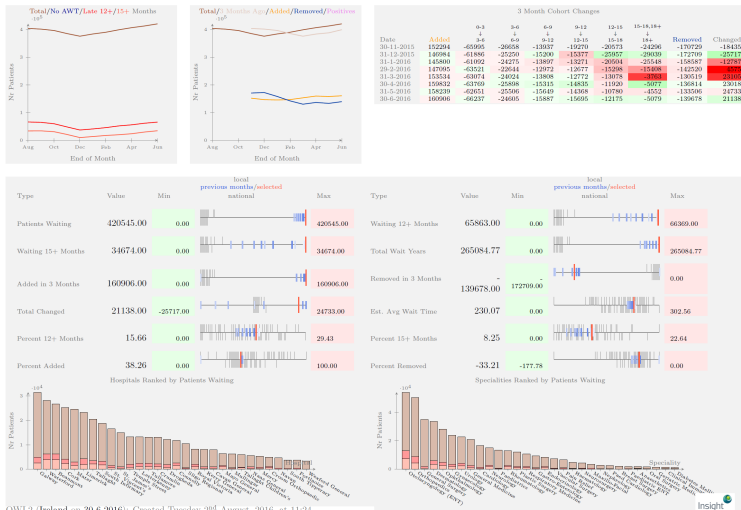
- Best is years of existing data and solutions
- Important: Set with manageable problem size
- Independent checker of solutions
- Possible: Trivial problem example for manual exploration

## Step 4: Visualizing Results

- Develop before solver
- Visualize existing solutions
- Perhaps end-users have existing visualizations
- Generic views for classes of problems (global constraints)
- Helps to understand poor performance
- Also: Compute KPI (Key Performance Indicators)



# Example Dashboard: Patient Waitlists



## Step 5: Implement Core Model

- One constraint type at a time
- Start with finding feasible, good solutions
- Find lower/upper bounds to estimate solution quality
- Start with basic search strategy

## Step 6: Feedback from Domain Experts

- Are you solving the right problem?
- Are all stakeholders happy with solution and objectives?

## Step 7: Study Obvious Alternatives

- If you have time (PhD students have time)
- Is there a straight-forward MIP/SAT model of problem?
- Do they work on small scale, large scale problems?
- Can you come up with good, feasible heuristics?

## Step 8: Solve Integration Issues

- Not too early, time wasted if solver does not work
- Not too late, without integration solver is just a demonstrator

## Step 9: Performance Engineering

- Problem specific search strategies
- Parallelism
- Improved model
- Improved solver
- Parameter tuning

## Step 10: Fight Feature Creep

- If it works, then people want more
- Not in first release
- Implement core use case, nothing more
- Exception: Allow all constraints to be optional

# Step 11: Improve Stability

- What is really required?
- Remove experimental code
- How far can we push model?
- Code review against model description
  - Allow changes in description



## Step 12: Tell the World

- Dozens of good CP applications hidden from view
- Consider writing application paper
  - Involve end-users and stakeholders
  - Describe problem from their perspective
  - If possible, publish data set and constraint description
- Submit instances to solver competitions
  - Other people will work on improved performance of your model

# Outline

The Bigger Picture

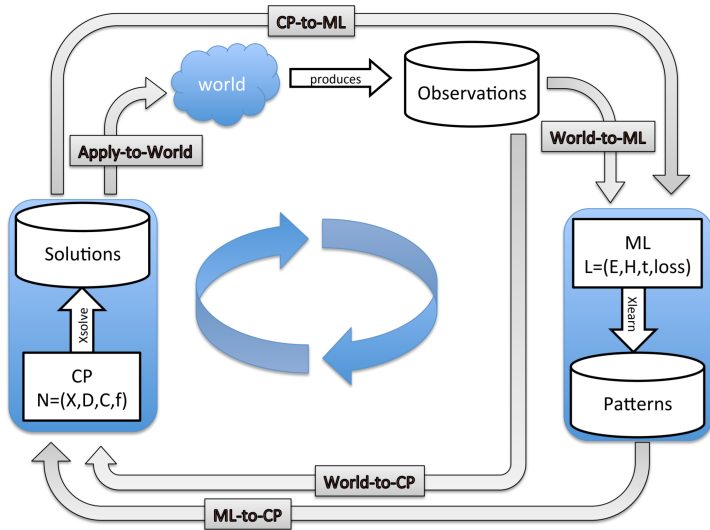
12 Steps to Success

**Constraints in an Uncertain World**

There is no “The Model”

Conclusion

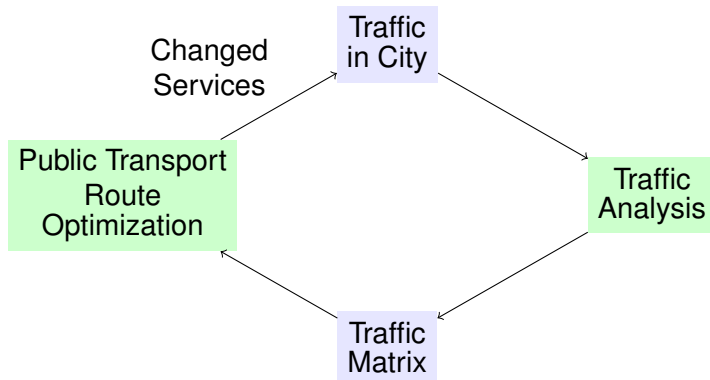
# The ICON Loop



# A Blueprint for Interaction

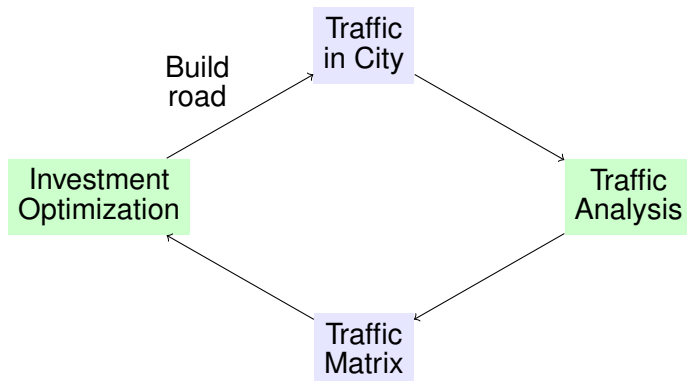
- Developed in the European ICON project
- Partners KU Leuven, Montpellier, Pisa, UCC
- Ways of combining Machine Learning with CP

## Example: Intra-City Transport



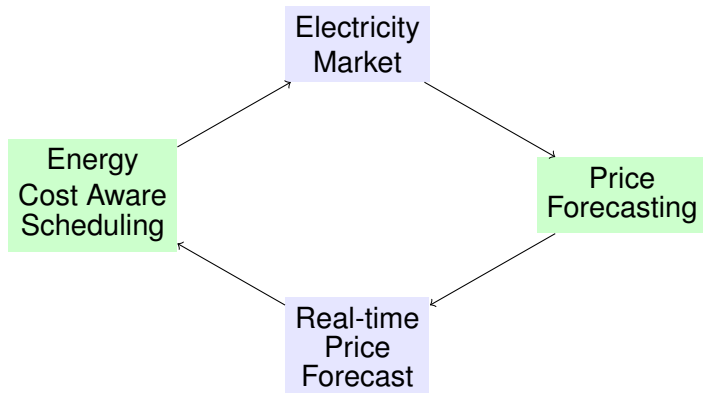
- Optimization only as good as data feeding into it

# Feedback May Lead to More Traffic



- The “world” reacts to changes
- That may be difficult to predict

# Reacting to Real-time Electricity Prices



- Good way to optimize cost individually
- May lead to oscillation if everybody does it

# Outline

The Bigger Picture

12 Steps to Success

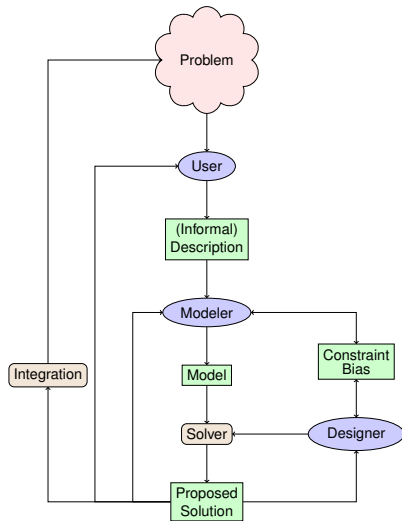
Constraints in an Uncertain World

There is no “The Model”

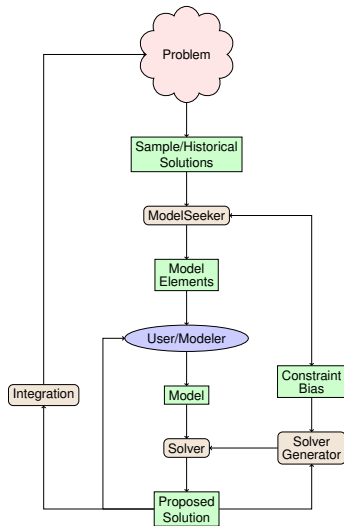
Conclusion



# Feedback Loops in Modelling



# The Future: Automated Modelling



# Outline

The Bigger Picture

12 Steps to Success

Constraints in an Uncertain World

There is no “The Model”

Conclusion

# Points to Remember

- A CP application is part of a larger system
- CP Model is rarely cause of project failure
  - No clear champion
  - No clear use case
  - Data not available/data quality
- Every problem is different, you decide what to model
- Understand the interaction between tools and problem