The Business Intelligence Model (BIM)

Representation, Reasoning, and Application

MORE-BI Keynote, ER 2015
Stockholm, Sweden
October 22nd, 2015
Jennifer Horkoff

Outline

- Business Intelligence
- BIM Motivation and Design Input
- Illustrative Example
- Concepts
- BIM Indicator Reasoning
- Semantics and Formal Reasoning
- BIM in Action: Hospital Case Study
- Extensions and Current Work
  - Tactical BIM
  - Five forces model
  - Stress testing strategic goal models

Business Intelligence

- (from Wikipedia) **Business intelligence** (**BI**) is the ability for an organization to take all its capabilities and convert them into knowledge, ultimately, getting the right information to the right people, at the right time, via the right channel.

- Produces large amounts of information
  - leads to the development of new opportunities for the organization.

- Opportunity + strategy provides an organization with:
  - a competitive advantage in the market
  - stability in the long run (within its industry)

Business Intelligence

HighJump.com

Interfacing.com

Pentaho.com

Business Intelligence Model (BIM) Motivation

- BI Systems are widely used, but…
  - Systems are still very technical and data-oriented
  - Hard (for non-technical people) to understand what the data means
  - Hard to design queries or make new reports
  - Gap between business and IT-supplied data

- Business people would rather reason using their own terms:
  - Strategic objectives, business models and strategies, business processes, markets, trends and risks

- Raise the level of abstraction of BI systems using a modeling language
  - Uses concepts more familiar to business users

Business Intelligence Network (BIN)

- BIM is part of the Business Intelligence Network, a Canadian project for the definition of the next generation of Business Intelligence Technologies.

- 2009-2014

- http://bin.cs.toronto.edu

- Covering work by several authors in several publications:

Jiang et al. ER11	Barone et al. ER11
Barone et al. CAiSE12	Horkoff et al. ODBASE12
Francesconi et al. ER13	Horkoff et al. SoSym14
Topaloglou & Barone CAiSE'15	Francesconi et al. RCIS15
Maté et al. ER15	Paja et al. (to be submitted)

BIM Development: Design Input

- Many existing languages and techniques for capturing business strategy
  - Strategy Maps and Balanced Scorecards (Kaplan & Norton)
  - Business Motivation Model (OMG)
  - Dynamic SWOT (Strength, Weakness, Opportunity, Threat) Analysis (Dealtry)
  - Goal Models

- These techniques offer many useful concepts, but often not clearly defined
  - visions, objectives, goals, means, strategies, plans, metrics, indicators, measures, strengths, weaknesses, threats, vulnerabilities, opportunities, etc..

- BIM aims to select a consolidated set of core concepts

Illustrative Example: BestTech

- Generic company developing and selling consumer electronics
  - Model contents extracted from real-world DataMonitor reports
- BestTech has a number of concerns, including increasing sales, maintaining revenue growth and reducing risks
- It's concerned about increased competition and the economic slowdown (in 2012), but is also interested in low-cost financing
- Wants to answer some strategic questions, for example:
  - *Develop technology in-house or acquire technology through acquisition?*
  - *Given business metrics and target values, what increase in sales volume can be expected?*
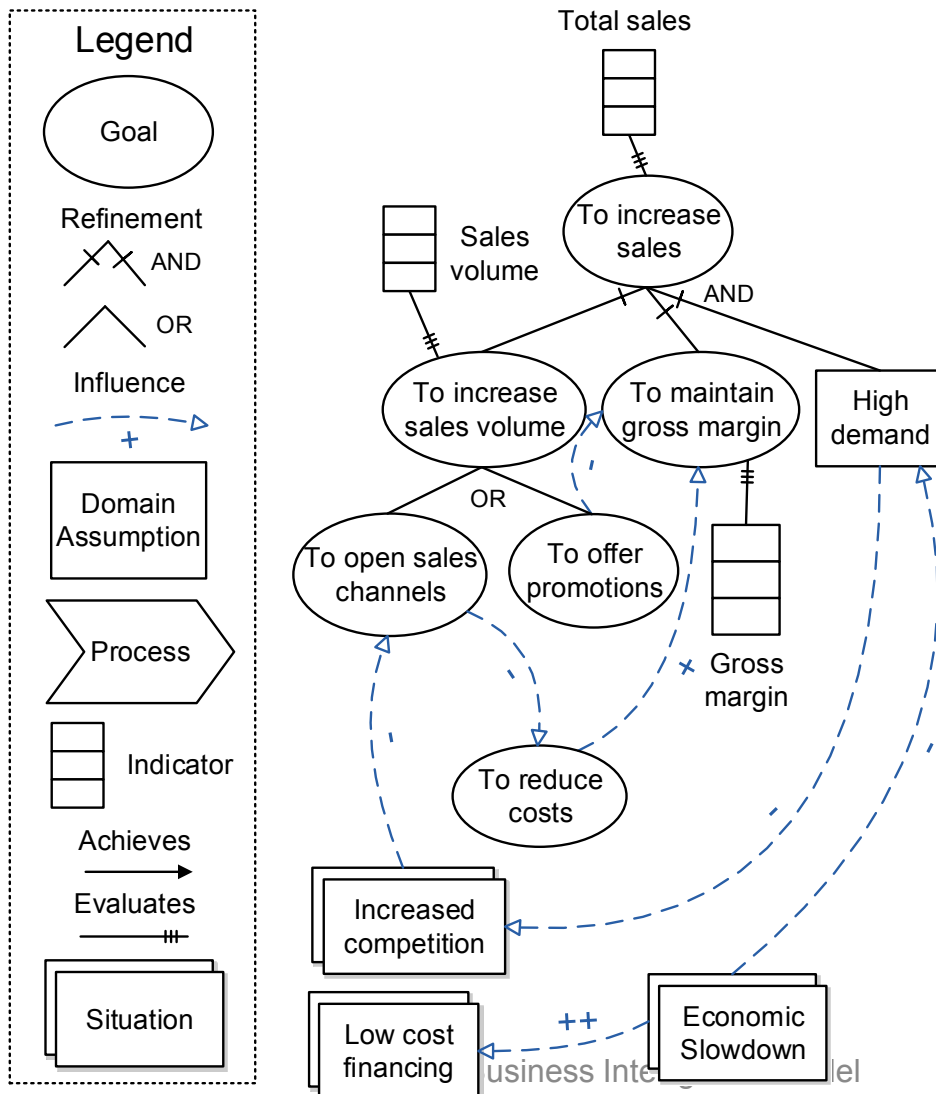
BIM Concepts

- Goal: an objective of a business
  - Can be AND/OR refined
- Process: achieves goals
- Domain Assumption: properties required for goal satisfaction
- Situation: internal or external factors influencing fulfillment of goals
  - Could be SWOT for a particular goal
- Influence: situations/goals influence situations/goals
  - Can be logical (implication) or probabilistic (P(A|B))
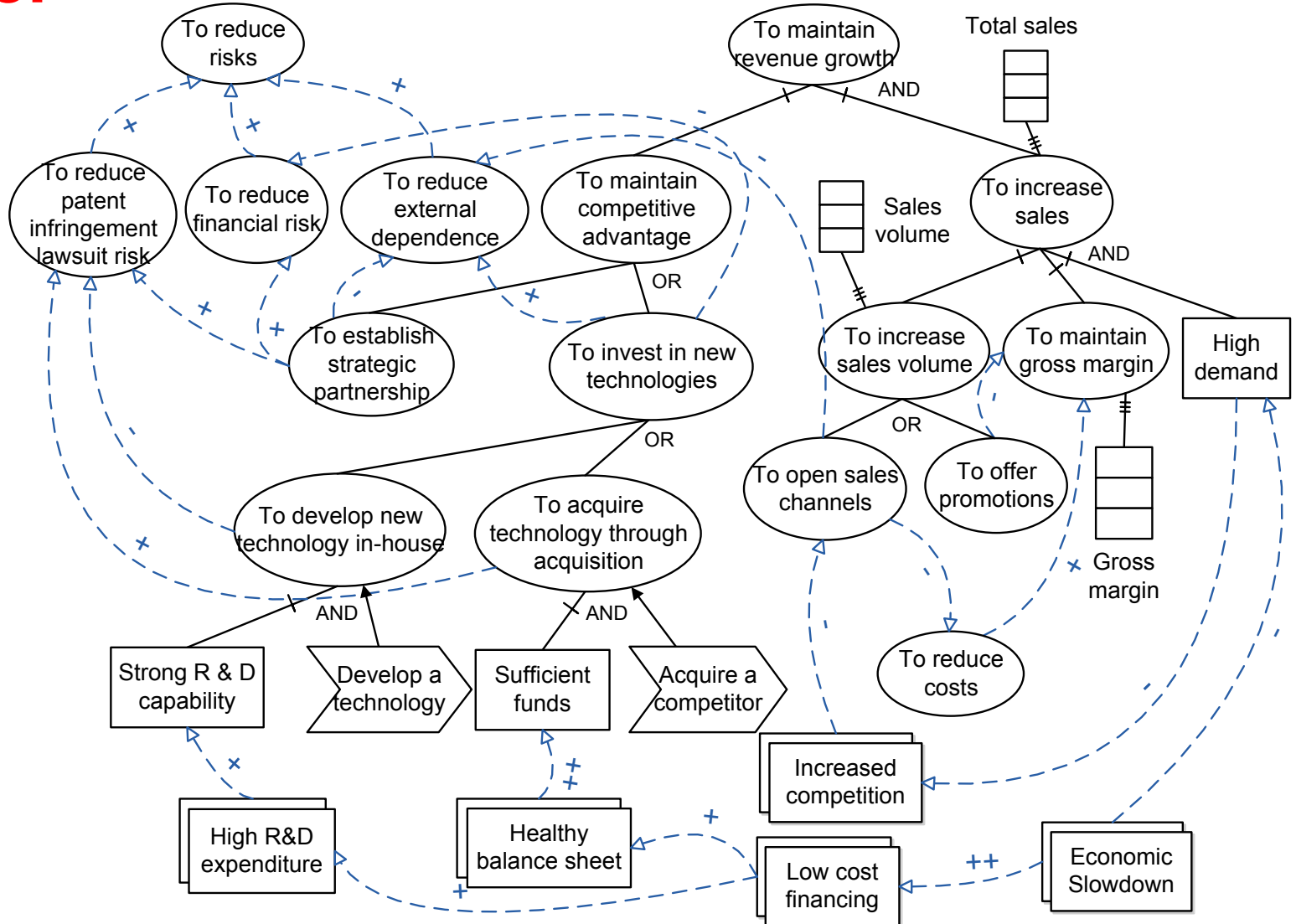- Indicator: performance measure, quantifies aspects of strategic activities (KPI)

To increase sales

Develop a technology

Sufficient funds

Increased competition

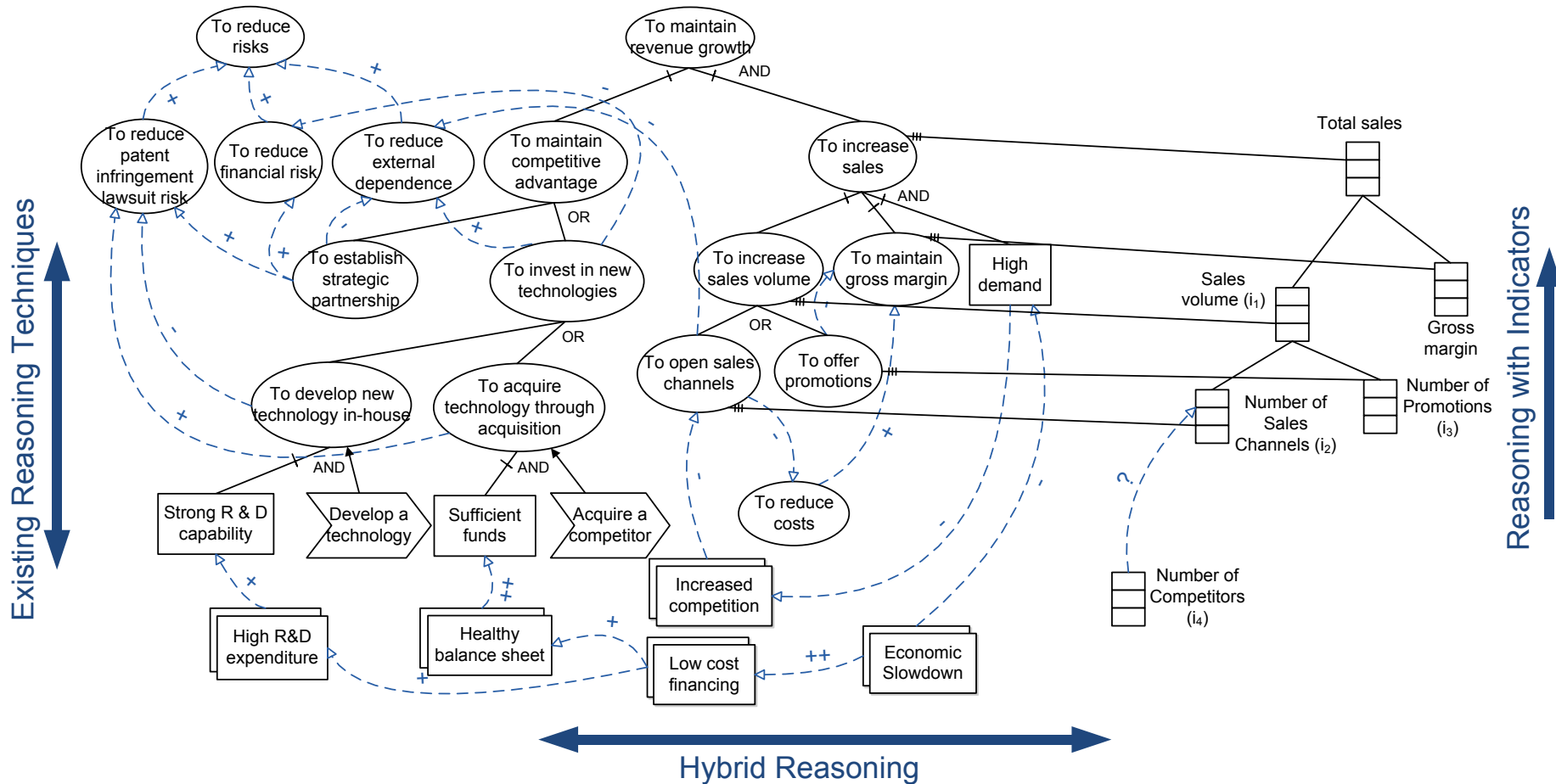Total sales
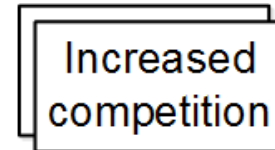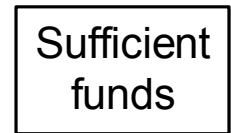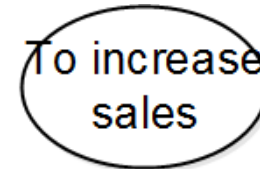
BestTech Example

Bigger

BIM Reasoning: Two Approaches

- Reasoning with BIM allows an organization to answer strategic or monitoring questions.

- (1) Qualitative and Quantitative Reasoning using indicators
  - Not using formal semantics
  - Some mapping to existing reasoning procedures (and subsequent semantics)
    - Goal model reasoning
    - Probabilistic decision analysis
    - Reasoning with indicators
    - Hybrid reasoning (Reasoning with incomplete indicators)
- (2) Qualitative reasoning with DL reasoners
  - Requires formal semantics (show later)
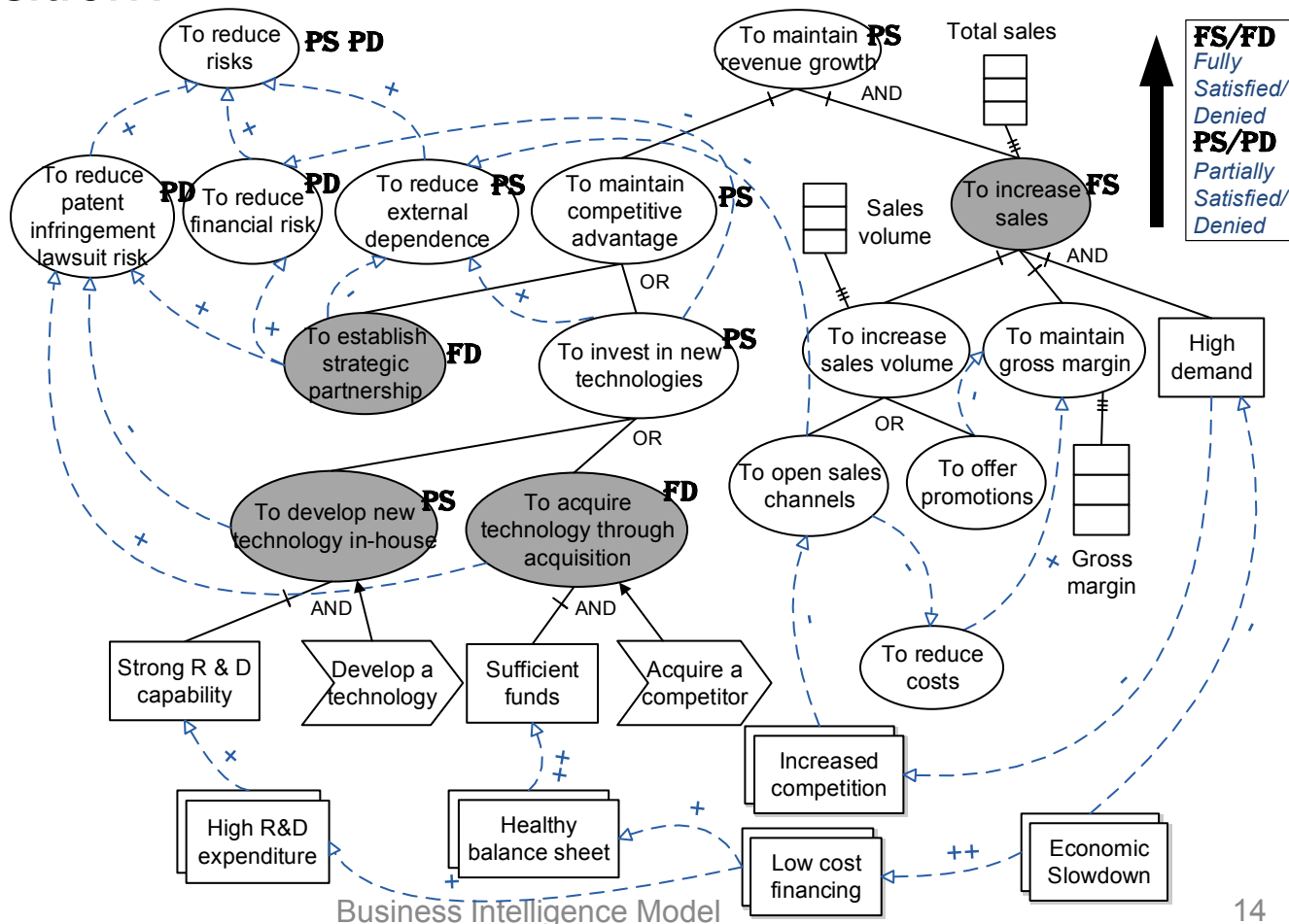
Reasoning Overview

Evaluation of Specific Strategies

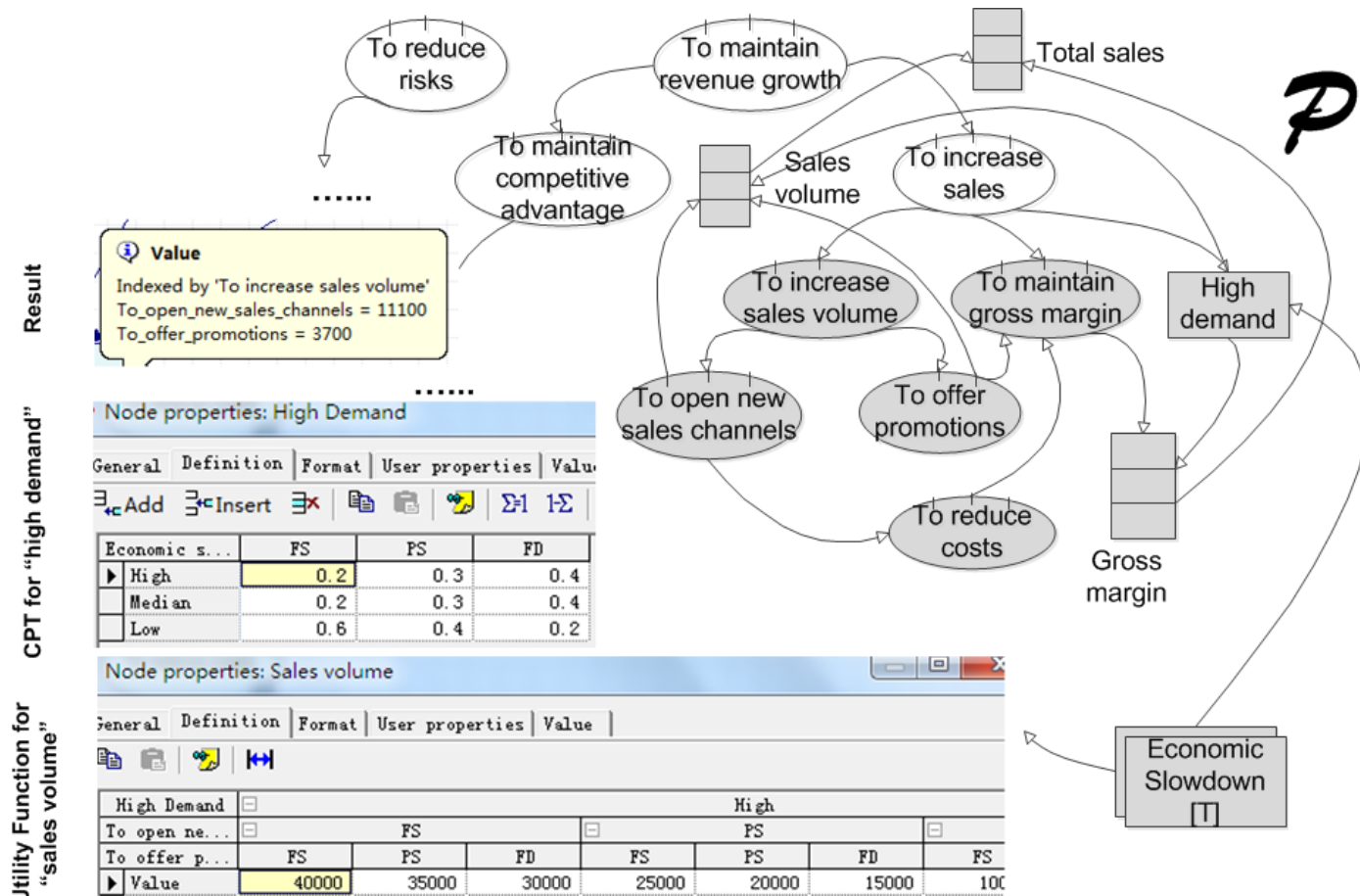- *Develop technology in-house or acquire technology through acquisition?*

Goal Model Reasoning (Giorgini et al.), mapped to BIM

FS > PS > PD > FD

Business Intelligence Model

Probabilistic Strategy Evaluation

- *Should we develop technology in-house or acquire technology through acquisition?*

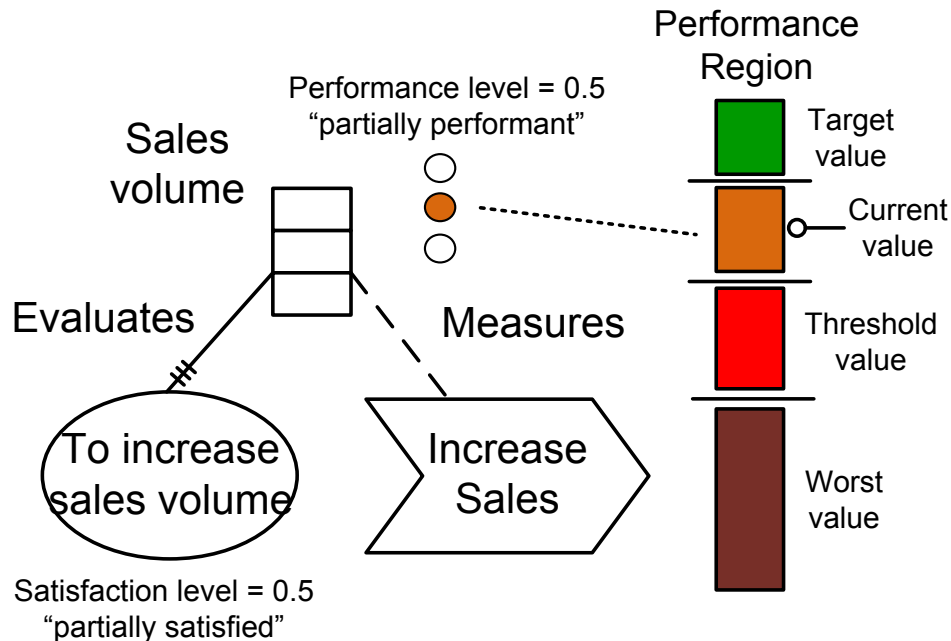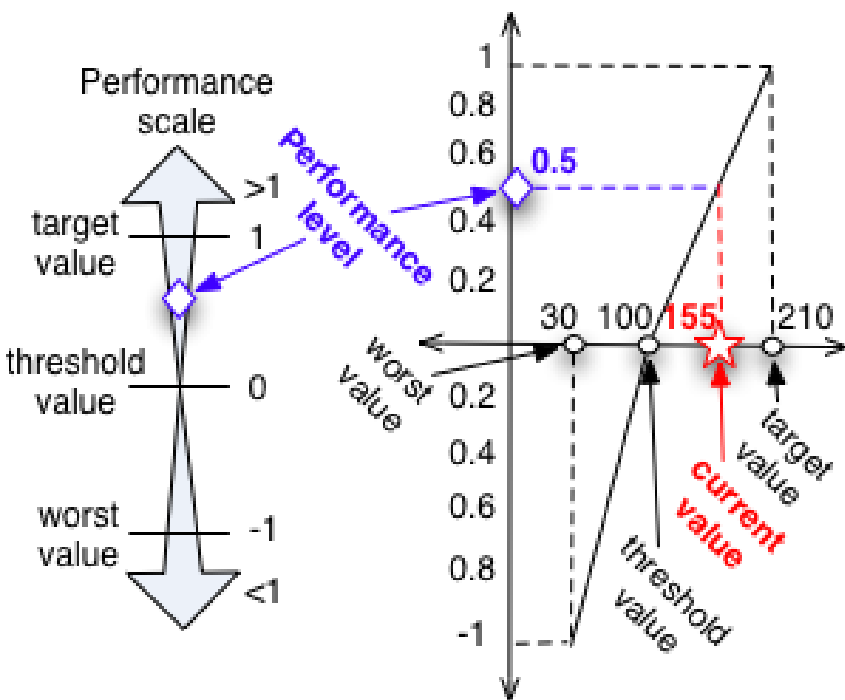Influence diagrams (Howard & Matheson), mapped to BIM

BIM Reasoning: Two Approaches

- Reasoning with BIM allows an organization to answer strategic or monitoring questions.

- (1) Qualitative and Quantitative Reasoning using indicators
  - Not using formal semantics
  - Some mapping to existing reasoning procedures (and subsequent semantics)
    - Goal model reasoning
    - Probabilistic decision analysis
    - Reasoning with indicators
    - Hybrid reasoning (Reasoning with incomplete indicators)

- (2) Qualitative reasoning with DL reasoners
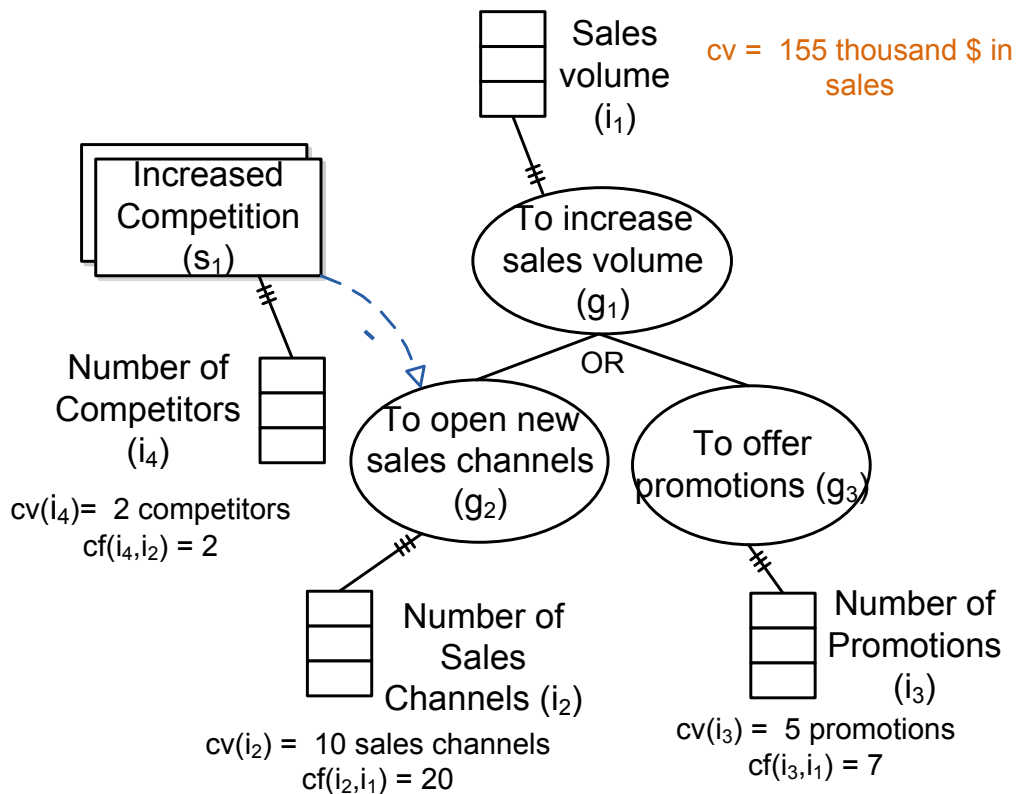 - Requires formal semantics (show later)

Reasoning with Indicators

Parmenter, D.: Key Performance Indicators (2007)

Indicator Reasoning using Business Formulae and Unit Conversion

Sales volume (i_1)

cv = 155 thousand $ in sales

Increased Competition (s_1)

To increase sales volume (g_1)

OR

Number of Competitors (i_4)

cv(i_4)= 2 competitors
cf(i_4,i_2) = 2

To open new sales channels (g_2)

To offer promotions (g_3)

Number of Sales Channels (i_2)

cv(i_2) = 10 sales channels
cf(i_2,i_1) = 20

Number of Promotions (i_3)

cv(i_3) = 5 promotions
cf(i_3,i_1) = 7

Indicator Reasoning using Business Formulae and Performance Levels
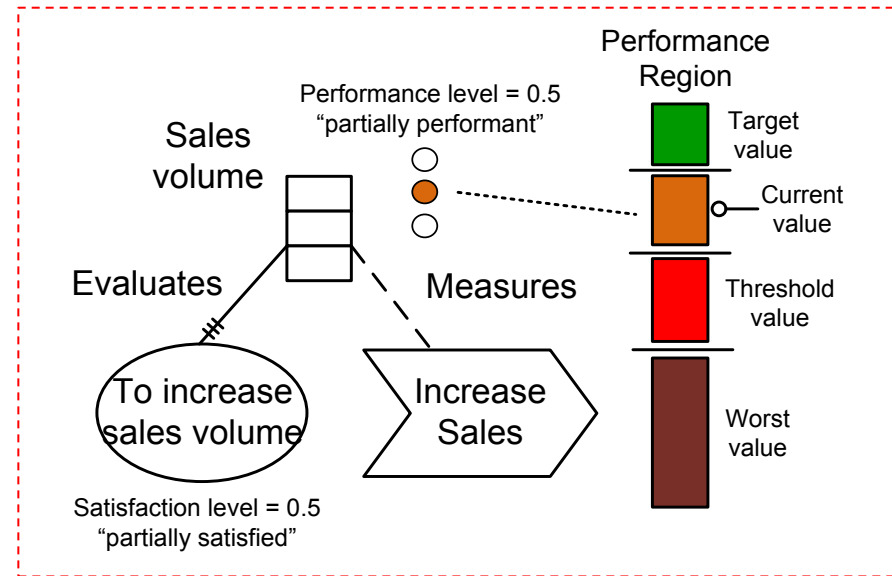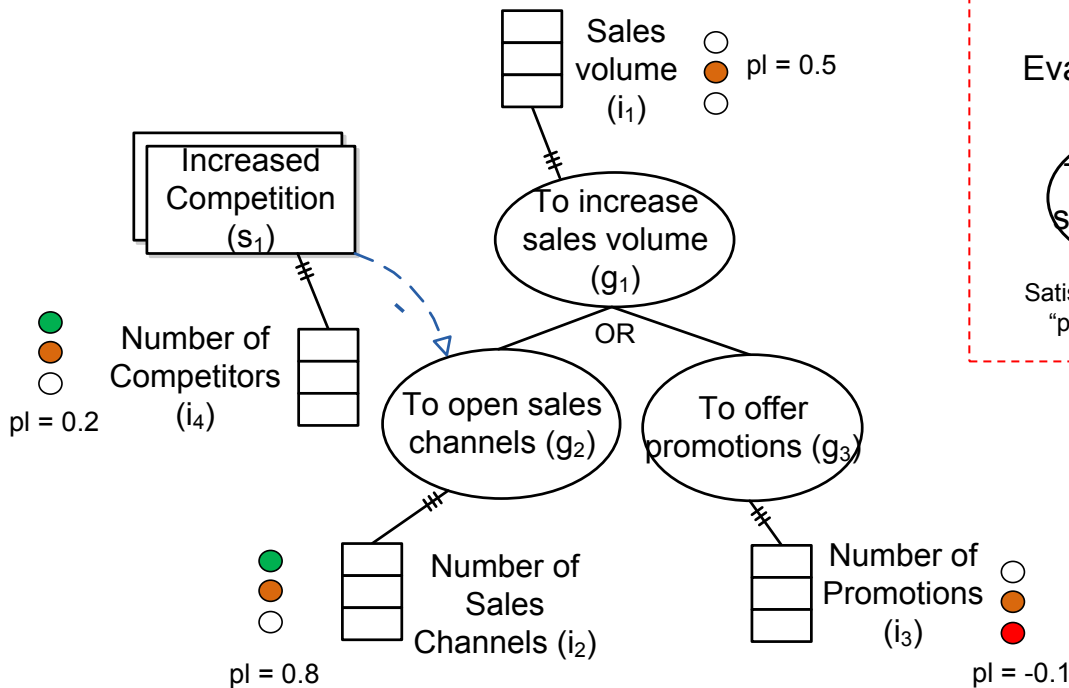
Hybrid Reasoning (Reasoning with Incomplete Indicators)
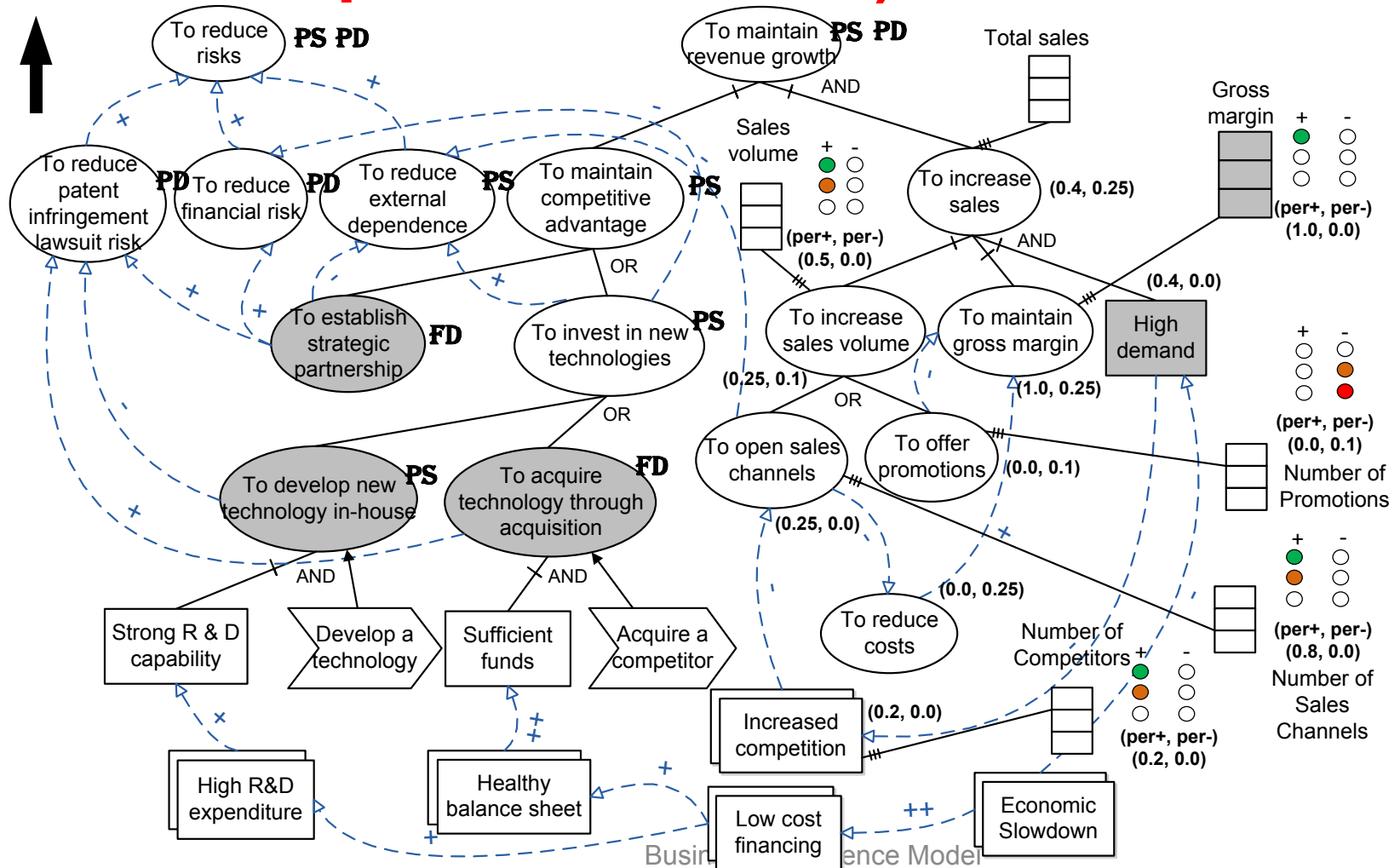
BIM Reasoning: Two Approaches

- Reasoning with BIM allows an organization to answer strategic or monitoring questions.

- (1) Qualitative and Quantitative Reasoning using indicators
  - Not using formal semantics
  - Some mapping to existing reasoning procedures (and subsequent semantics)
    - Goal model reasoning
    - Probabilistic decision analysis
    - Reasoning with indicators
    - Hybrid reasoning (Reasoning with incomplete indicators)

- (2) Qualitative reasoning with DL reasoners
 - Requires formal semantics (show later)

Formal Semantics in Description Logic

- Select set of "core" BIM concepts and relationships

- Determine how concepts and relationships interact
  - What is allowed, what is not?
  - Small changes

- Formal definition of language concepts and relationships
  - Using description logic, e.g.,
    - **Class:** Goal **SubClassOf**: Situation
    - **Property**: influences   **Domain**: Situation **Range**: Situation **InverseOf**: infBy

BIM Language Semantics and Reasoning: Metamodel

- Language "metamodel"/upper-level ontology
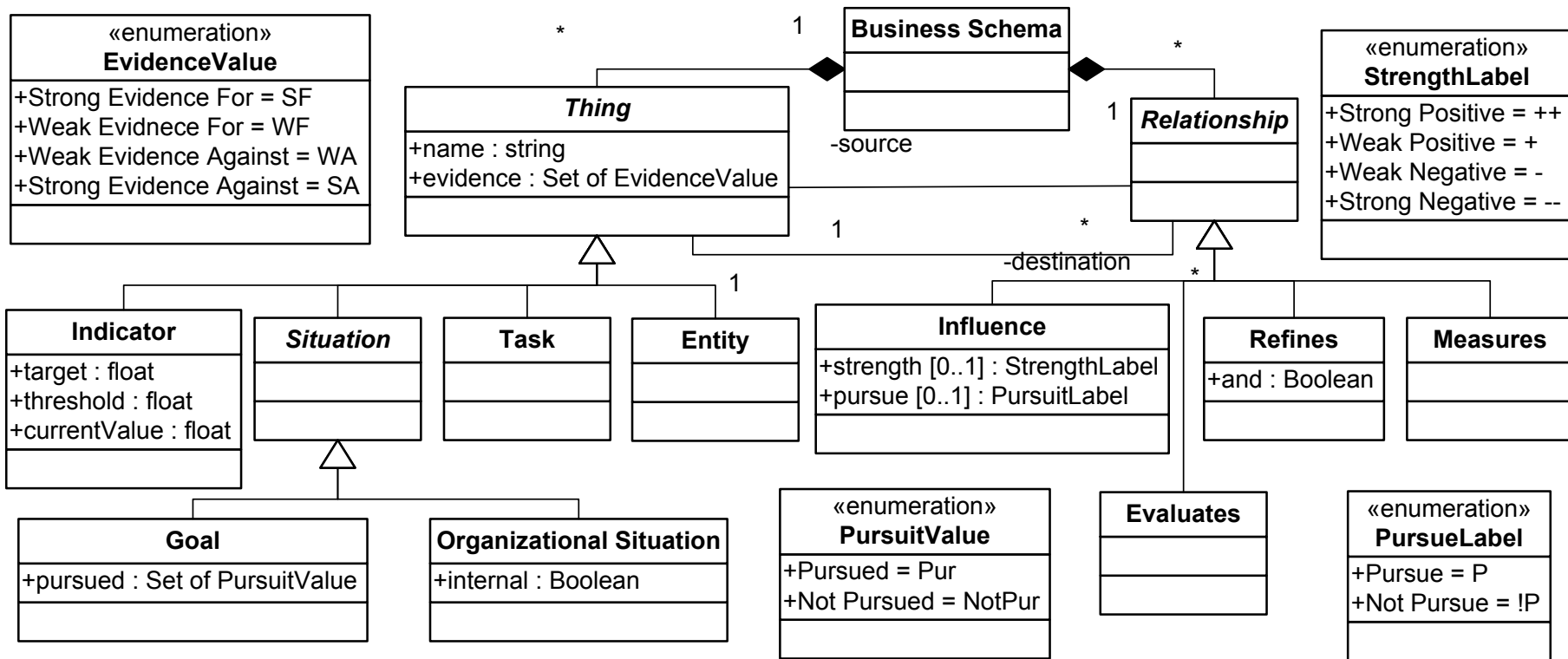
Reasoning with BIM in DL

- All things are BIM *Things*, e.g.,

- BIM considers multiple sources and degrees of *Evidence*, either for or against each thing

- Uses a qualitative evidence scale similar to the satisfaction/denial scale used in goal models
  - **S**trong/**W**eak evidence **F**or/**A**gainst a thing, **SF**, **WF**, **WA**, and **SA**

  Property: evidence **Domain**: Thing **Range**: {SF,WF,WA,SA}
  Class: SFThing **EquivalentTo:** Thing **and** (evidence **value** SF)

- "Evidence for…?" is answered depending on the specific type of thing:
  - *satisfaction* of goals, *occurrence* of situations…

  Property: satisfied **Domain**: Goal **SubpropertyOf:** evidence
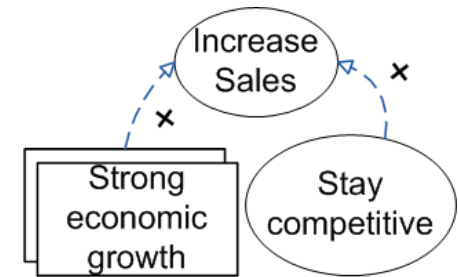
Reasoning with Evidence and Influence

- We use rules for propagating evidence on influence links adapted from Goal Modeling (e.g., Giorgini et al., 2004)
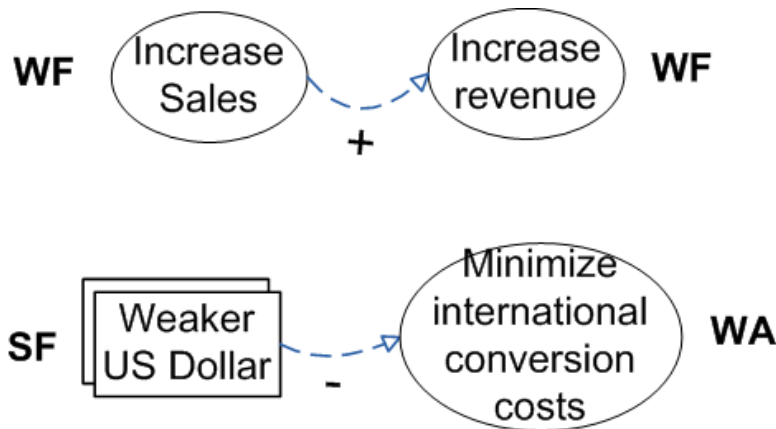
Source Evidence Set Contains	Link Label Contains			
	++	+	-	--
SF	SF	WF	WA	SA
WF	WF	WF	WA	WA
WA	WA	WA	WF	WF
SA	SA	WA	WF	SF

- Sample axioms (2 of 16):

(infBy+ **some** WFThing) **SubClassOf** WFThing
(infBy- **some** SFThing) **SubClassOf** WAThing

SF	Strong For
WF	Weak For
WA	Weak Against
SA	Strong Against

Reasoning with BIM Models

- "What if?" scenarios
  - In our example, what if we develop technology in house and don't acquire technology externally?

  Class: InHouse   **SubClassOf:** SF_Thing

  Class: Acquisition   **SubClassOf:** SA_Thing

  - Then check which elements are subclasses of SF_Thing, WF_Thing, etc.

- Consistency testing
  - Find classes which may always be empty/inconsistent
  - Find errors in using the language constructs

- Automatic classification of defined concepts…

BIM Meta-properties

- Allow users to introduce more specialized concepts from other languages (e.g., Vision, Mission, Strategy (BMM), Softgoal, Hardgoal (GM), Initiative (BSC))

- Use six meta-properties over elements
  - *duration* (long-term/short-term), *likelihood of fulfillment* (high/low), *nature of definition* (formal/informal), *scope* (broad/narrow), *number of instances* (many/few), *perspective* from BSC (financial/ customer/ internal/ learning and growth)
  - E.g., **Vision** is a "goal with a long duration, broad scope, low chance of fulfillment, informal definition, and few instances"

Have a worldwide presence

Class: Vision **EquivalentTo:** Goal **and** (duration **value** long-term) **and … and** (nature_of_definition **value** informal)

Extensibility

- Consider coverage of concepts in existing languages

BIM Concept/ Relationship	Covers Concept (Language), possibly using metaproperties
Goal	End, Vision, Objective, Goal (BMM); Soft/Hardgoal (GM), Objective (SWOT); Mission, Vision, Goal/Objective (BSC/SM);
Task	Means, Course of action, Mission, Strategy, Tactic, Business process (BMM); Task (GM); Strategy, Initiative (BSC/SM);
Situation	Internal/External Influencer (BMM), Issue (SWOT)
Situation + influence	Strength, Weakness, Opportunity, Threat (SWOT)
Indicator	Metric (BMM), Measure (BSC/SM)
Indicator target	Target (SWOT), Target (BSC/SM)
AND/OR Refinement	AND/OR Decomposition (GM); aggregation (UML)
Influence	Contribution (GM)

BIM Reasoning Compared

DL Reasoning	Reasoning with Indicators
Semantics inherent to the language	Mapping semantics from existing frameworks (fit not perfect)
Allows publishing of generic BIM models as ontologies on the semantic web	Allows probabilistic analysis (if data is available)
Easily extensible	Allows quantitative reasoning with indicators
Reason with incompleteness	Allows for hybrid reasoning
Detect inconsistencies	
Automatically classify defined concepts	

OWL Protégé Implementation

BIM Tool www.cs.toronto.edu/~jm/bim/

- Downloadable, open source, Eclipse-based

BIM IN ACTION

A Hospital Case Study

Daniele Barone*, Thodoros Topaloglou**, and John Mylopoulos*
*Computer Science Department, University of Toronto, Canada
**Rouge Valley Health System, Toronto, Canada

- Use **BIM** in the definition of **requirements** for a Business Intelligence (BI) Solution at the **Rouge Valley Health System (RVHS)**

- RVHS is a two site hospital with 479 beds in the east greater Toronto area

- Has a corporate performance management framework and corporate scorecard

- In 2010-11, RVHS launched two transformative IT initiatives
  - create a competency center in business process management
  - develop an enterprise Business Intelligence system

Case Study Questions

- Questions:
  - What is the value of BIM in a BI implementation?
  - Is the initial BIM language sufficient to support the business modeling needs of the case study?
  - Who are the users of BIM?
  - Is there a development methodology that matches with BIM?
  - How does BIM map to data?

Method: AGIO (Actor Goal Indicator Object)

- Started with BIM
- Eventually developed AGIO method which builds on BIM, simplifying the language
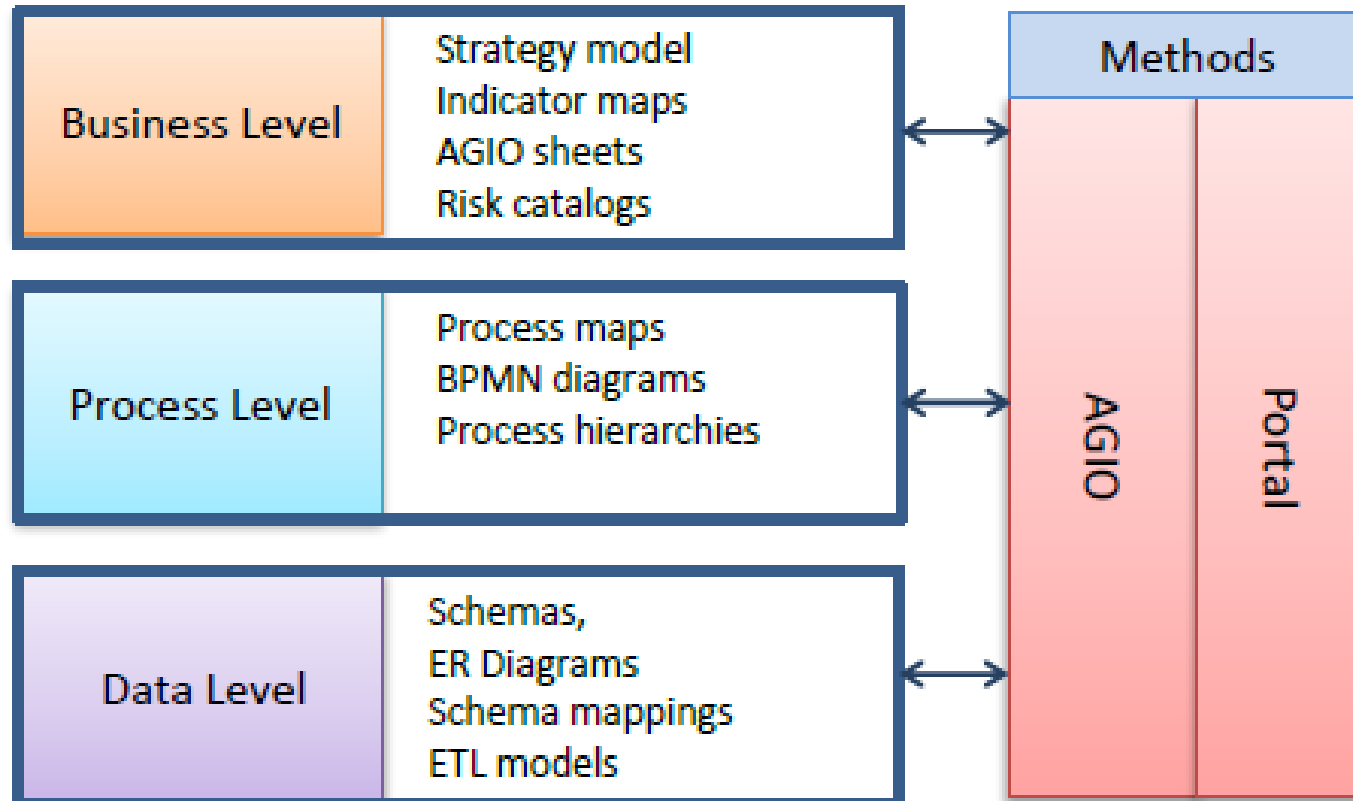
Business Problem: Emergency Department Patient Flow

ED Length of Stay

| Arrival | Triage | Registration | | Non Physician Initial Assessment (NPIA) | Physician Initial Assessment (PIA) | Special Consult | Clinical Decision Unit (CDU) | | Disposition Decision | Patient Left ED |
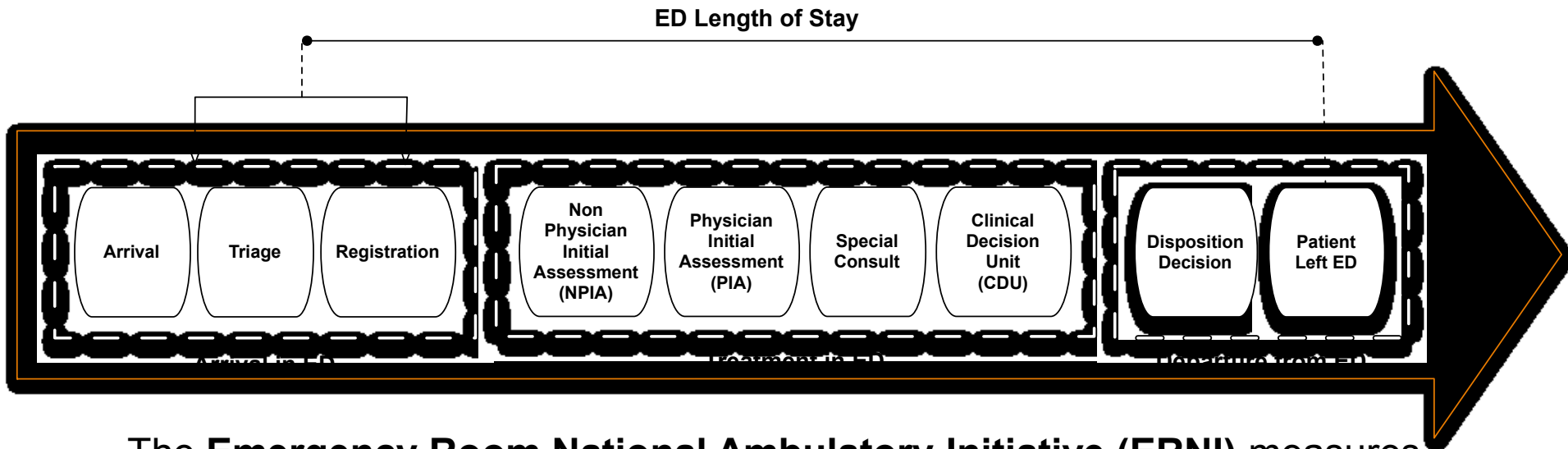
The **Emergency Room National Ambulatory Initiative (ERNI)** measures and reports how long patients spend in Emergency Departments. Clinicians (will) collect **38 data elements** (*DART*) related to the **patient journey** through the Emergency Department from arrival to departure.

Improve the quality of Patient care

CITY UNIVERSITY LONDON

The Seven Phases for the Design of the Emergency Department Data Mart:
A Mixed approach
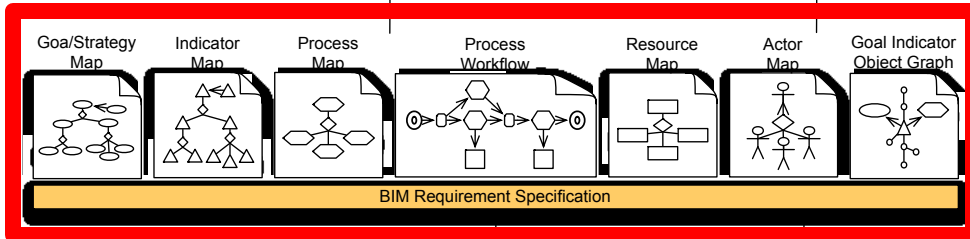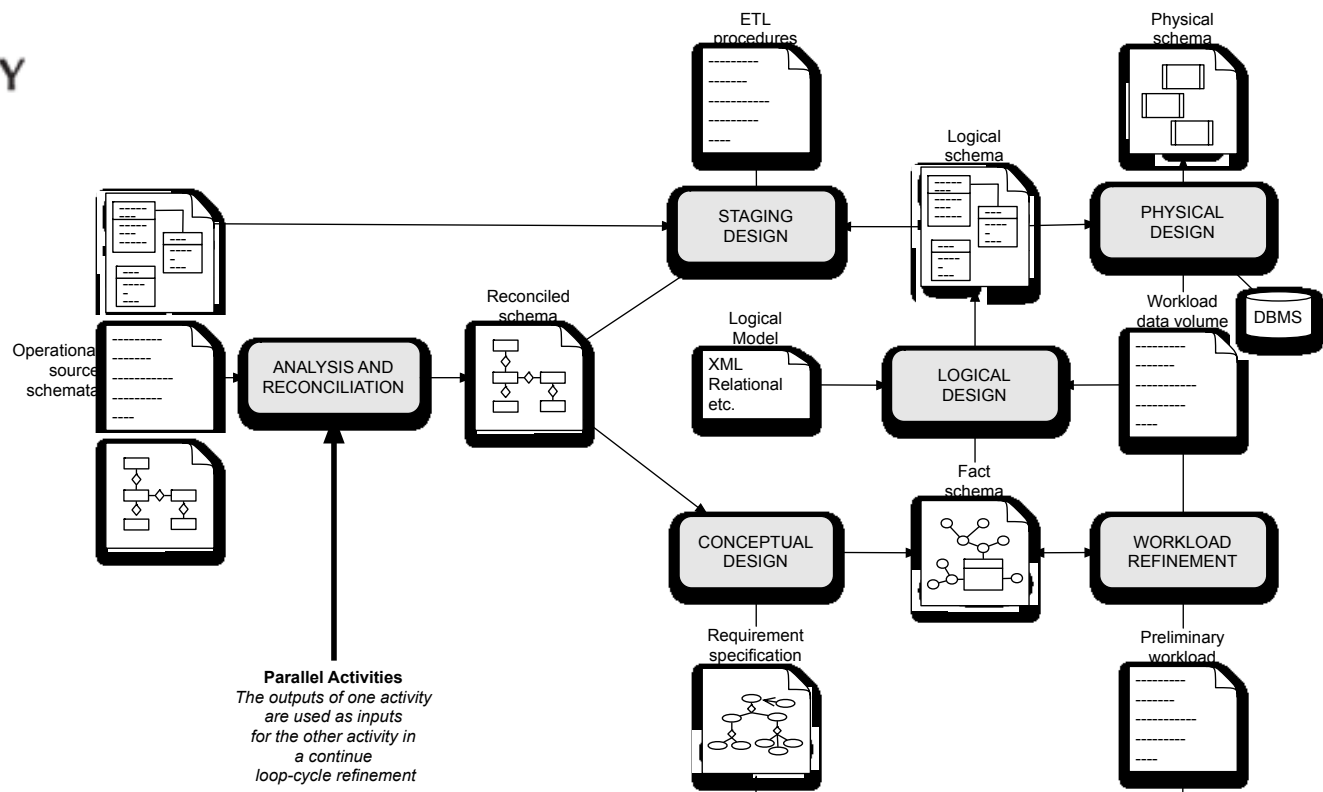
Requirement Analysis with BIM

Requirement Analysis: AGIO

Dart

- 38 Indicators

AGIO Sheet

- Informal Requirement

AGIO Graph
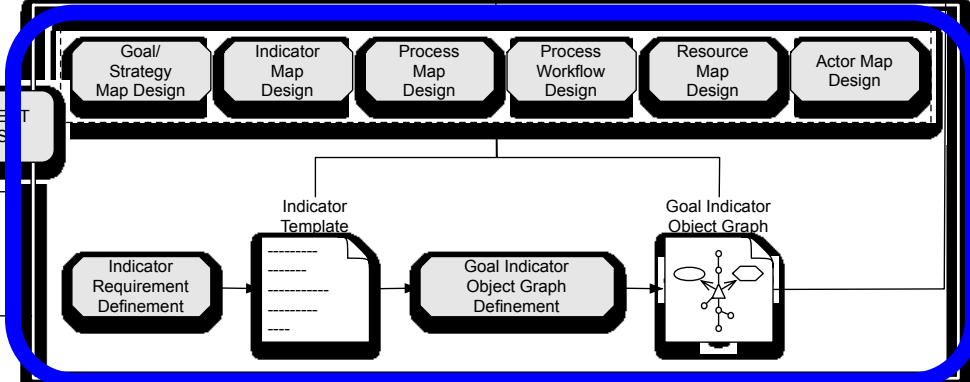
- Formal Requirement

Requi...

Daily Access Report Tool DART
Corporate Activity

For Date: 4/14/2011

Rouge Valley HEALTH SYSTEM

Metric outperforming target　　Metric within 25% of target　　Metric underperforming target by more than 25%

NaN or **Infinity** = no records for denominator

Rouge Valley Centenary

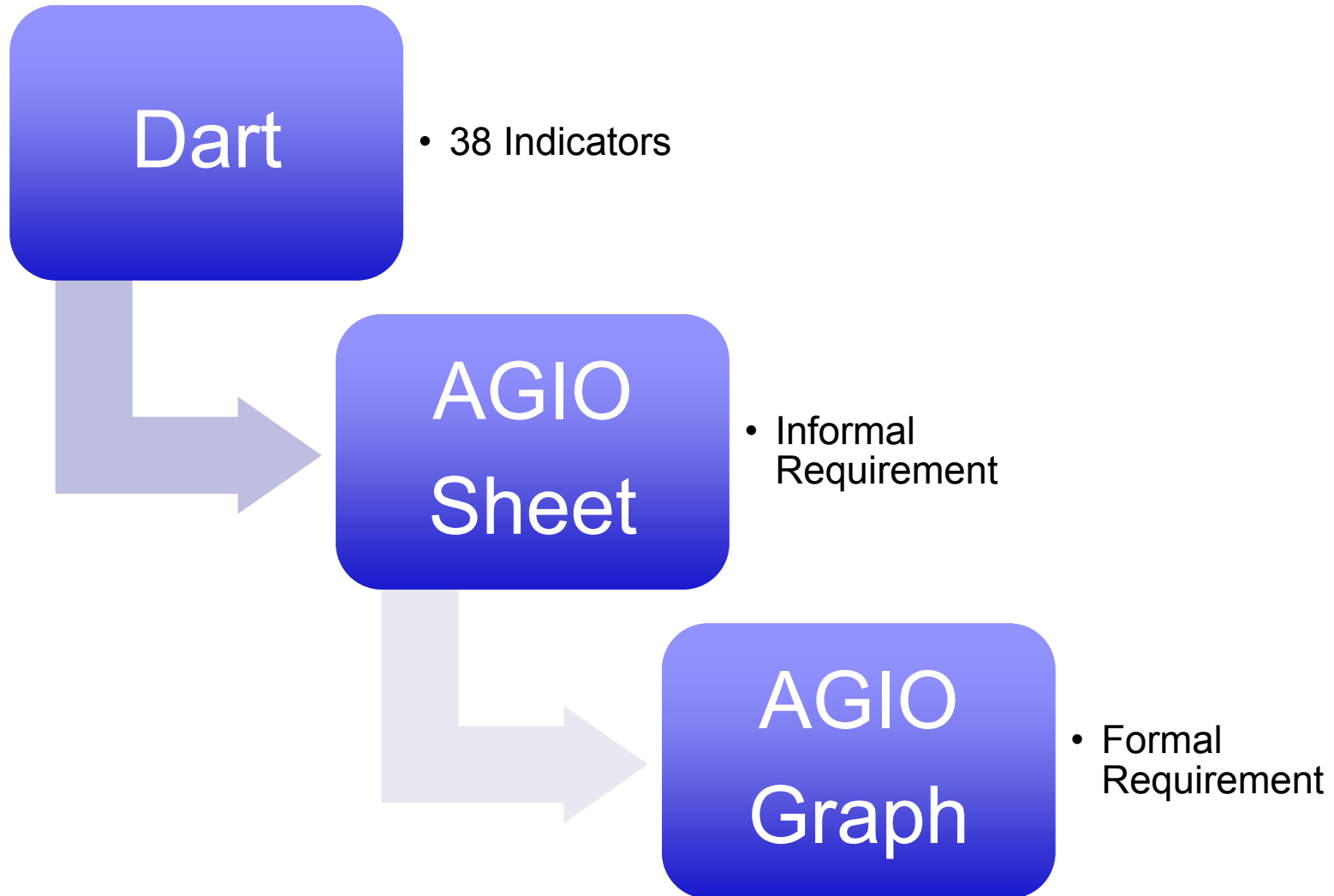| Area	Indicator	4/14/2011	7 Days	30 Days	Targets
Admits and Discharges					
	Percent of Acute Inpatients Discharges by 11:00	29.8 %	23.9 %	16.3 %	16.5 %
	Number of ALC Patients Currently in Hospital	36.0	33.0	33.0	28
	Number of Patients Past Expected Date of Discharge	136.0	137.0	138.0	30
Emergency Department					
	Number ED Registrations (Avg Registrations in ED with no constraints)	151	163	157	136
	Number Departed ED Visits (#) (excludes LWBS)	132	154	147	136
	Number of admitted patients with LOS <=8hrs	8	5	5	5
	Percent ED Visits Admitted	15.9 %	11.0 %	10.2 %	10.5 %
	ED LOS at 90th percentile in hours (only excluding LWBS)	8.3	10.2	9.0	9.9
	Average ED stay - all dispositions in hours	3.6	6.2	5.2	5.9
	Number of CTAS I-III non-admitted patients with LOS <=8hrs	56	83	77	59
	Number of CTAS IV-V non-admitted patients with LOS <=4hrs	48	39	42	37
	Number of ED Patients Left Without Being Seen	0	1	2	4.0 %
Public Emergency Department Indicators (in Hrs)					
	90th percentile LOS for Adm and NonAdm Pts w/complex conditions	9.6	14.7	12.5	11.9
	90th percentile LOS for NonAdm pts w/minor or uncomplicated conditions	3.5	4.3	4.1	4.6
Pay for Results					
	Admitted patients with LOS <=8hrs (%)	38.1 %	29.4 %	33.3 %	36.0 %
	Non-admitted CTAS I-III<=8hrs (%)	96.6 %	92.6 %	93.3 %	92.0 %
	Non-admitted CTAS IV-V<=4hrs (%)	90.6 %	84.8 %	86.3 %	84.0 %

Requirem

Dar

Technical Term	Non-technical user description
General Description	
ID	7
Name	Percentage of Emergency Department Patients left without being seen (LWBS)
Description	The indicator calculates the percentage of Emergency Department Patients that leave the ER department without seen by the doctor
Scorecard(s)	Daily DART Report
Organization context	
Goal	Reduce the percentage of left without being seen Emergency Department Patients
Goal' responsible	ER Deparment Manager
Measured Object (Process and/or Resource)	Document left without being seen Emergency Department Patients
Measurement	
Metric description	Percentage of Emergency Department Patients left without being seen
Numerator	Count the number of Emergency Department Patients **[Field X: AccountNumber = +E*]** left without being seen **[Field x: ErDispositionED = "LWBS"]** in a specific period of time **[Field X: ErTriageDateTime]**
Denominator	Count the total number of patient registrations **[Field X: AccountNumber = +E*]** in a specific period of time **[Field X: ErTriageDateTime]**
Unit of measure	
Extra details for	
Dependencies	
Frequency	
Datamart(s) and	
DataMart(s)	
Dimensions and	
Performance Par	
Type	
Target	
Threshold(s)	
Worst value(s)	
Parameters moti	
Interpretation	
Datasources Det	
IT Responsible	
Sources	
Source Numerato	
	FIELD x: ErTriageDateTime
	FIELD x: TriageLevelID
	TABLE x: AdmDischarge
	FIELD x: ErDispositionID = "LWBS"
Source Denominator	Look the sournce numerator field
Indicator Data Collection Process	1)Data are collected by Unit Clerks and inserted in Meditech-ER-Registration Routine
	2) Information are replicated in the DR repository
Security	
Confidential level	All with exception of Public
Visualization	
Dimension Configurations for user	SMT (Senior Management Team) - TIME(Daily) LOCATION{FLOOR = {CONSTRAINED TO EMERGENCY DEPARTMENTS})
	ER Department Manager - TIME(Daily) LOCATION{FLOOR = {Constrained to the specific emergengy department the manager manages})
Information and Data Quality	
Issues	Not relevant issues are documented

Overlay box:

- General description
- Organization's Context
- Measurement
- Data Mart and Navigability
- Performance Parameters
- Data sources details
- Security / Data Access
- Information and Data Quality

ormal
equirement

Business Intelligence Model

40

Requirement Analysis: ASIS

Who — ER Manager

<responsible for>

Why — Reduce **the percentage of ER Left Without Being Seen** patients

Which (perspective) — Location, Time, Patient

What — Physician Initial Assessment

<evaluate> — <measure>

Percentage of ED LWBS patients **(ID 7)**
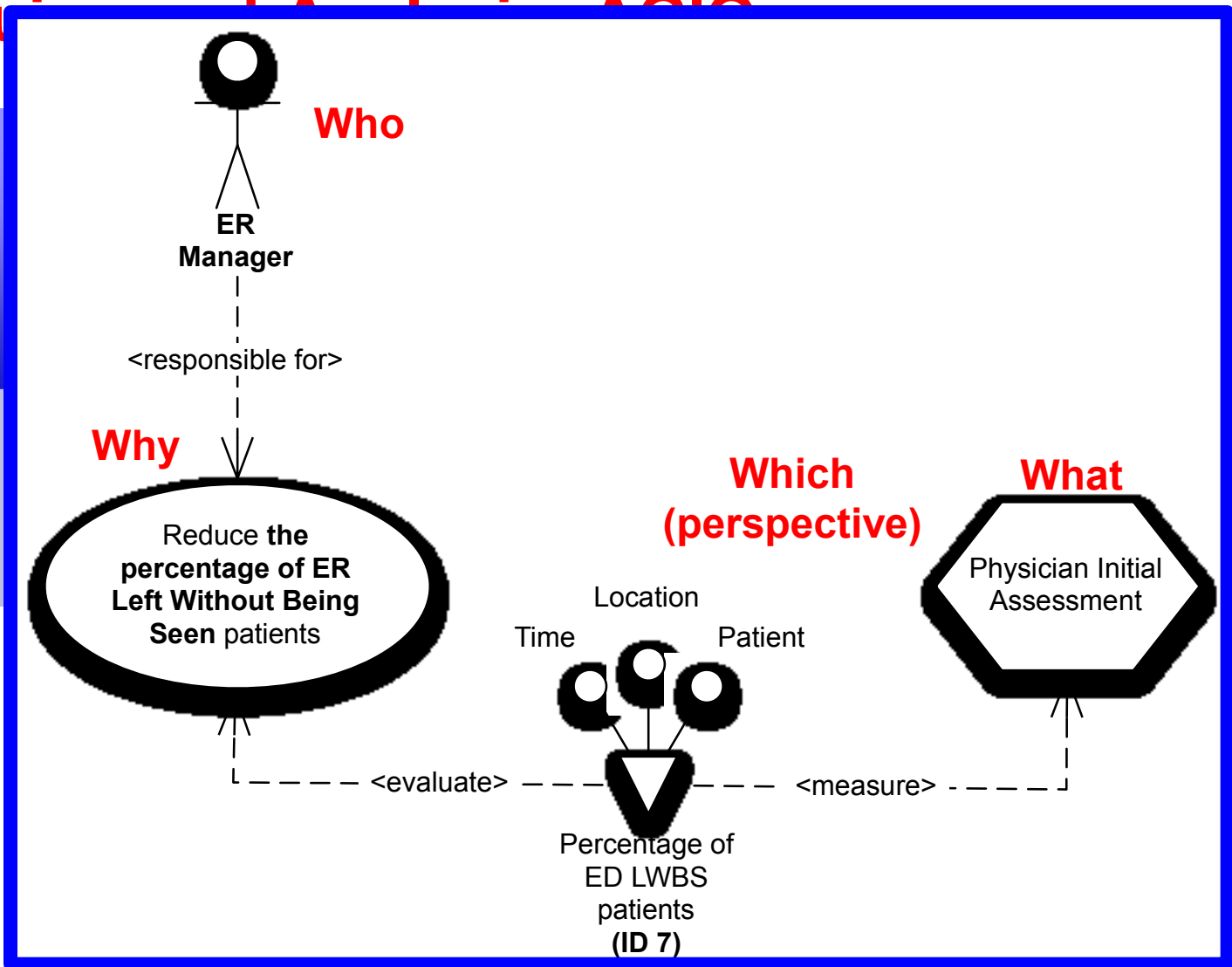
From AGIO Sheet and AGIO Graph

- Extrapolate:
  - Actor Map
  - Goals/Strategy Map
  - Indicator Map
  - Process and Workflow Map
  - Resource Map
- Whatever combination of the above:
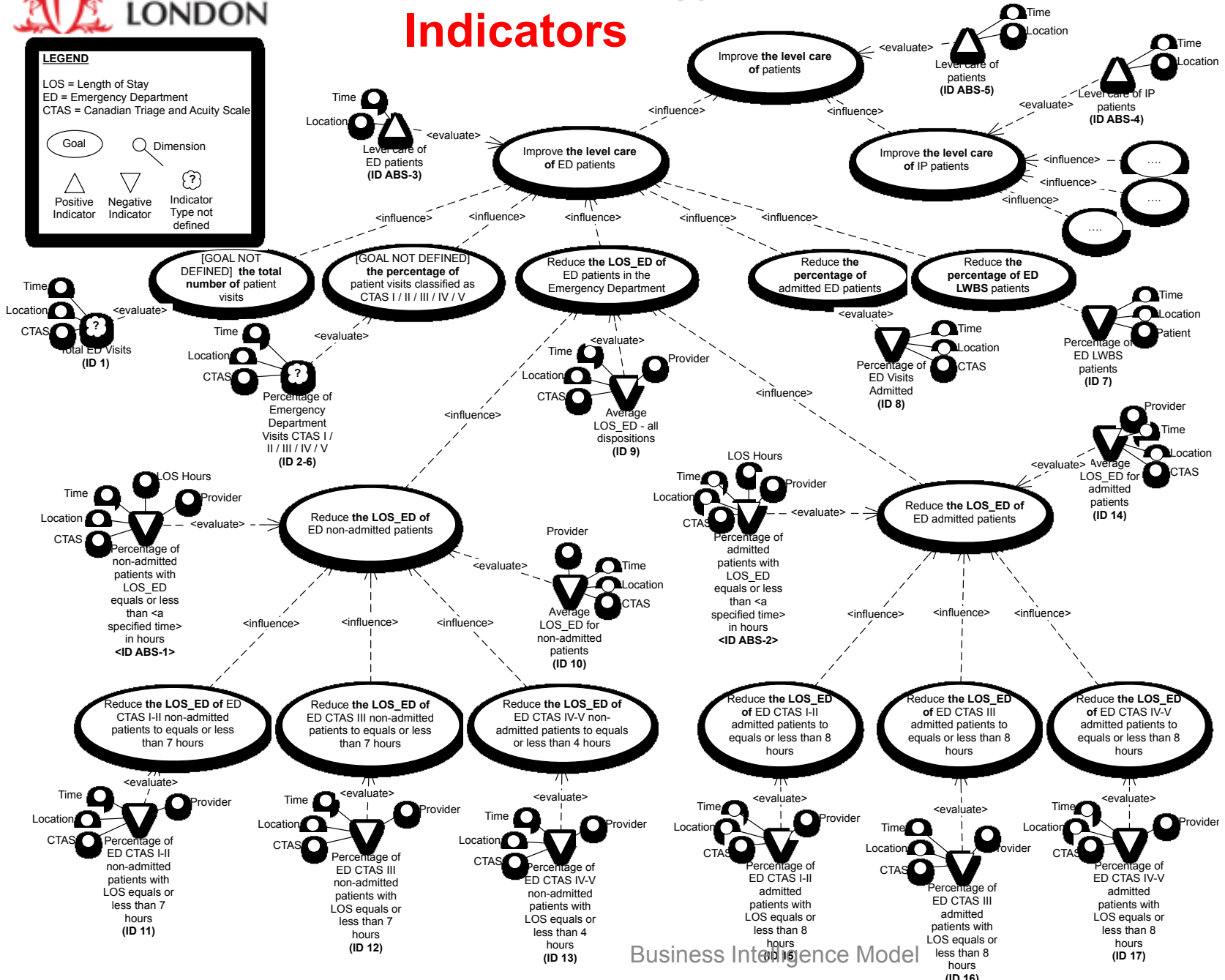 - e.g., Goal/Strategy Map + Indicator Map

Goal/ Strategy Map + Indicators

Business Intelligence Model

43

ED Fact Schema and a Dashboard

(A)
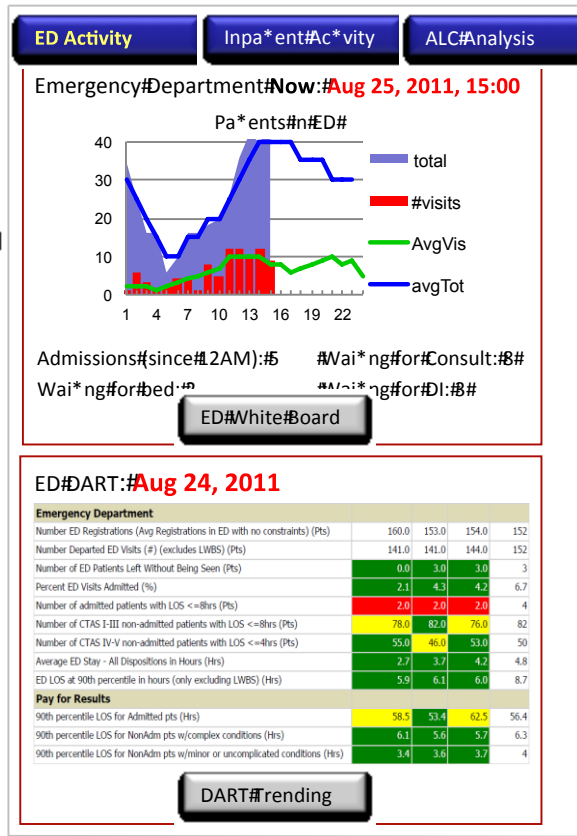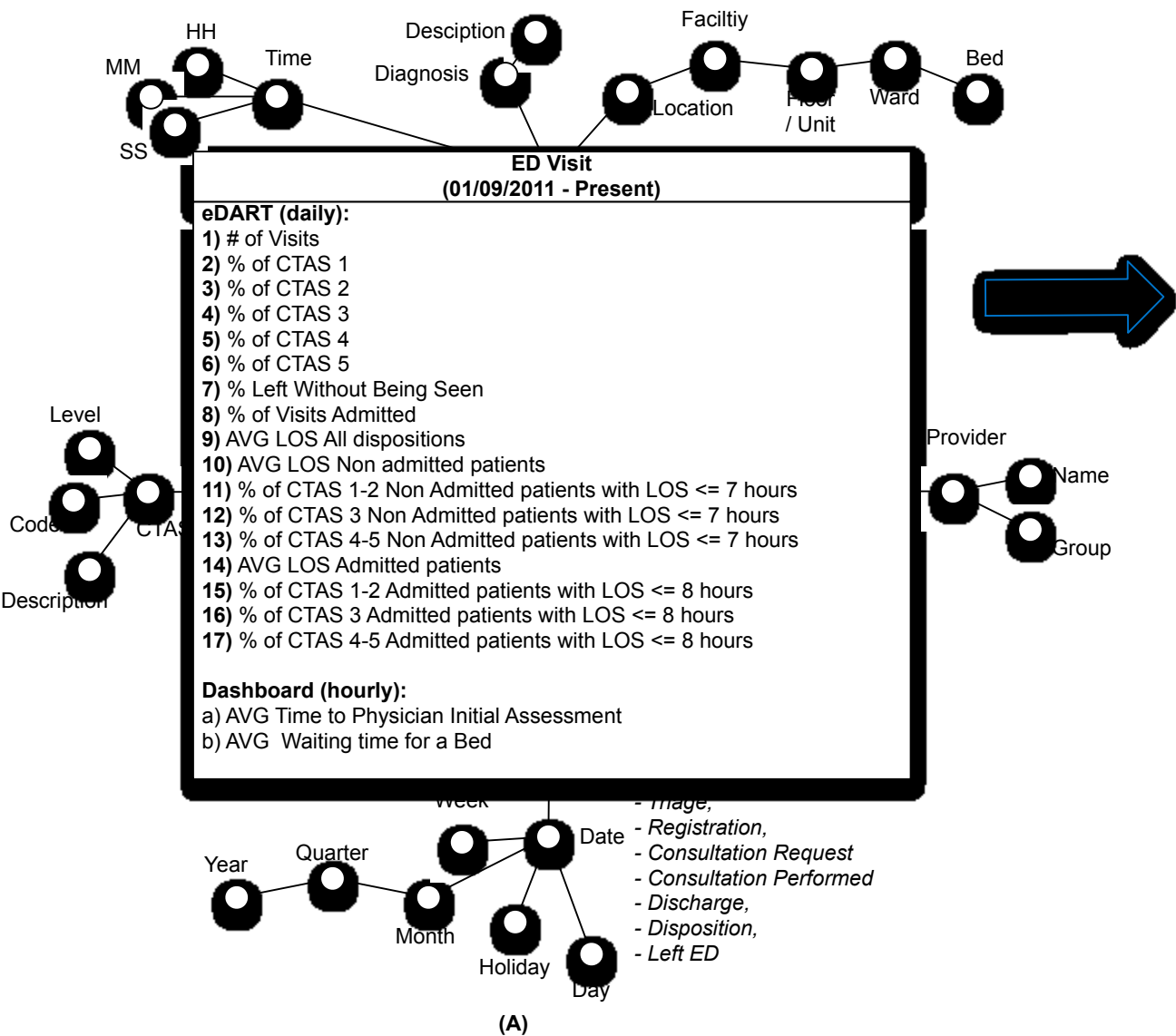
(B)

Lessons Learned

- What is the value of BIM in a BI implementation?
  - BIM concepts enhance communication and collaboration between designers and domain experts
  - Provide a roadmap for project team

- Is the initial BIM language sufficient to support the business modeling needs of the case study?
  - Used goals, processes, KPIs, etc.…
  - Added stakeholders (actors) and resources
  - Some concepts and methods not used (situations, reasoning, …)

- Is there a development methodology that matches with BIM?
  - Extended widely practiced BI solution development techniques by enriching them with BIM concepts

Lessons Learned

- Who are the users of BIM?
  - Business analysts and not business managers
  - Designers and domain experts understood and used the models for communication
  - Transferred BI team from system developers to data problem solvers

- How does BIM map to data?
  - Indicator maps used to derive fact schemas, map current indicators to objectives

- BIM reworked to deal with scalability

- BI platform altered organizational attitudes
  - Users learned to take action and improve processes based on data evidence
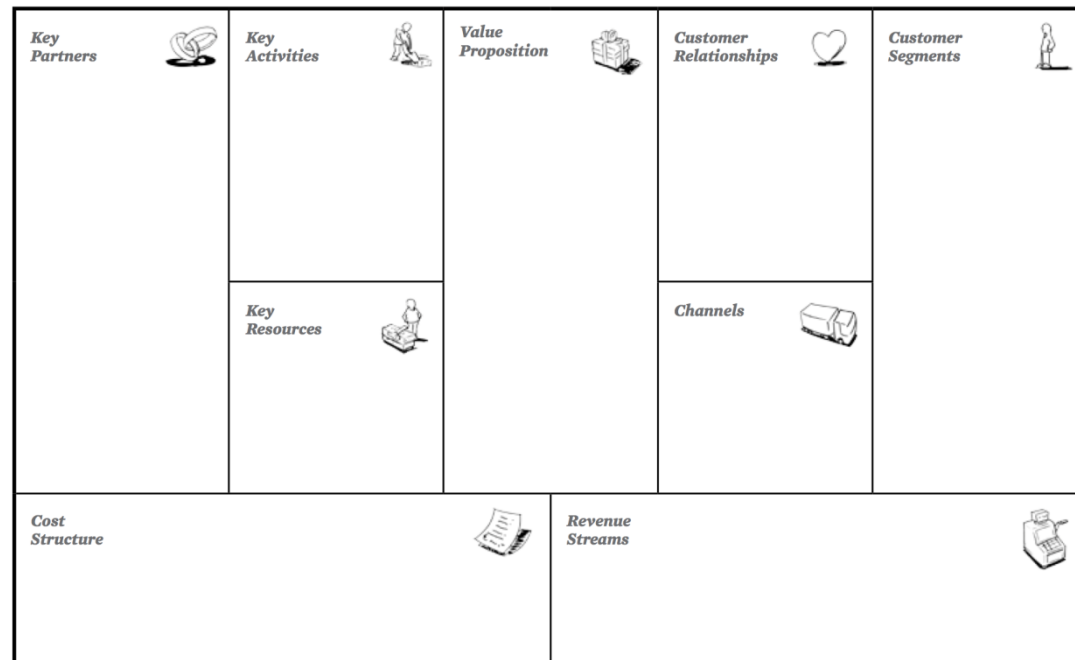
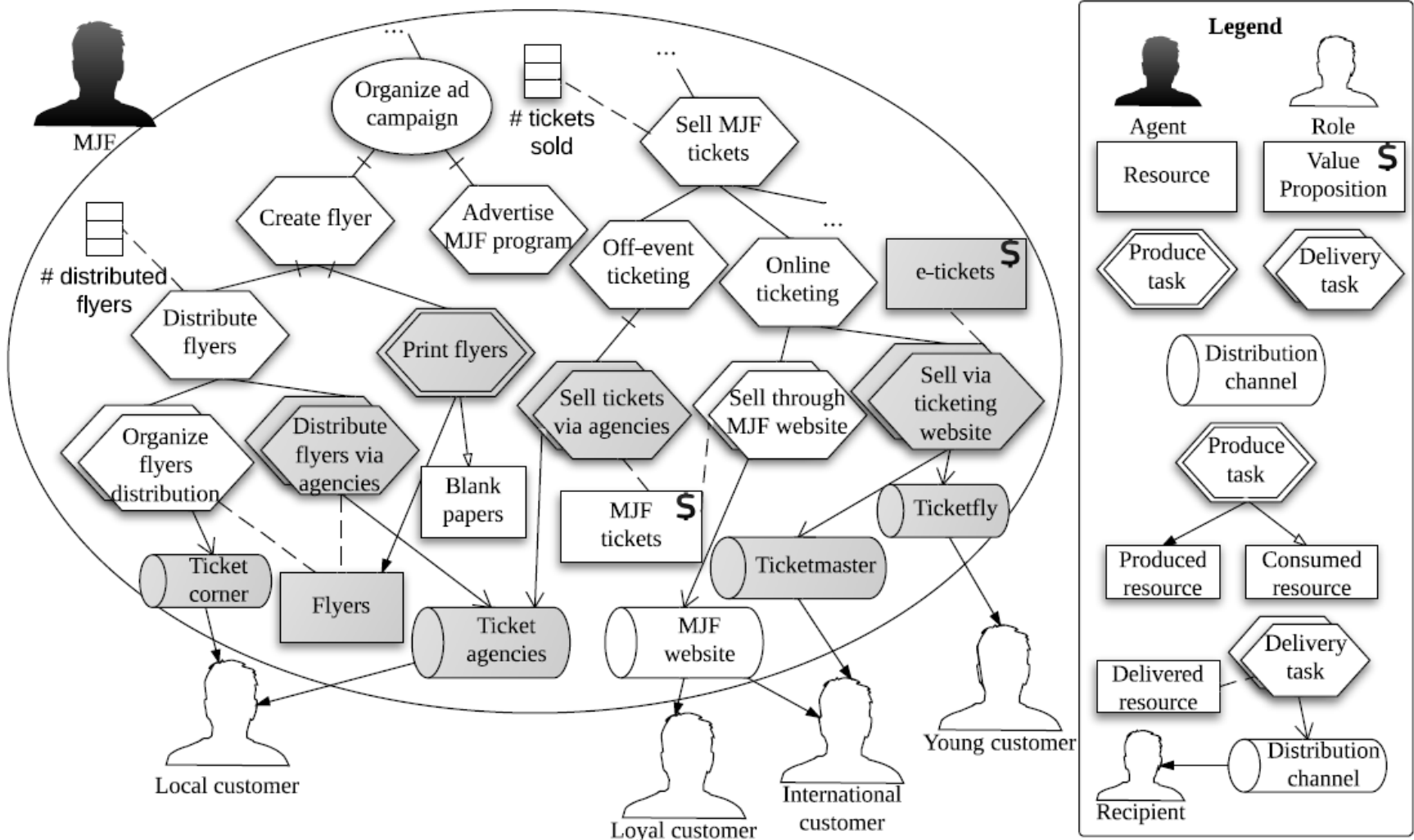# EXTENSIONS AND CURRENT WORK

Challenge: BIM reasoning

- Case studies have not applied reasoning thus far…
- Fit with needs?
- Existing reasoning similar to goal model-type analysis
  - With variations + extensions
- Strategic analysis such as SWOT analysis, Five-Forces Model analysis, Balanced Scorecard are more complicated (more considerations), but less formal
- How can we make BIM analysis more familiar to business users while still capturing the desirable aspects of conceptual modeling (semantics, systematic reasoning)?

Francesconi et al. ER13

Tactical BIM (TBIM)

- Tactical BIM refines BIM strategies through tactics
- Merge of concepts from BIM and Osterwalder's Business Model Canvas/Ontology
- Maps TBIM models to BPMN
  - Each alternative is a process model
  - Process simulations allow evaluation of alternatives
- Has a tactical view and partnership view

The Business Model Canvas: Key Partners, Key Activities, Value Proposition, Customer Relationships, Customer Segments, Key Resources, Channels, Cost Structure, Revenue Streams.
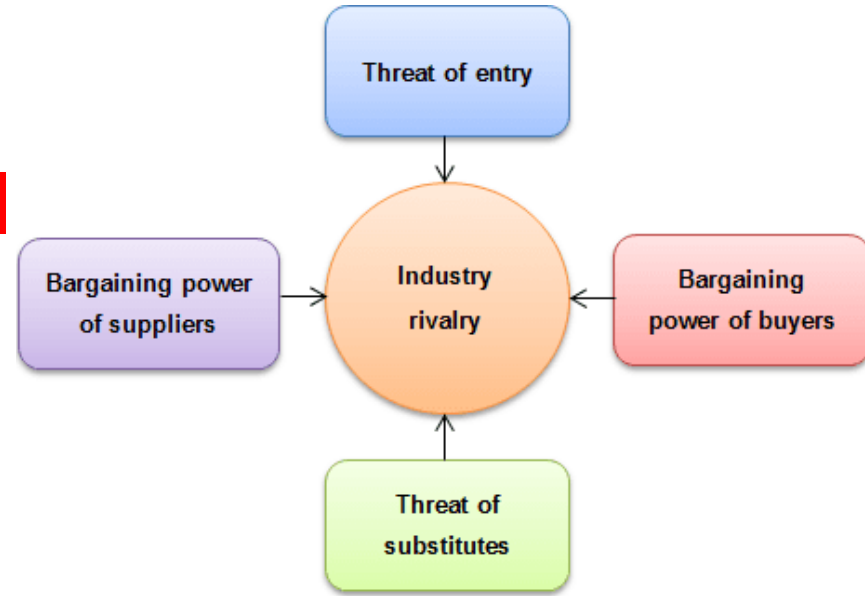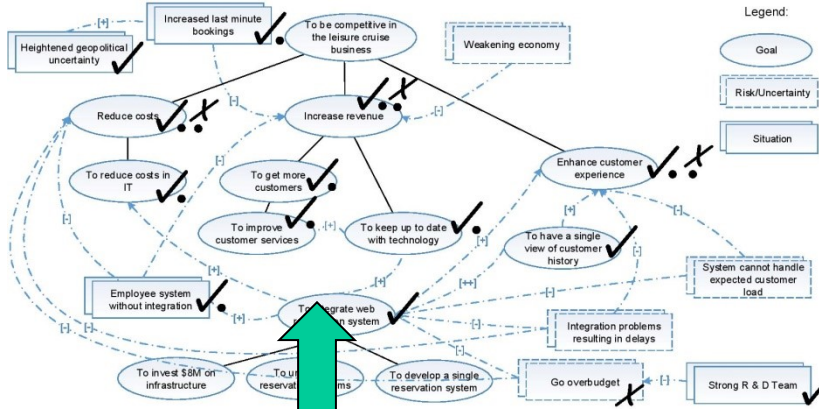
Tactical BIM (TBIM)

Five Forces Model

- ## Comparative study of strategic decision making techniques (without indicator data)
  - With the help of a realistic case study from the leisure cruise business: Royal Caribbean Cruise Ltd (RCCL)
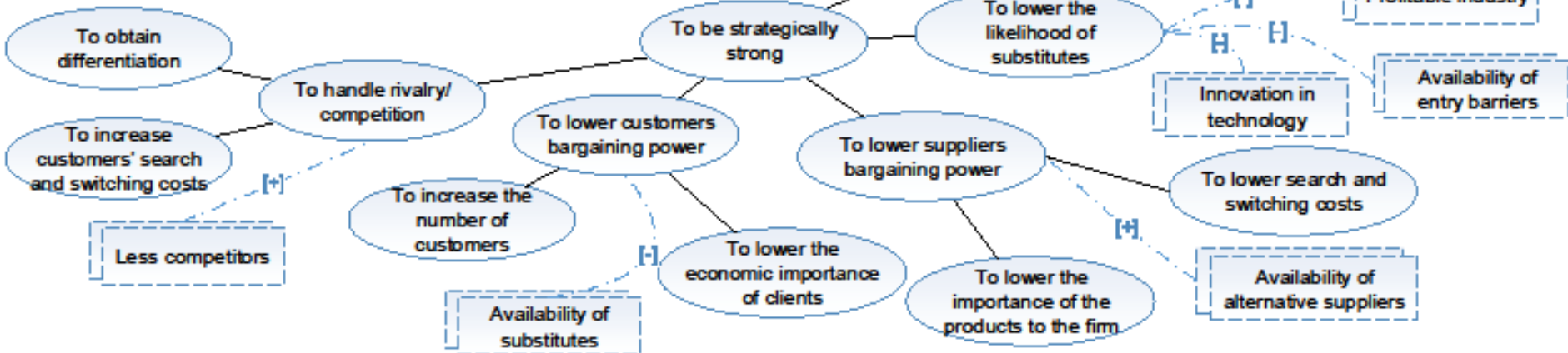 - Compared i* goal reasoning with BIM modeling and SWOT analysis
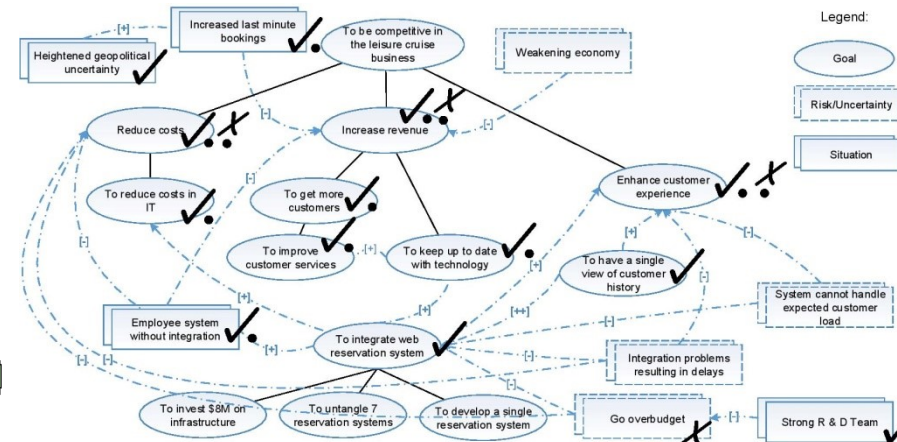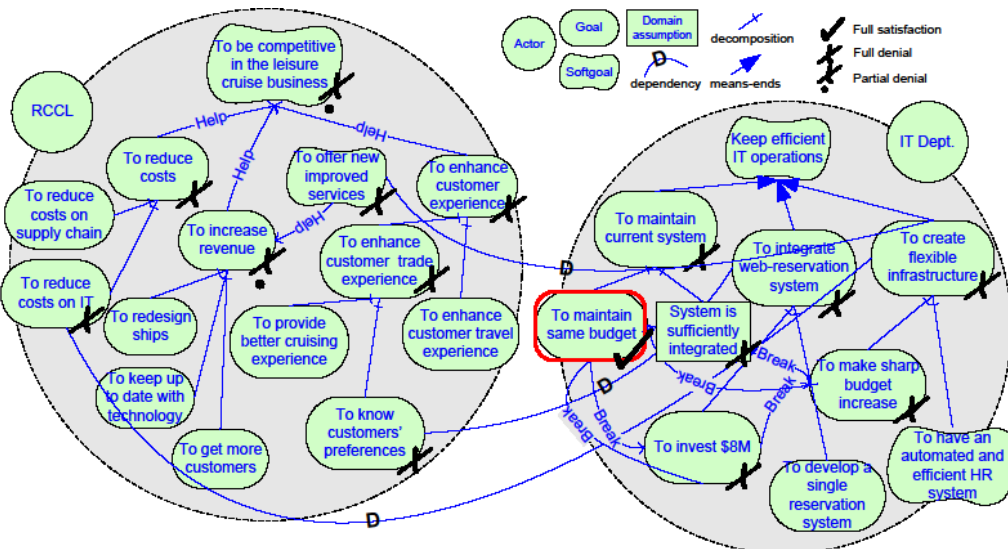
Add Five Forces Model

Stress testing strategic goal models

- Extended BIM metamodel to support **stress testing**

  Maté et al. ER15

- Input: Stress testing information
  - BIM instance model
  - Certain & Uncertain factors
  - Expected strength of situations/initial indicator satisfaction (context independent)
- Output: reasoning results
  - Critical factors
  - Struggling goals and courses of action
  - Exceptional performance/underperformance

Stress testing strategic goal models
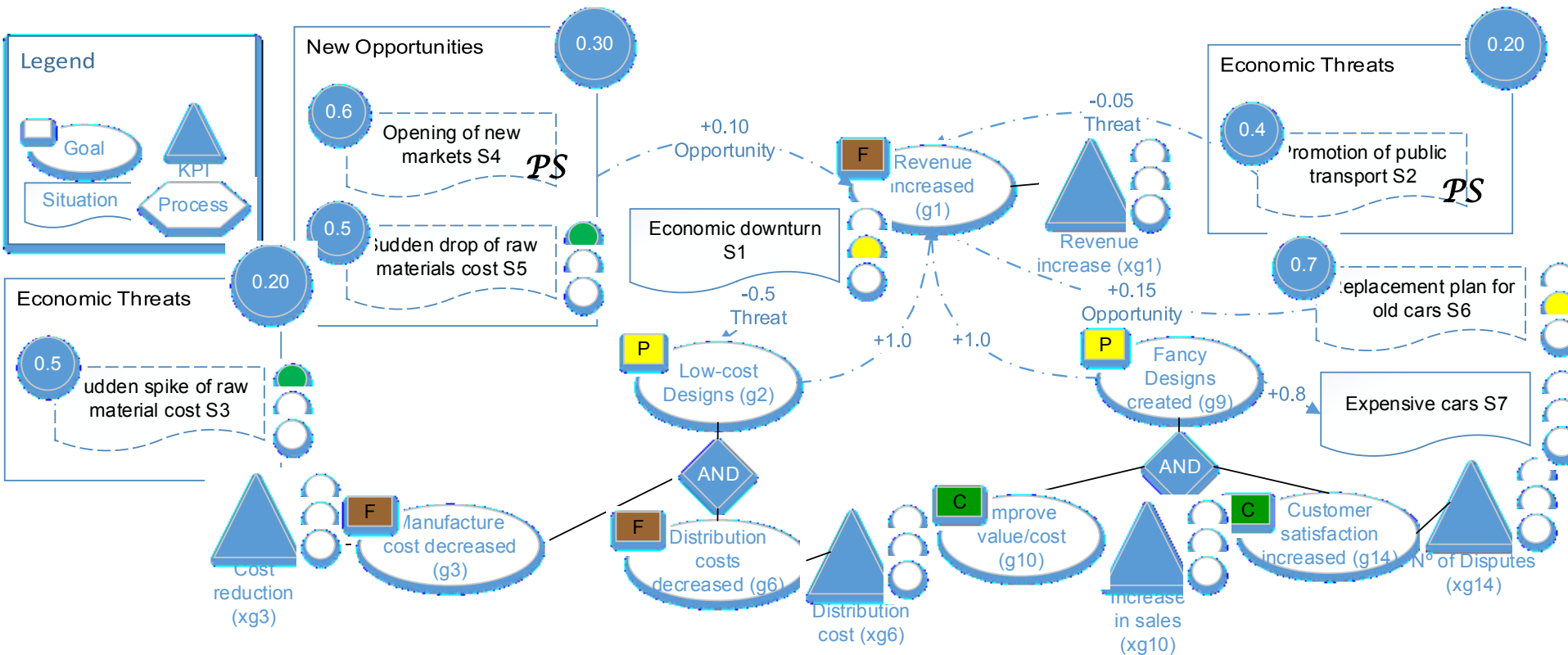
Stress Testing Results

| Goals/Situations	Base	S2	S3	S6	S2+S3	S2+S6	S3+S6	S2+S3+S6
G1	0,65	0,627	0,15	0,749	0,127	0,726	0,249	0,226
G2	0,6	0,6	0,1	0,6	0,1	0,6	0,1	0,1
G3	0,8	0,8	0,3	0,8	0,3	0,8	0,3	0,3
G4	0,8	0,8	0,3	0,8	0,3	0,8	0,3	0,3
G5	1	1	1	1	1	1	1	1
G6	1	1	1	1	1	1	1	1
G7	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6
G8	1	1	1	1	1	1	1	1
G9	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05
G10	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3
G11	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6
G12	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3
G13	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3
G14	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05
G15	-0,2	-0,2	-0,2	-0,2	-0,2	-0,2	-0,2	-0,2

Interpreting Results
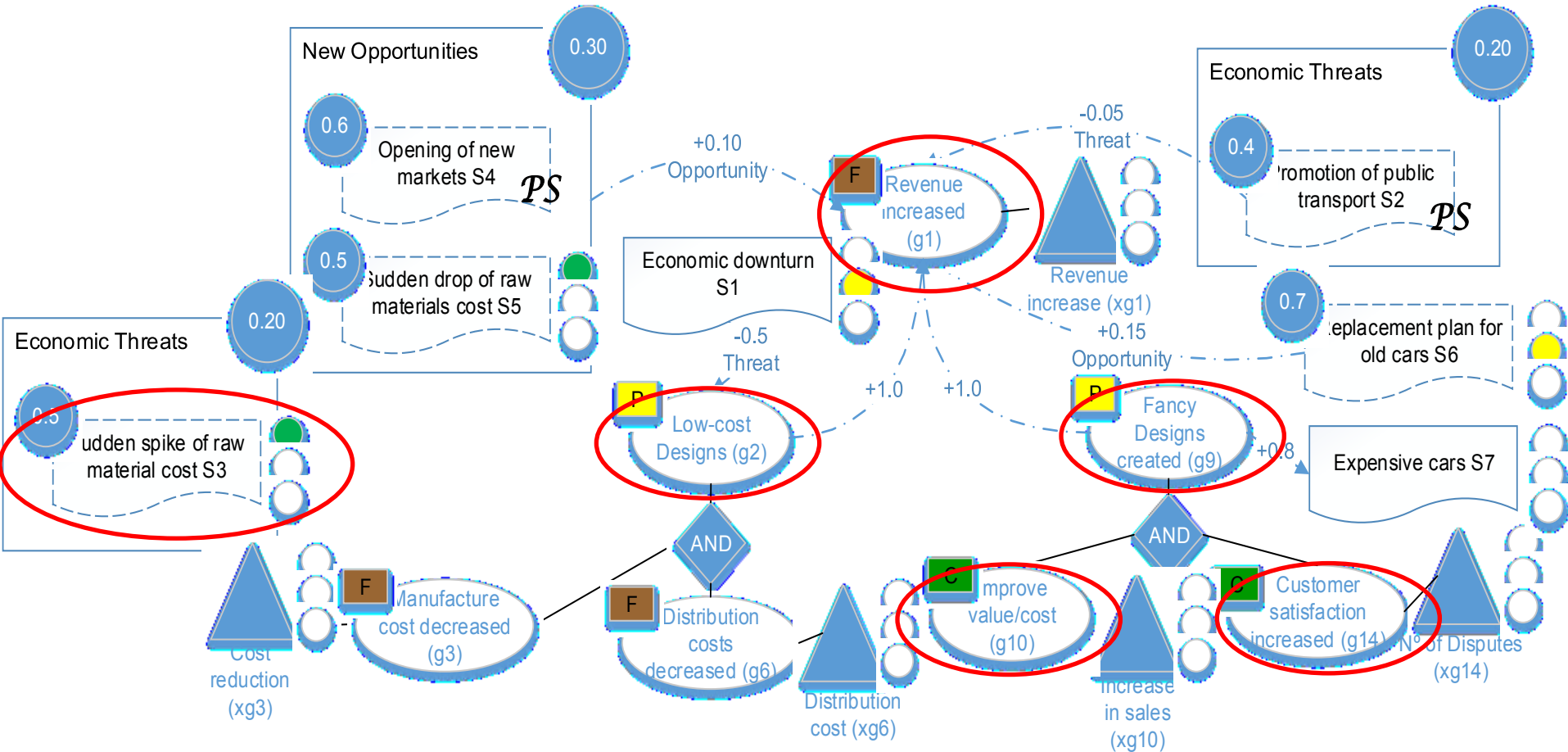
- Best performance, worst performance, most stable strategy, goals that would need corrective actions…

Future Work: Dimensional BIM

- BIM strategic goals are dimensional
  - E.g., time, scope, perspective
  - Captured via meta-properties
- Goal refinement should account for such dimensions, e.g.,

Increase sales by 2% over 3 years

- Can be refined per quarter, per region, per product line…
- Refinements similar to data warehouse dimensions
- Visualization? Complexity management?

Complimentary Work

- Pourshahid, Richard, and Amyot, Toward a Goal-Oriented, Business Intelligence Decision-Making Framework, MCETECH 2011

- Badreddin et al., Regulation-Based Dimensional Modeling for Regulatory Intelligence, RELAW 2013

- Akhigbe, Amyot, and Richards, A Framework for a Business Intelligence-Enabled Adaptive Enterprise Architecture, ER 2014

- Much work in adaptation and monitoring with conceptual modeling (e.g., SEAMS)

Conclusions

- BIM bridges the gap between business users and technical data to make BI more accessible

- Supports reasoning

- Evidence of applicability

- More work to be done:
  - Quantitative reasoning inherent to language?
  - Make modeling more accessible?
  - Reasoning in practice?
  - More varied case studies

Thank you!

- Questions?

- Contact:

- jenhork@cs.utoronto.ca
- barone@cs.toronto.edu