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New developments in logistics and data science

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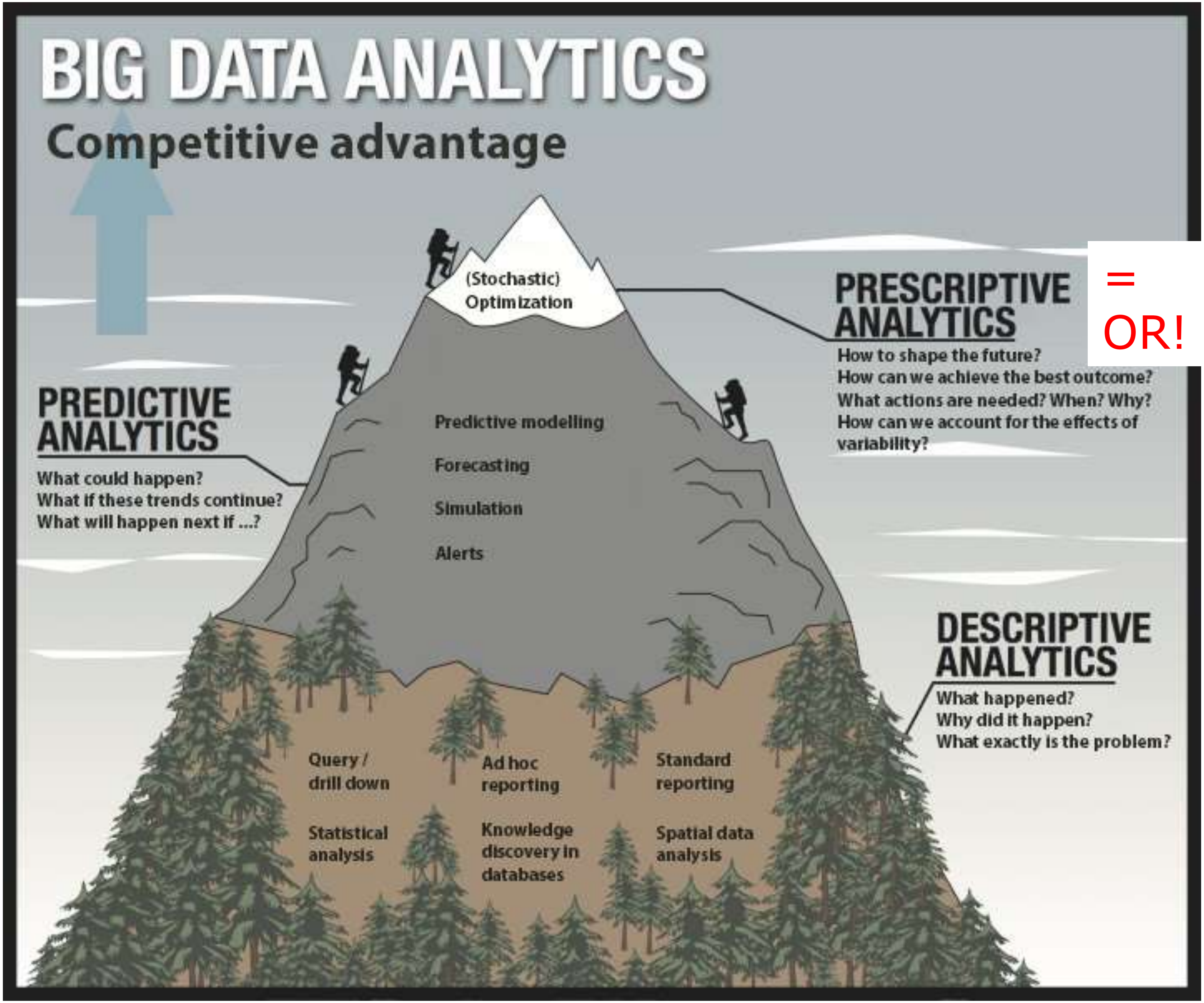
Overall Logistics trends

- Digitisation
- Data analytics
- Automation & Robotising & Autonomous Vehicles
- Environment & Electrification
- Urban logistics & last mile logistics
- Real-time decision making

All allow input from Operations Research and Analysis!


BIG DATA ANALYTICS
Competitive advantage
(Stochastic)
Optimization
PRESCRIPTIVE ANALYTICS
How to shape the future?
How can we achieve the best outcome?
What actions are needed? When? Why?
How can we account for the effects of variability?
PREDICTIVE ANALYTICS
What could happen?
What if these trends continue?
What will happen next if ...?
Predictive modelling
Forecasting
Simulation
Alerts
DESCRIPTIVE ANALYTICS
What happened?
Why did it happen?
What exactly is the problem?
Query / drill down
Ad hoc reporting
Standard reporting
Statistical analysis
Knowledge discovery in databases
Spatial data analysis

= OR!

Contents

- Intro to Service Logistics
- Predictive Maintenance and Dynamic Stock Control
- Service Control Towers
- Ship ETA prediction
- Synchromodal transport

Service Logistics

All logistics services after the sales

- Spare parts provision
- Repair, maintenance and overhaul
- Upgrades
- Information and community forming (Harley-Davidson)

Allows higher margins and more stable market than on new products (e.g cars, planes, chip machines, computers, military equipment, etc) (Aberdeen Group).

Challenges service logistics

- Demand is dispersed over the globe
- Demand in small numbers and often very critical.
- Demand arranged by service contracts with various response times (2h, 8h, next day,...)
- Hence logistics is important and has high margins (express companies love it)..
- Similar challenges apply to military logistics, especially on missions.

Dutch Service Logistic Forum

- Long standing research cooperation between universities and companies on a variety of service logistic aspects:

- Contract types (pay per part or pay per flying hour)

- Demand forecasting and predictive maintenance

- Obsolescence management

- Control tower development

Some research achievements

- Using Installed Base Information demand can be better forecasted (see Dekker et al. 2015) and inventories can be adapted beforehand!
- Part obsolescence can be predicted from supply chain data (varying leadtimes, last order long ago, low demand)
- Repair shop planning can be improved by dynamic priority setting, inventory control of piece parts
- Lateral transhipments and preventive emergency shipments improve performance.

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Predictive maintenance /Condition Monitoring (CM)

- Apply sensors to machines to measure state and predict failures.

- Typical in aircraft, trucks, heavy machinery, weaponry, etc.

- Gives warnings, reduces failure consequences and extends maintenance intervals.

- Companies, like Shell, Gen Electric, ASML have set global data analysis centres for CM info on major installations.

Predictive maintenance and stock control

- But what is the benefit for logistics? (right part at right place at right time).
- Medium-term (month) predictability of many CM techniques seems still low. Can we order the part in time? Is leadtime shorter than CM warning time?
- Hence it may yield little savings on logistics.

New model: Dynamic stock control

- Assume CM may give a signal at time t. This signal indicates that in periods $t+\tau$ a failure occurs with probability p_τ for τ in $[\tau_{low}, \tau_{up}]$. If no failure occurs, the signal was a false alarm.

- Costs: for holding parts, (regular/express) ordering, returning as well as for downtime for waiting for part.

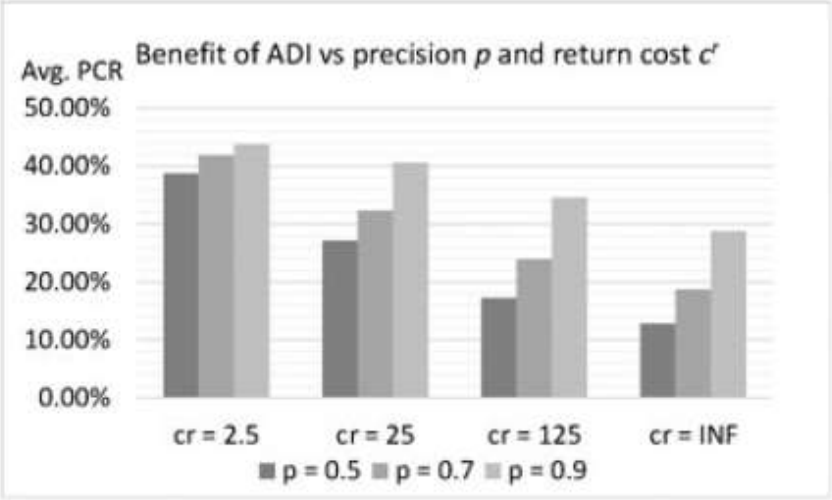
- Policy: state and pipeline stock dependent policy for ordering and returning items; leadtime L.

- Analysis: transform cost function and use $L^\#$ convexity to prove monotonicity. Use value iteration to evaluate policies.

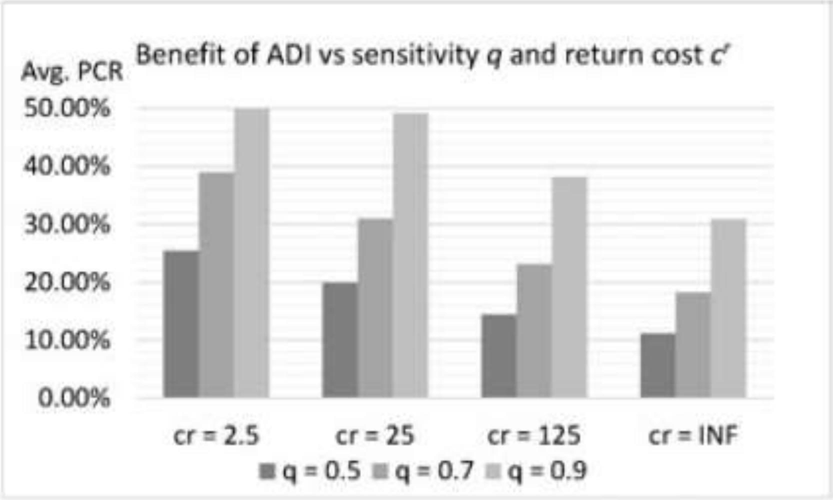
Dynamic stock control (ADI)

- Savings depend on precision p (probability that signal turns into failure), sensitivity q (ratio of predicted demand vs overall parts demand)

- Big requirement: part leadtime $L < \tau$ (warning interval), otherwise savings drop substantially.



a) Avg. PCR by using ADI with respect to p and c^r



b) Avg. PCR by using ADI with respect to q and c^r

- See Topan et al. 2018 IISE. Idea applied by ASML.

Intuition behind policy

- Low demand, high expensive parts: stock centrally
- High demand, low value parts: stock locally
- In between parts: stock in principle centrally, but in case of failure signals move to downstream unless transportation costs are high.
- Issue: you need at least two parts centrally.
- Idea of dynamic stock control can also be used for moving assets (ships, trucks, installed base forecasting).

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Service control tower

- Combines information on the status of all service processes in one IT system, typically with a dashboard and click-through system for detailed system info.

- Generates alerts for planners to take action

- (Preferably) advises planner on all kind of corrective and preventive actions (lateral transhipment, expediting, stock reallocation, emergency shipment)

- Service contracts have finite review periods!

Example dashboard

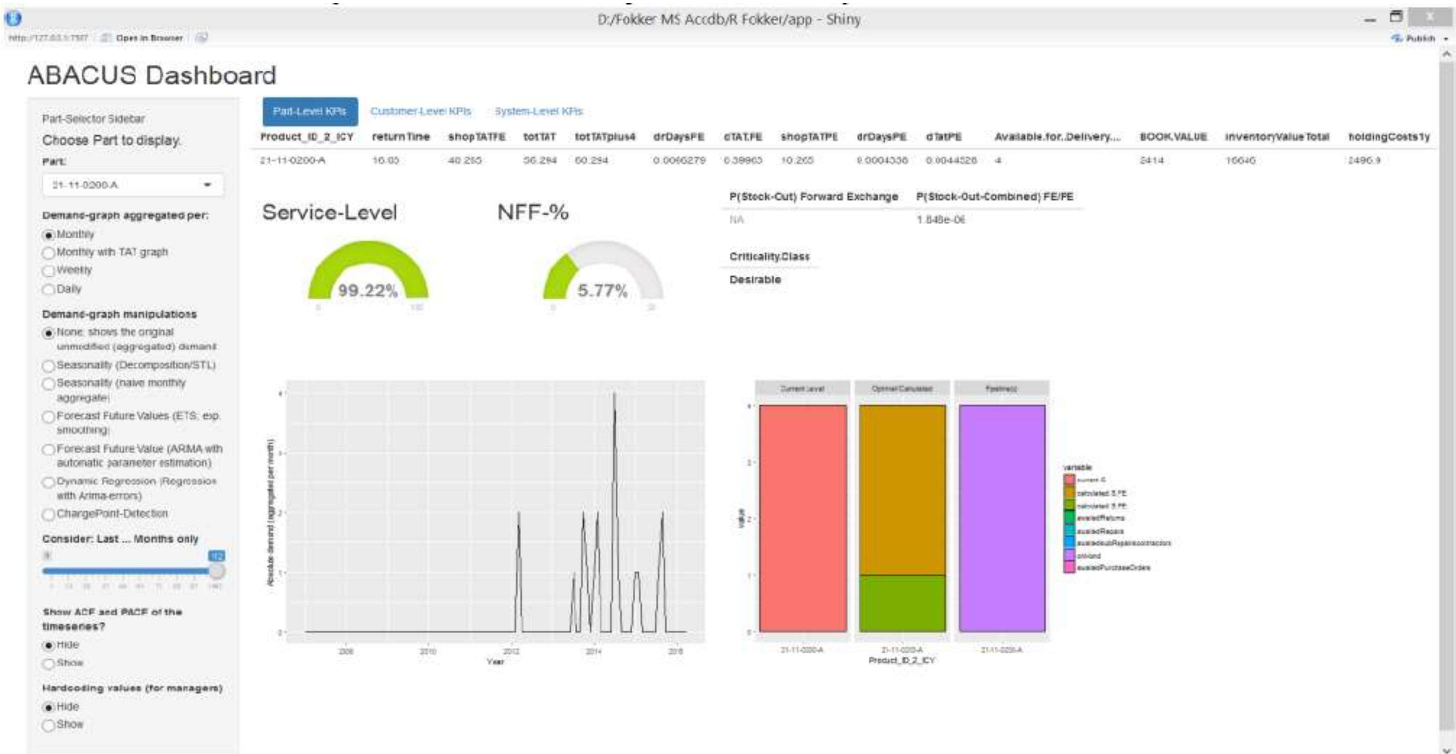
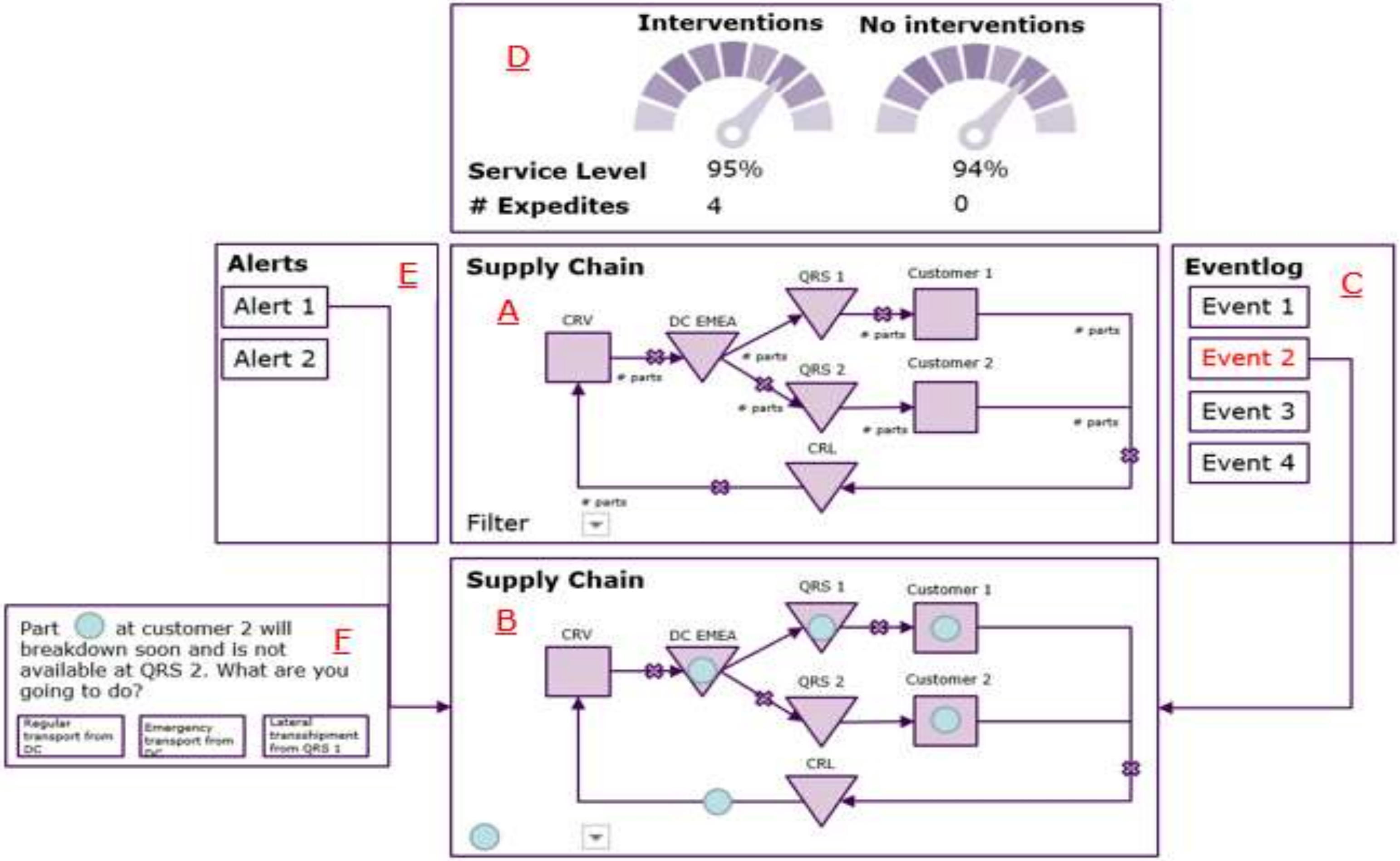


Figure 3: dashboards' main screen: part-level the dashboard

Example integrated dashboard



Practice and issues Control Towers

- Only two firms involved have a control tower, mainly combining information; other companies want to have one. Limited decision support so far available.

- Information should also be provided by other suppliers / parties in a standard format

- Processes should be split-up in phases and completion should be reported: e.g.
  - part arrived
  - initial inspection done
  - all piece parts needed are available
  - repair started

- Analytics should be performed on these data to allow predictions

Finite versus infinite horizon planning

- Tactical planning models typicallly oriented at infinite horizon planning.
- Eg. (S-1,S) or also called base stock policy with base stock S (replenish upon each demand). Assumption: demand is Poisson process with rate λ and leadtime L.
- Long-term Fill rate (= % of demand fulfilled from stock) is given by:

$$P(IL > 0) = P(D_L < S) = \sum_{k=0}^{S-1} \frac{(\lambda L)^k}{k!} e^{-\lambda L}$$

Finite versus infinite horizon

- Yet for a short period, the fill rate is a random variable, which can be higher (100%) or lower (0%)

- Control tower gives information on current situation:

  For a given starting situation: e.g S = 2,
  demand rate = 0.5 /month;
  penalty of stockout 10.000 euro
  present inventory: 0, one item to come in 1 month, the other in two months.
  two months to go to end of period

  should we advance the first replenishment with 2 weeks for 500 euro?

Issues CT decision support

- How to limit the number of options? Extra info needed may not be available.

- Exact calculations seem to be more difficult: explosion of possibilities. Heuristics may work well, but how far away are they from optimal?
  A simple rule saved Turkish Airlines 2 mln euro!

- Simulation is a much simpler technique and works fast.

- A Control Tower may be an interesting option for military (service) logistics. Definitely for the F35!

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Arrival time (ETA) prediction of ships

- The handling of an ocean ship in a port requires many parties (pilots, port master, tugs, boatsmen, terminal, surveyors and fuel barges)

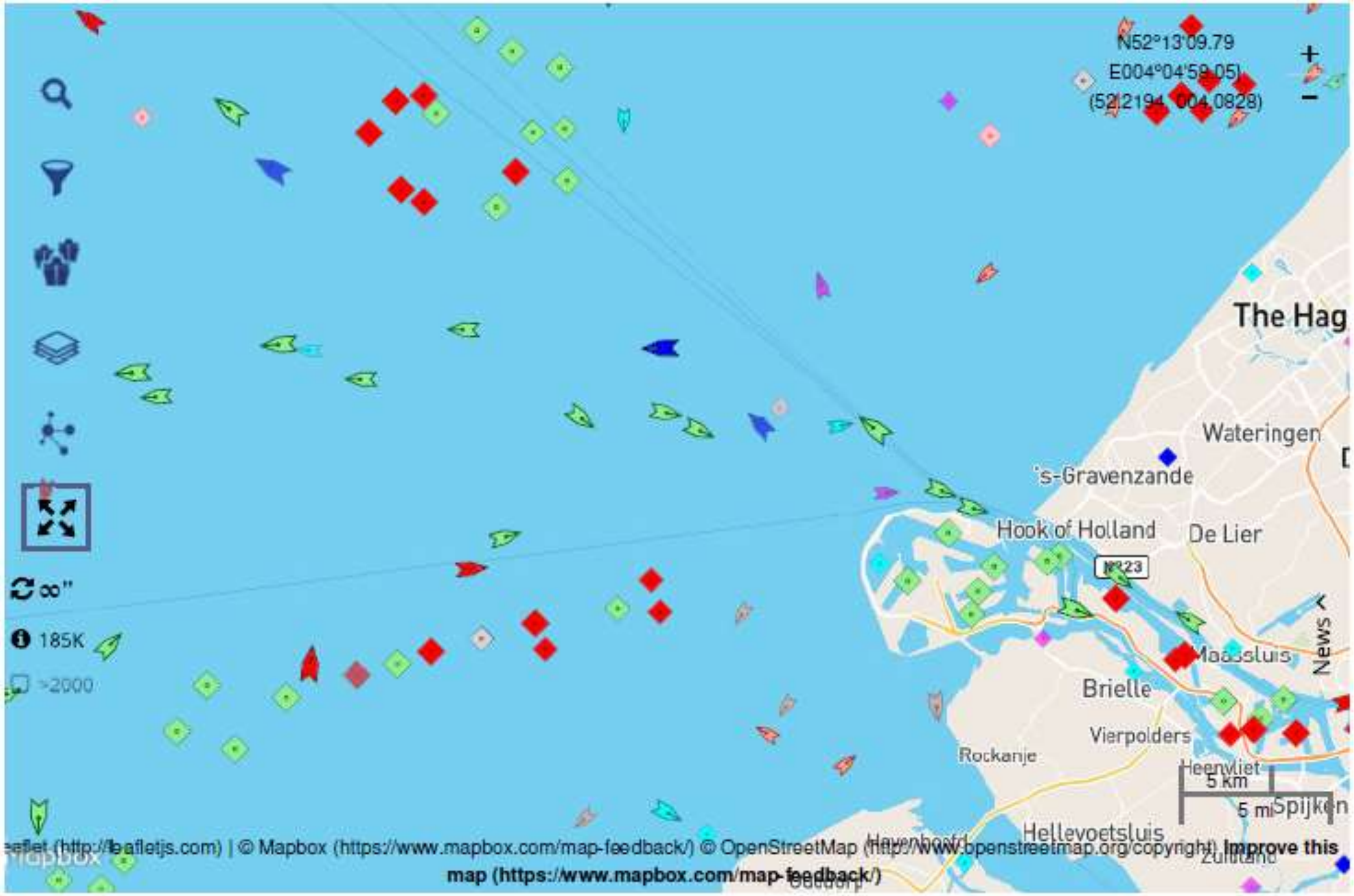
- The planning and scheduling of these parties benefit if they have more accurate information on arrival and departure times of ships.

- Shipping companies do not always share that information.

AIS data

- Automatic tracking system used on ships and by vessel traffic services (VTS)
- Exchange with other nearby ships, AIS base stations, and satellites.
- Real-time data: unique identification, position, course and speed.
- Required for ships with Gross Tonnage > 300 tonnes and passenger ships

Example



N52°13'09.79
E004°04'59.05
(52.2194, 004.0828)
185K
>2000
The Hag
Wateringen
's-Gravenzande
Hook of Holland
De Lier
Maassluis
Brielle
Vierpolders
Rockanje
Heenvliet
5 km
5 mi
Hellevoetsluis
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Arrival (ETA) prediction

- Machine learning can be used to predict the ETA. Exact model depends on additional user info (shipping line or 3rd party)
- Predict ETA through: ETA = present moment + remaining sailing time. Direct prediction of date does not work!
- Machine learning works if there is a lot of replication of events and data!

ETA(D) ML method results

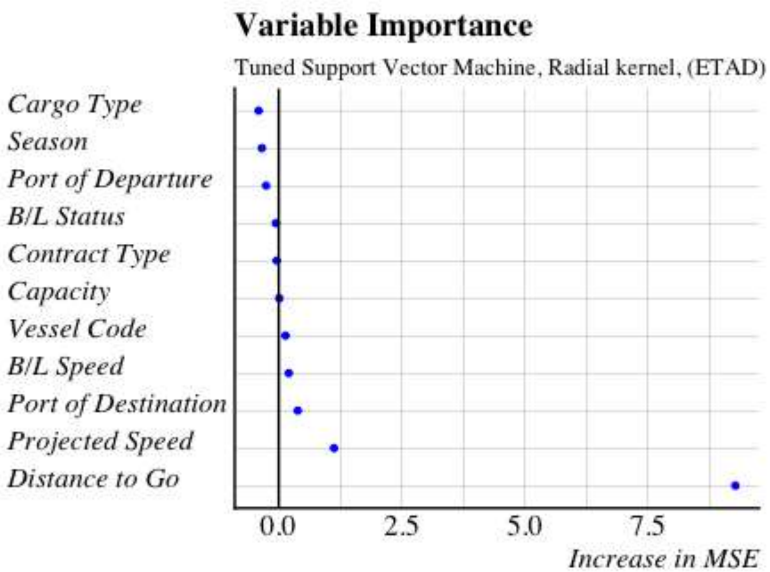
SVM – support vector machine
RF – random forest
BL – base line model parameters
Tuned – parameters optimised

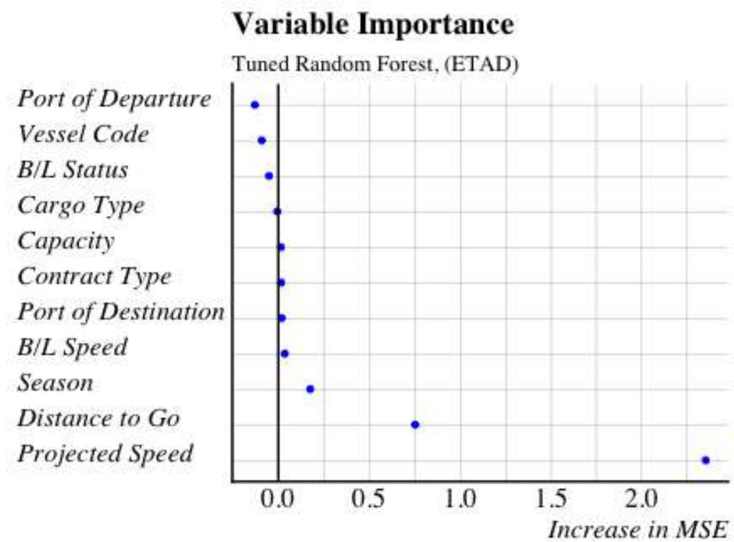
	Model	MAE	RMSE	MAPE	Kernel
BL	SVM	1.82	2.62	6.15%	Radial
BL	RF	1.58	2.49	4.31%	
Tuned	SVM	1.62	2.70	4.27%	Radial
Tuned	RF	1.49	2.33	4.06%	

Performance is better than captain's (MAE 4 hr)

The estimate from the First Noon Report are worse, than those at departure port (D).

ETA – interpretation ML results





Variable importance:
left Support Vector Machine,
right Random Forest.
Note the difference.

ETA prediction ships

- A better forecast is nice, but only it should create value by allowing a better berth planning.
- Machine learning does not work if humans change the arrival time (e.g. Anchoring in case of waiting for an oil price increase).
- Legal rules regarding demurrage block an overall optimal solution.
- Analytics approach can also be applied to other transport chains and identify irregularities!

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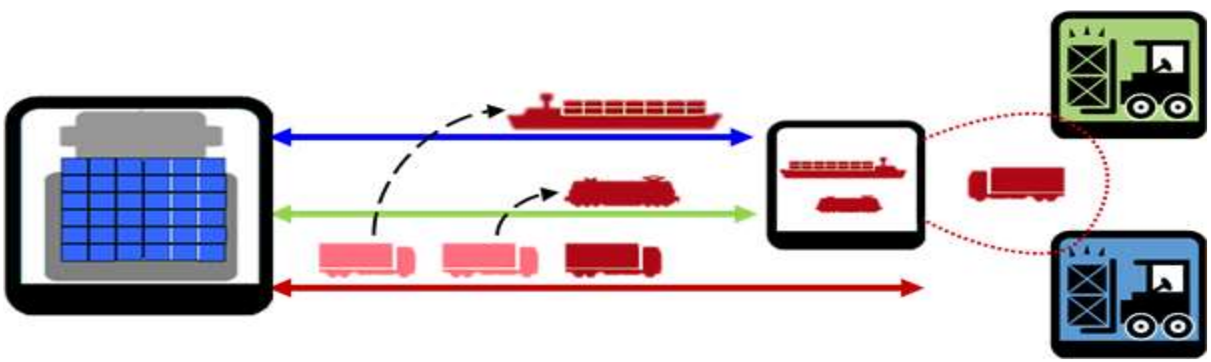
Synchromodal transport

- Transport of containers in multiple modes with the possibility to switch between modes in real-time.
- Example: use barge from Rotterdam to Duisburg if it is on time, else switch to truck.
- Flattens fluctuations in transport demand and mitigates delays.



Extended gateways

- Terminals develop inland networks with terminals and high transport frequencies

- Ocean part of container shipping gets cheaper because of economies of scale, yet land part gets more expensive because of increased road charges.

Synchromodal planning

- Real-time planning with dynamic bottleneck identification, adaptive dynamic programming
- A good network with routing flexibility at nodes works well.
- This also allows a floating stock concept, where goods are sent before demand is realised (Ochtman et al 2009).
- Agent-based technology is proposed to route the containers one by one.

Conclusions

- Civil research on logistics also yields interesting ideas for the military.

- Service logistics, predictive maintenance and control towers seem particular attractive to military and the F35!

- Synchromodal transport and ship eta prediction improve transport chains.

- AI is very attractive and provides new applications, but also has limitations