Overview: Enterprise-Level Industrial Fire Risk Modeling and Analysis for Automobile Manufacturing Facilities

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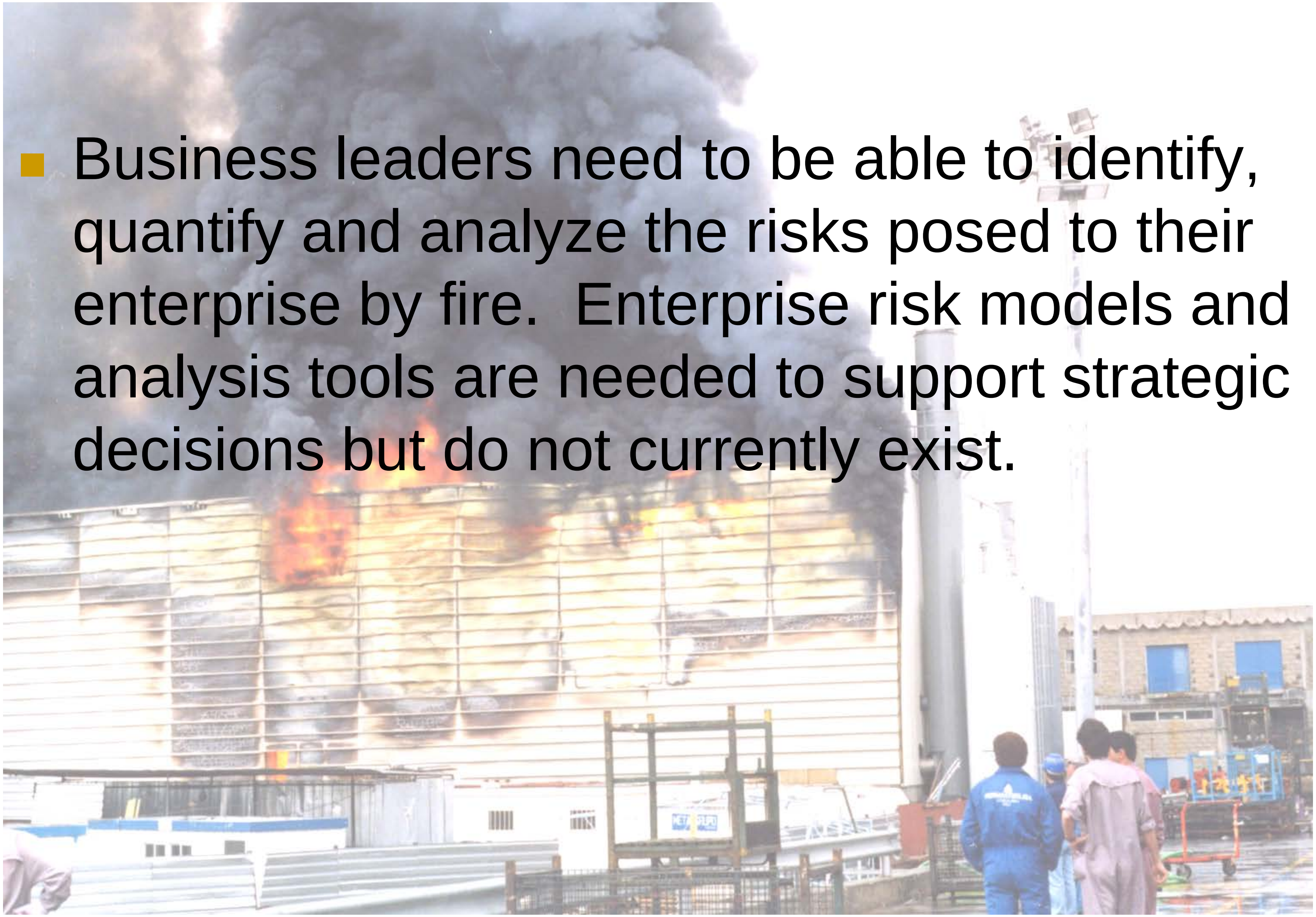
May 15, 2012

Agenda

- Problem Statement
- Summary of Methods
- Summary of Results/Outputs

Problem Statement

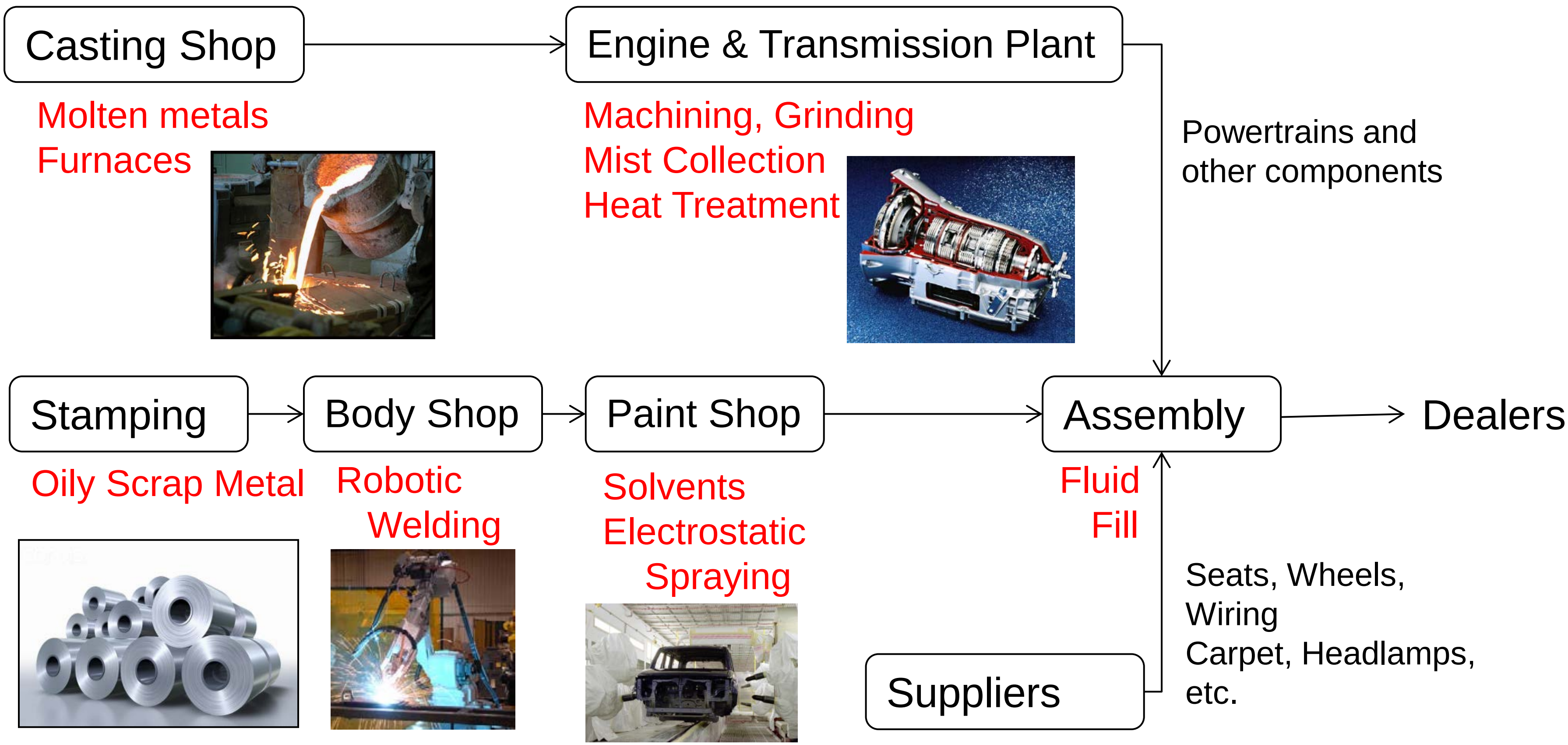


- Business leaders need to be able to identify, quantify and analyze the risks posed to their enterprise by fire. Enterprise risk models and analysis tools are needed to support strategic decisions but do not currently exist.

Background on the GM Enterprise

- General Motors:
  - 158 manufacturing sites
  - Located in 30 countries
  - 202,000 employees
  - Produces 7.5 million vehicles per year
  - Sold in 120 countries

Overview of Auto Manufacturing Process and Associated Fire Hazards

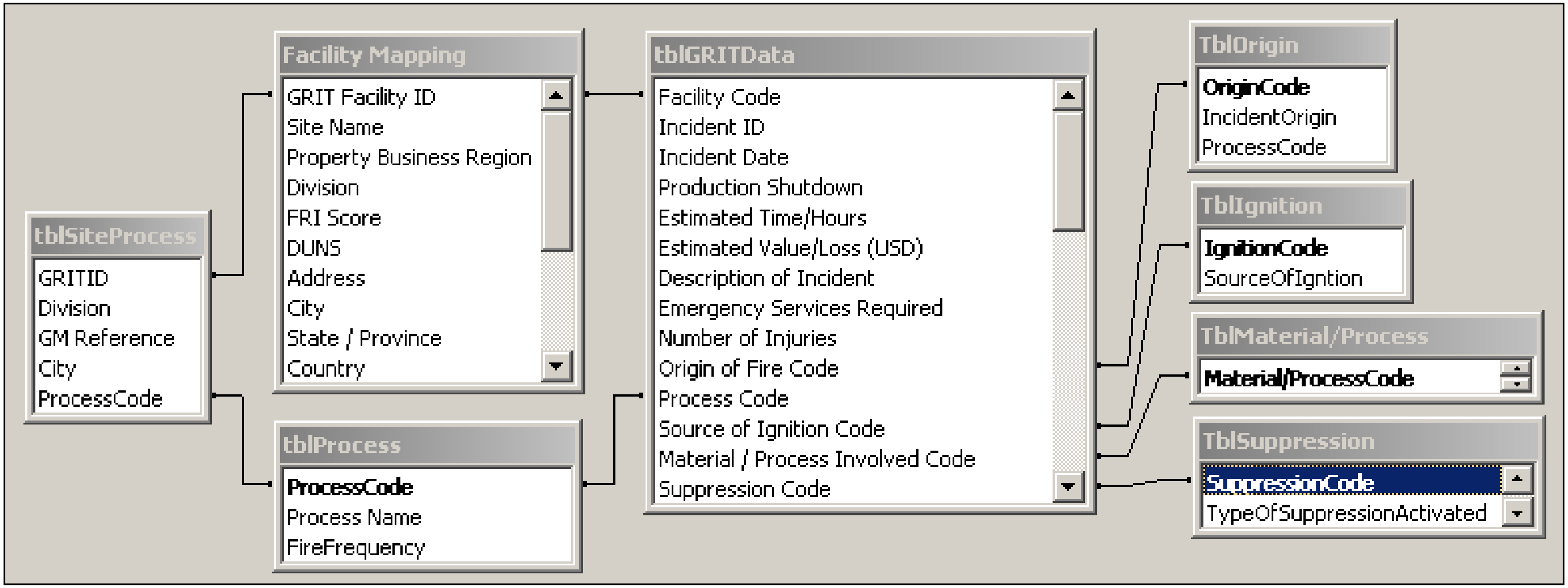


Summary of Methods

- Developed a multi-dimensional systems modeling framework for aggregating/disaggregating fire frequency and severity
- Designed and implemented an enterprise fire risk database
- Developed and deployed a global procedure for fire data collection
- Built tools to visually analyze and compare fire risk across portfolio of manufacturing processes and plants
- Demonstrated utility of results in a specific case study analyzing costs and benefits of fire protection options in paint shop operation.

Key to the Analysis

- Data – Need accurate, complete data on fire events from the automotive industry
- Global loss reporting database developed to comply with Sarbanes-Oxley Act of 2002
  - GRIT – Global Reporting & Investigations Tool
  - Database Architecture:



Process-Based Analysis of Frequency

- Determined that a Poisson distribution is the preferred model fit based on :
  - Theoretical property of aggregation/ disaggregation
  - Easy to measure mean number of fires per year (intensity parameter λ)
- Fire hazards are inherent to the process where fire originates
- Processes within automobile manufacturing are homogeneous across plants, countries and regions. This allows frequency model to be applicable to plants that did not contribute to the data.
- All fire origin areas in GRIT were mapped to 14 discrete process groupings
- Process fire frequencies were then calculated using modified Poisson model

Process Groupings

ProcessCode	Process Name
AS	Assembly
CA	Casting/Foundry
CO	Computer Room
DC	Dust/Mist Collector
DY	Laboratory/Dyno/Test Cells
HT	Heat Treat
HZ	Hazardous Material/Storage
MG	Machining and Grinding
PA	Painting & Ovens
RW	Robotic Welding
SP	Stamping/Press
ST	Storage
SU	Support Area
TR	Trash

Process Groupings

ProcessCode	Process Name	Fire Frequency (Chance of Fire per Day)
AS	Assembly	0.0038
CA	Casting/Foundry	0.0104
CO	Computer Room	0.0001
DC	Dust/Mist Collector	0.0009
DY	Laboratory/Dyno/Test Cells	0.0018
HT	Heat Treat	0.0022
HZ	Hazardous Material/Storage	0.0001
MG	Machining and Grinding	0.0056
PA	Painting & Ovens	0.0011
RW	Robotic Welding	0.0088
SP	Stamping/Press	0.0029
ST	Storage	0.0011
SU	Support Area	0.0059
TR	Trash	0.0011

Poisson approximation: Probability of one or more fires per day is roughly equal to the Poisson intensity λ*1 day (t) = λ

Mapping of Process Grouping to Plant

- Each process contributes distinct fire hazards and independent fire arrival rate λ
- Easy to map processes at each plant
- Site fire rate = Σ (process rates at plant)

Process Code	Plant 1	Plant 2	Plant 3
AS			
CA	x		x
CO	x	x	x
DC	x	x	x
DY		x	x
HT		x	x
HZ	x	x	x
MG		x	x
PA		x	x
RW			
SP			
ST	x	x	x
SU	x	x	x
TR	x	x	x

Process-Based Fire Frequency by Plant

Site Name	Aggregated Lambda Average Number of Fires Per Day
Plant B	0.046
Plant Y	0.046
Plant S	0.046
Plant F	0.044
Plant T	0.043
Plant C	0.039
Plant W	0.035
Plant N	0.035
Plant G	0.035
Plant K	0.035
Plant R	0.035
Plant Z	0.034
Plant O	0.033
Plant T	0.033
Plant A	0.033
Site B	0.032
Facility B	0.032
Plant E	0.031
Site E	0.031
Plant L	0.031
Site Z	0.031
Site A	0.030
Site D	0.030

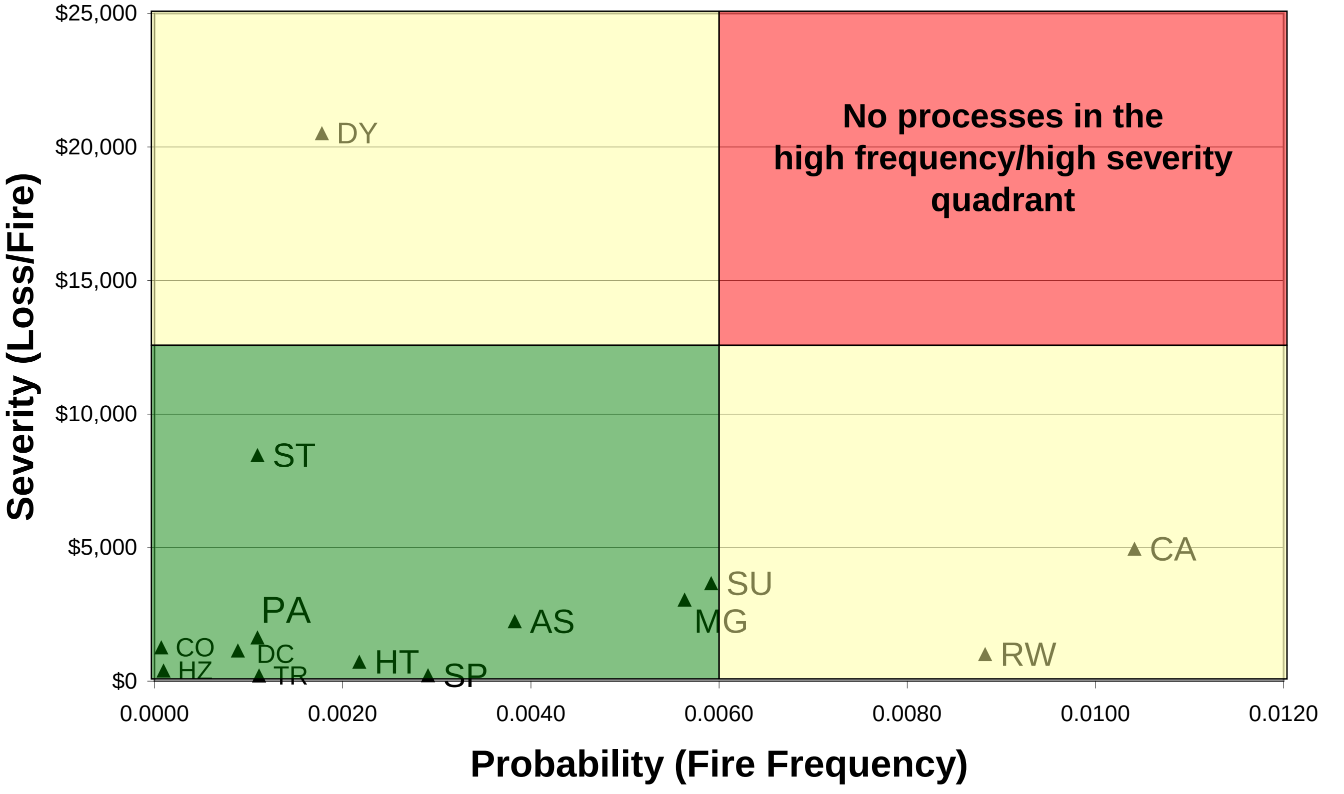
Note: The data has been disguised for confidentiality purposes, but is representative of results.

Severity Modeling

- Process-Based
  - Calculated from fire events – GRIT data
  - Are used to quantify loss from fires involving a given process
  - Are used to prioritize fire protection criteria at the process level
- Plant-Based
  - Represents the potential of a fire in a given facility to become a significant fire
  - Are used to estimate the potential size of the impact from a significant fire

Process-Based Severity Assessment

Process Grouping	Average Estimated Value/Loss (USD)
AS	$ 2,200
CA	$ 5,000
CO	$ 1,200
DC	$ 1,100
DY	$ 20,500
HT	$ 700
HZ	$ 400
MG	$ 3,000
PA	$ 1,600
RW	$ 1,000
SP	$ 200
ST	$ 8,500
SU	$ 3,500
TR	$ 200



Property damage only

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Plant-Based Severity Assessment

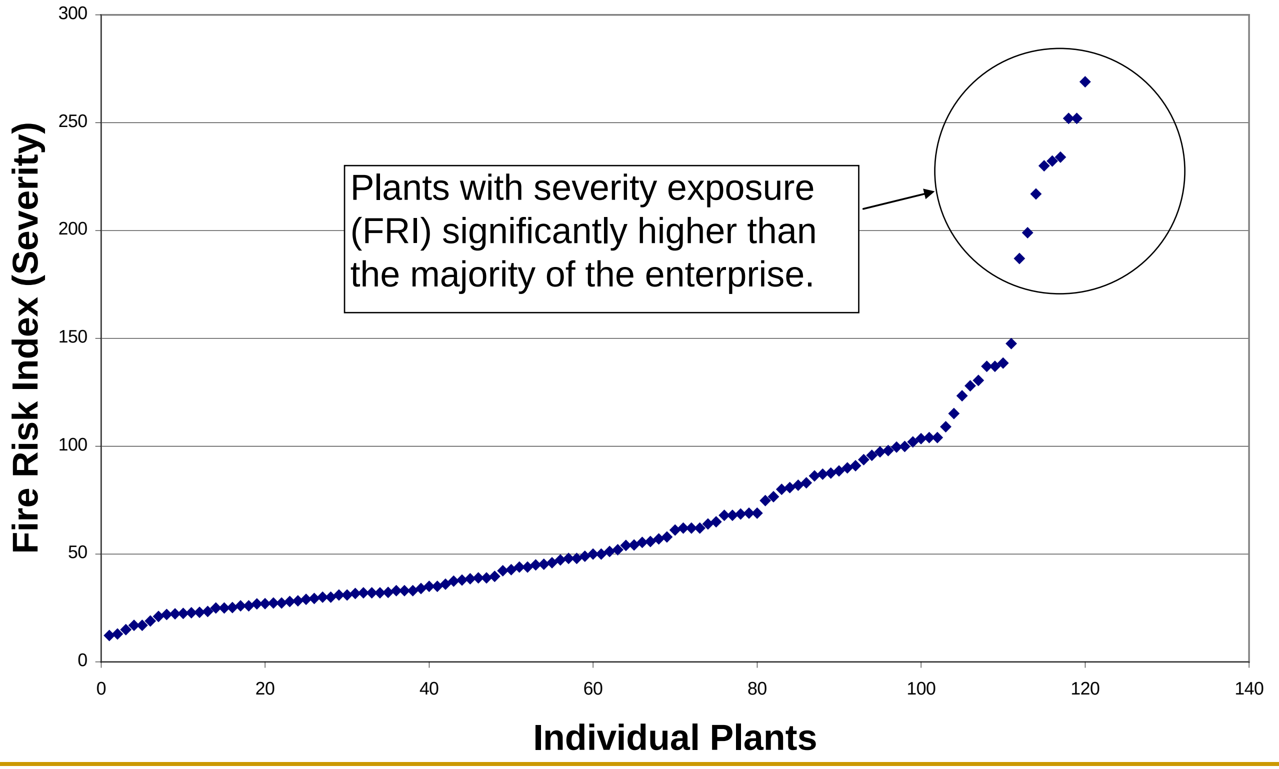
- Fire Risk Index (FRI) developed as a relative risk ranking to characterize the potential to be a severe fire.
- Business Interruption Value (BIV) used to quantify the potential exposure of a severe fire
  - Quantifies the severity in terms of dollars
  - Provides estimate of value of lost production

Fire Risk Index (FRI)

- Qualitative approach used because quantifying the potential for a fire to develop into a significant fire is extremely complex and involves detailed analysis of plant occupancy, configuration, and potential fire size
- Such data is not available for an entire enterprise and is not feasible to collect
- Absolute value of risk is not necessary for decision makers, only used as a comparison therefore relative risk ranking is appropriate
- Six hazard categories identified relative to severity:
  - Exposure, Construction, Supervision, Automatic Sprinklers, Water Supply, Special Hazards

FRI Results

Plant	Exposure	Construction	Supervision	Sprinklers	Water Supply	Special Hazards	FRI
Plant 1	0	9	0	1	0	3	13
Plant 2	0	15	0	15	0	60	90
Plant 3	0	9	0	20	0	0	29
Plant 4	10	12	0	75	50	68	215
Plant 5	0	12	0	5	0	0	17



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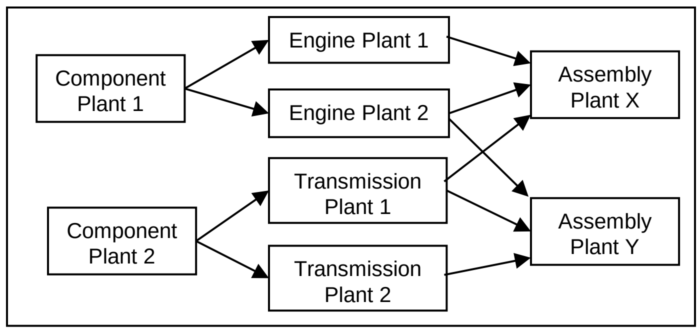
Business Interruption Value (BIV)

- Assembly Plant BIV

$$BIV(X) = \frac{NetProfit}{Vehicle} \times \frac{ProductionVehicles}{Day} \times NumberofDaysDown$$

- Source Plant BIV

$$BIV(A) = \sum_{iDependentPlants} PercentDependancy(i) \times BIV(i)$$

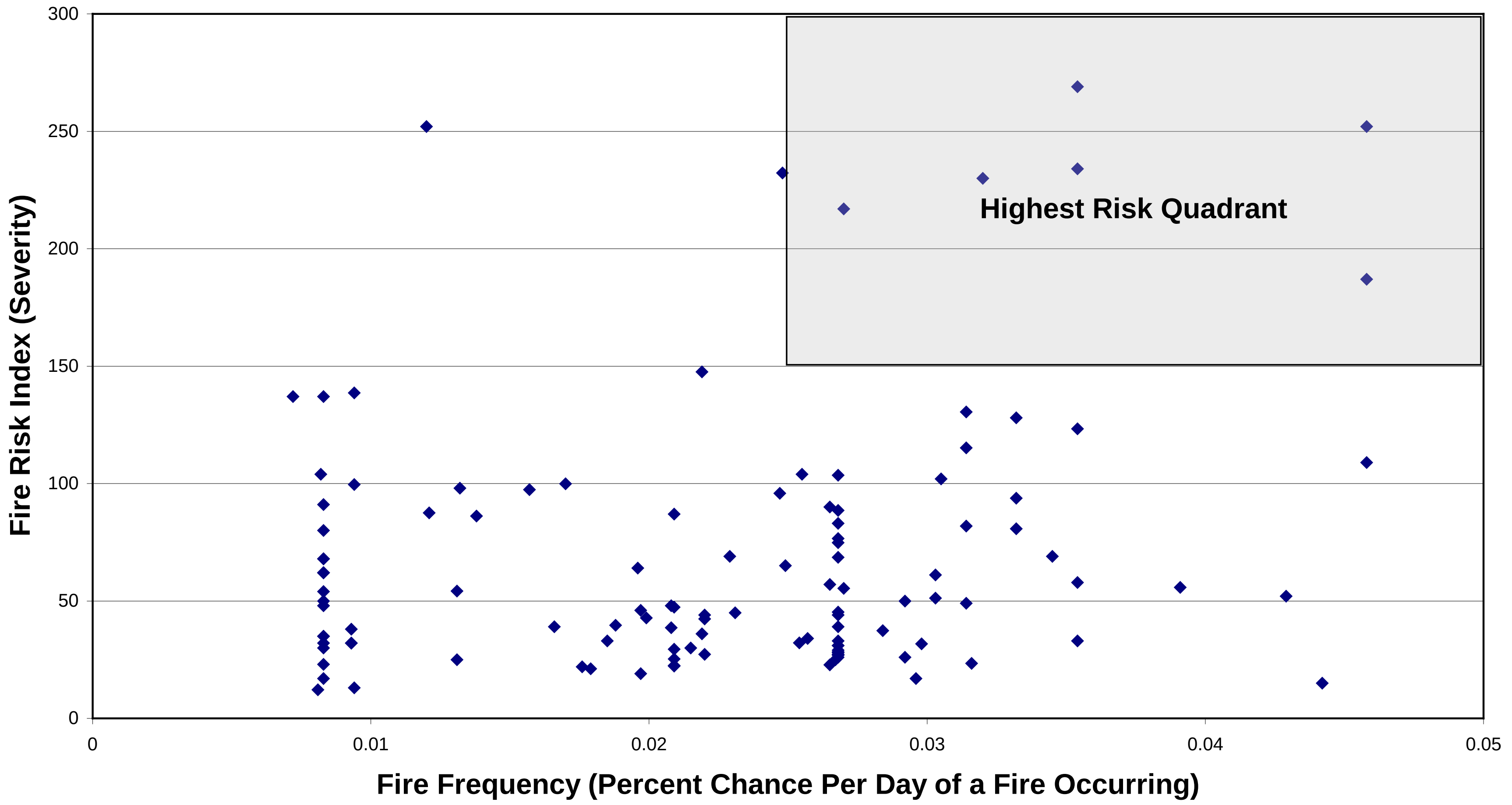


- Value for number of days down was 90 days based on manufacturing forecast data and industry convention.

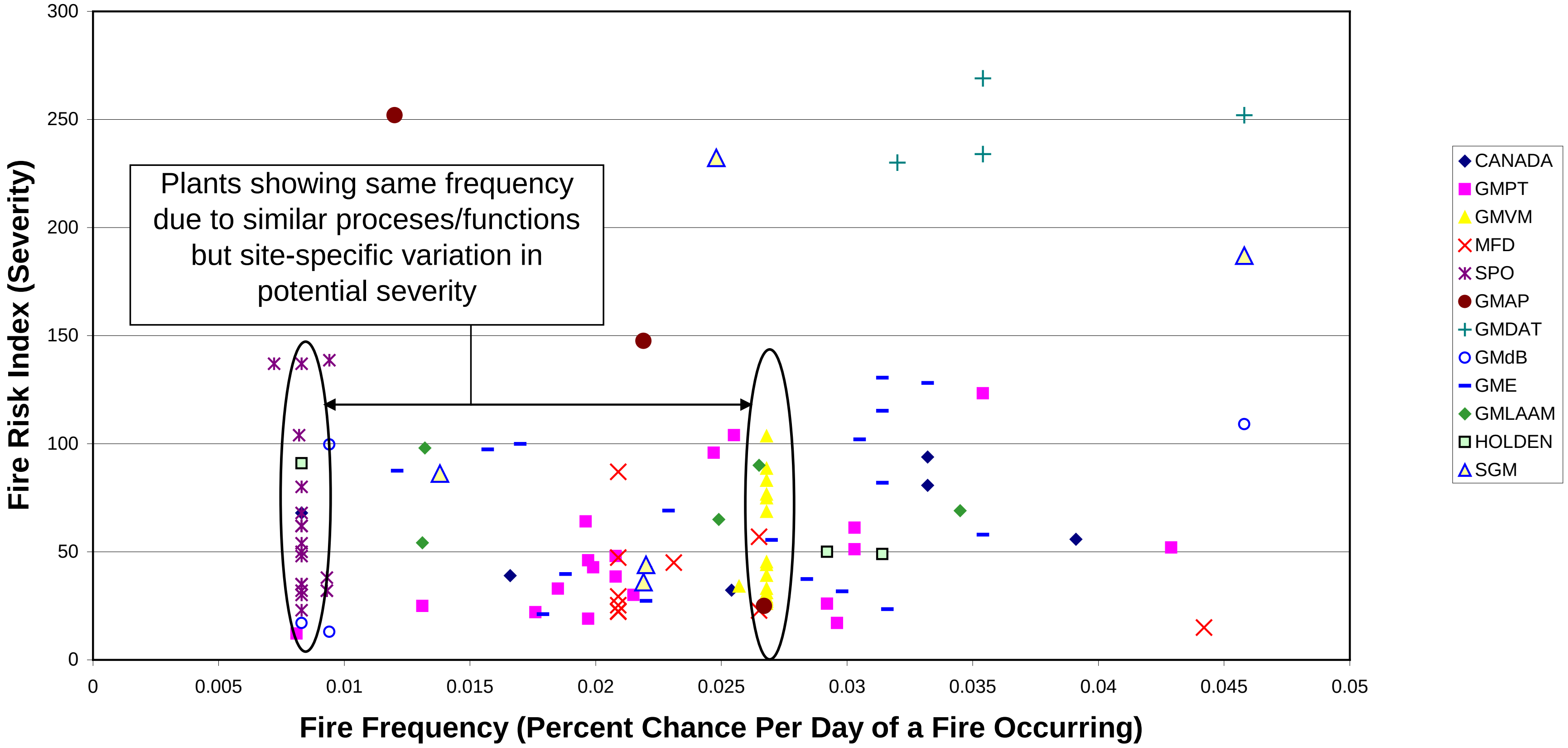
Summary of Results:
Decision Support Tools

- System Model outputs will include (Tools 1 - 8)
  - Risk profiles and risk maps to identify processes or plants with greatest risk factors
  - Quantification of fire risk to track progress of risk reduction initiatives over time
- Fire protection trade-off analysis (Tool 9)
  - Developed process-level event tree tool
  - Constructed event trees for individual fire protection criteria decisions
  - Allowed different fire protection criteria to be compared based on their impact on risk level. Can be analyzed by process, plant, or overall enterprise impact.

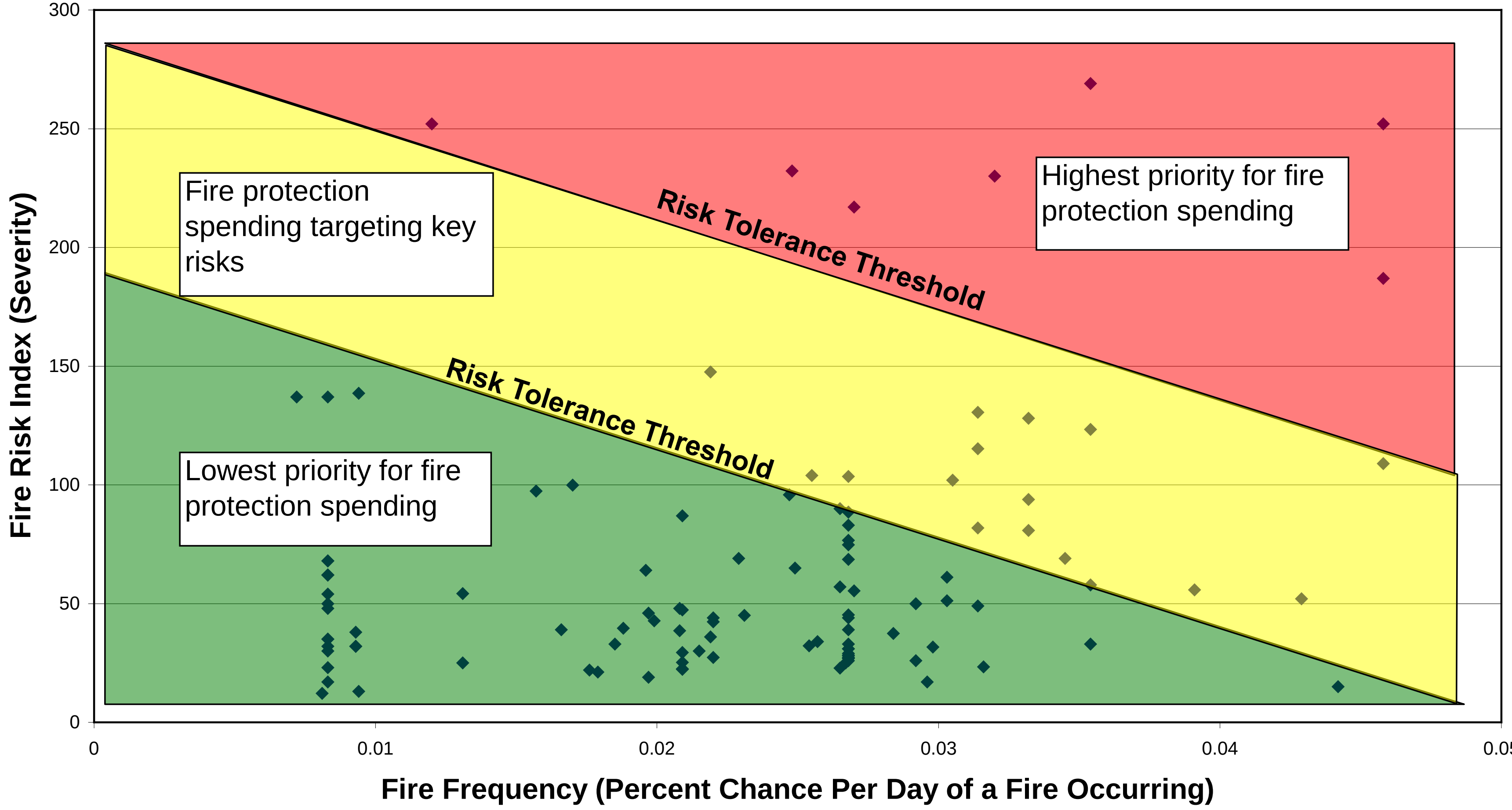
Tool 1: Global Fire Risk Profile



Tool 2: Fire Risk Profile by Division

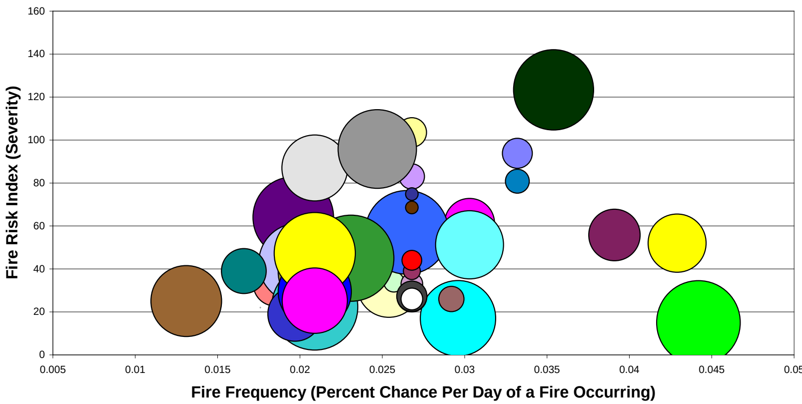


Tool 3: Risk-Based Fire Protection Spending Prioritization

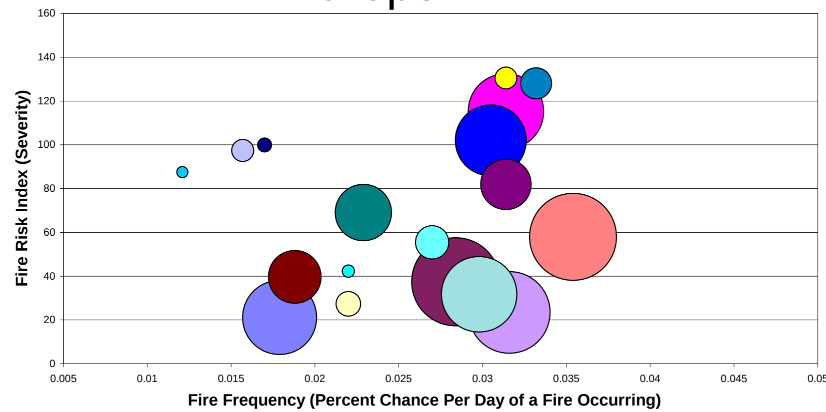


Tool 4: Regional Risk Prioritization Models

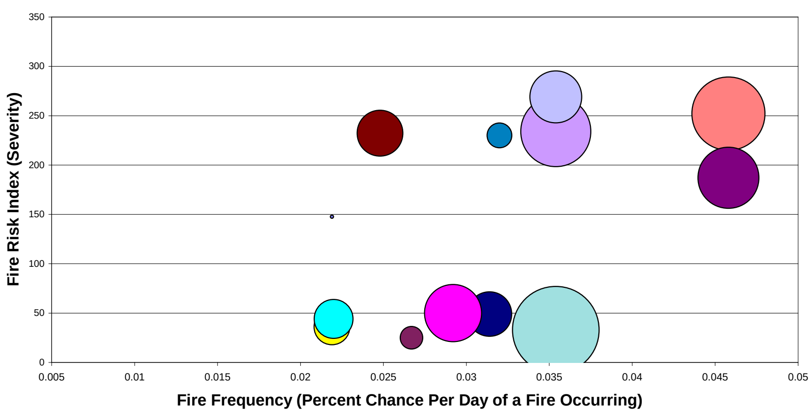
North America



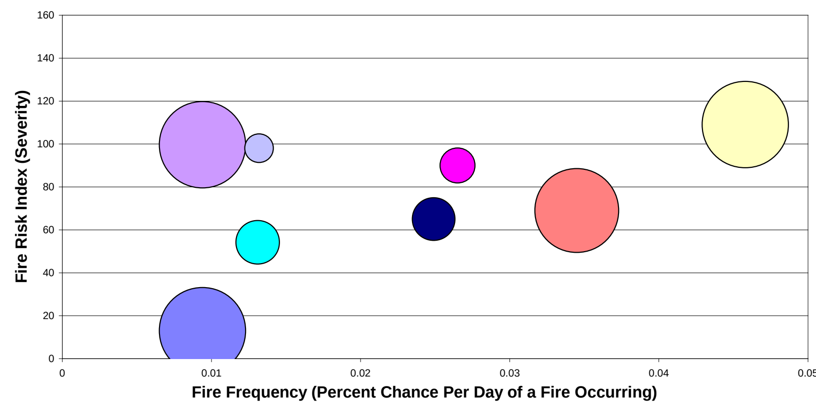
Europe



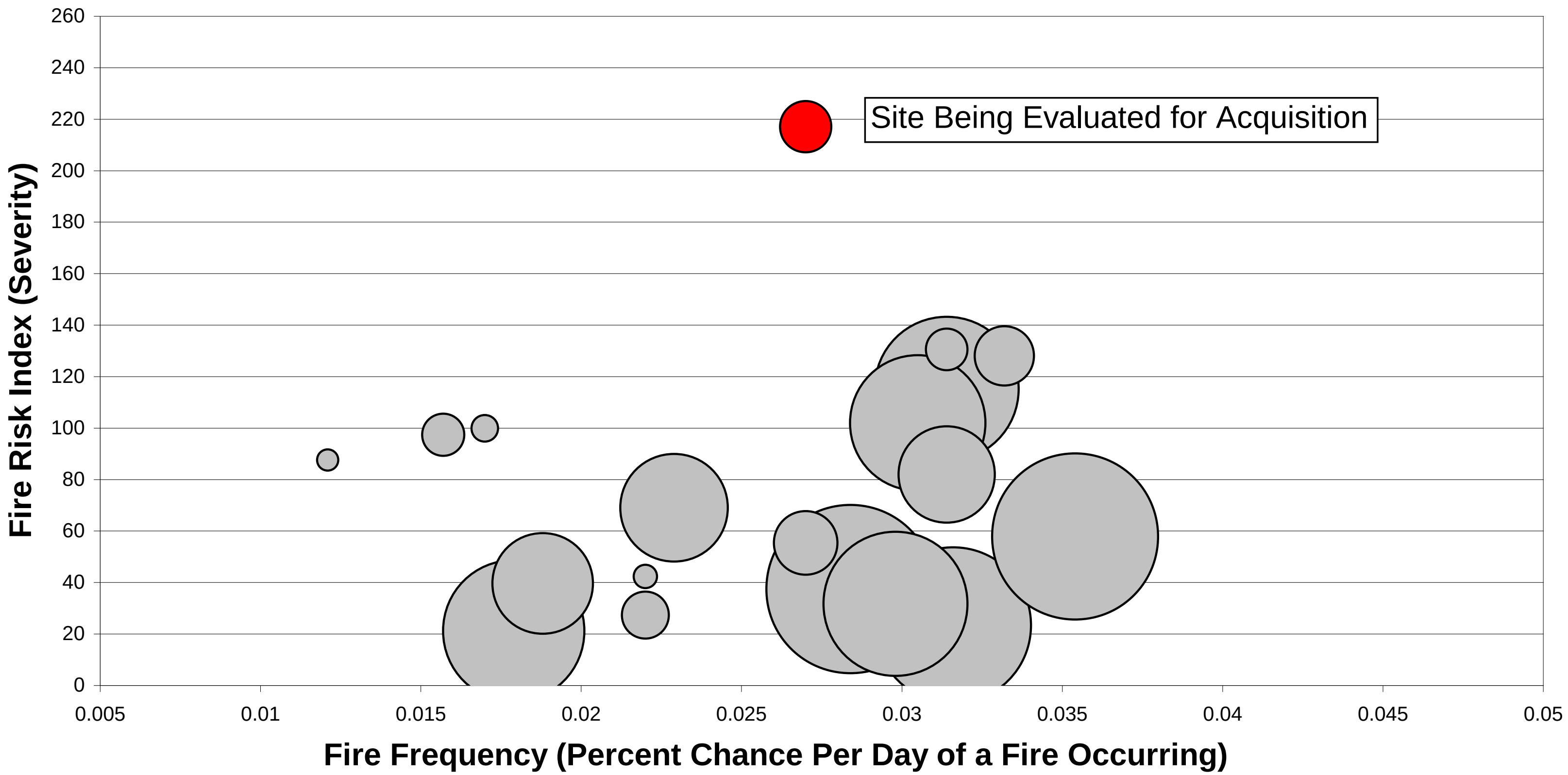
Asia Pacific



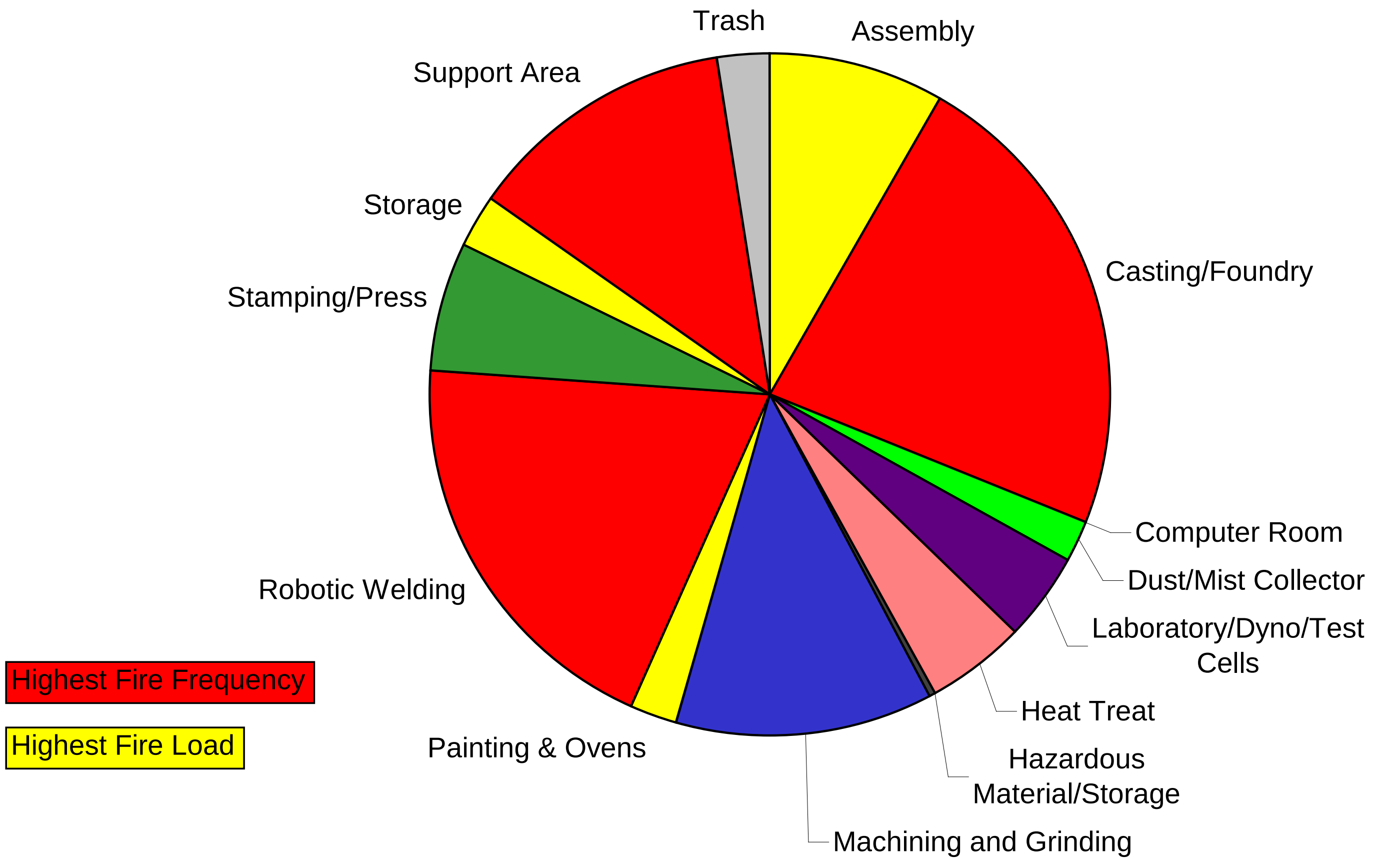
Latin America, Africa, Middle East



Tool 5: Facility Acquisition Risk Evaluation



Tool 6: Process Level Fire Risk Characterization



Tool 7: Process Level Ignition Source Analysis

Ignition Grouping	Count of Total Fires	Percent	AS	AS %	CA	CA %	PA	PA %	RW	RW %	ST	ST %	SU	SU %
0 - Liquid Fueled Equipment	102	4%	4	2%	7	7%	3	5%	3	1%	2	1%	24	3%
1 - Solid Fueled Equipment	15	1%	1	0%	0	0%	0	0%	3	1%	2	1%	6	1%
2 - Electrical Equipment	344	13%	47	22%	6	6%	22	39%	36	7%	27	16%	140	17%
3 - Hot Objects	364	14%	20	9%	58	59%	7	13%	21	4%	10	6%	107	13%
4 - Open Flames and Smoking	408	16%	57	27%	1	1%	1	2%	25	5%	34	20%	163	19%
5 - Natural Sources	25	1%	2	1%	2	2%	0	0%	8	2%	2	1%	8	1%
6 - Hot Work Operations	736	29%	41	19%	10	10%	10	18%	397	75%	25	15%	157	19%
7 - Other or Unknown	556	22%	40	19%	14	14%	13	23%	33	6%	65	39%	234	28%
Total	2550		212		98		56		526		167		839	

- Action items can be identified based on trends:
  - Electrical equipment fires in key areas
  - Improper disposal of smoking materials
  - Hot work fires show need for better housekeeping and control of permit process

Tool 8: Process Level Materials Involved Analysis

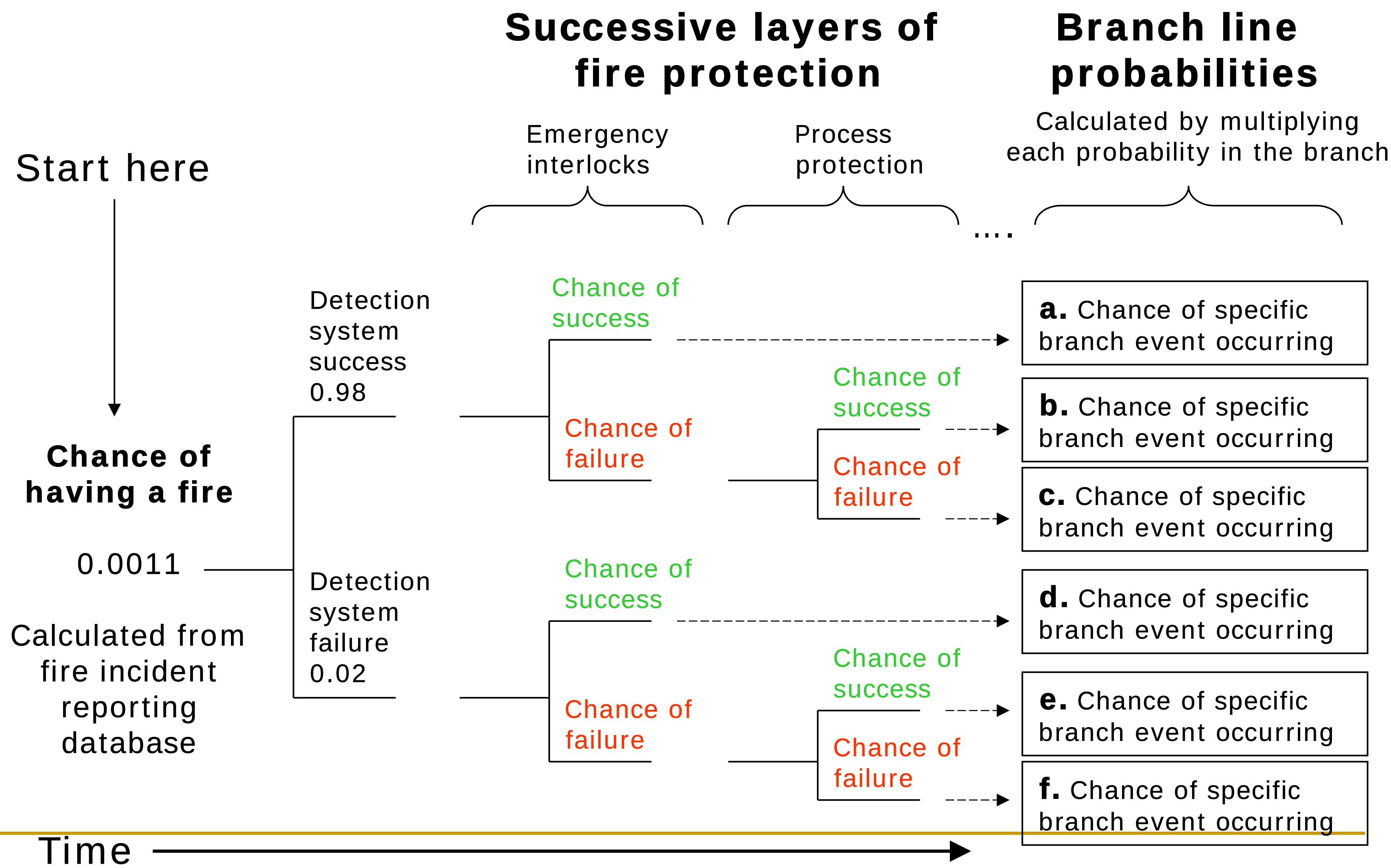
Material Grouping	Count of Total Fires	Percent	AS	AS %	CA	CA %	PA	PA %	RW	RW %	ST	ST %	SU	SU %
0 - Industrial and Production Vehicles	226	9%	59	28%	3	3%	24	5%	7	13%	42	25%	73	9%
1 - Cooking Equipment	35	1%	1	0%	0	0%	0	0%	0	0%	0	0%	33	4%
2 - Electrical Distribution Equipment	225	9%	21	10%	3	3%	37	7%	5	9%	14	8%	106	13%
3 - Office Equipment	20	1%	2	1%	0	0%	1	0%	0	0%	0	0%	12	1%
4 - Manufacturing Equipment	307	12%	12	6%	34	35%	35	7%	13	23%	2	1%	43	5%
5 - Heat Transfer/Air Circulating Equipment	74	3%	8	4%	3	3%	7	1%	4	7%	1	1%	40	5%
6 - Production Materials (Liquids/gases)	55	2%	2	1%	5	5%	9	2%	6	11%	2	1%	16	2%
7 - Production Materials (Solids)	417	16%	28	13%	17	17%	190	36%	6	11%	21	13%	107	13%
8 - Residue/Overspray Build-up	209	8%	10	5%	6	6%	30	6%	5	9%	5	3%	45	6%
9 - Other/Misc incl. Trash	919	36%	66	32%	27	28%	193	37%	10	18%	80	48%	334	41%
	2550		209		98		526		56		167		809	

- Action items can be identified to address:
  - Trash fires in all key areas
  - Production and production-support vehicle fires
  - Manufacturing equipment fires will impact production capability

Tool 9: Fire Protection Criteria Analysis - Case Study

- Provide a **decision support tool** for analyzing trade-offs in fire protection investment and prioritizing risk reduction strategies.
- Provide **cost benefit analysis** for business case support.
- Develop and justify **alternative fire protection criteria** in emerging, low cost markets with minimal legal fire code requirements.
- Provide a **reliable, consistent, engineering-based, and defendable** risk quantification framework for fire protection criteria

Overview of Event Tree Construction



Total Annual Risk Value

Branch Line Probabilities

- **a.** Chance of branch event occurring
- **b.** Chance of branch event occurring
- **c.** Chance of branch event occurring
- **d.** Chance of branch event occurring
- **e.** Chance of branch event occurring
- **f.** Chance of branch event occurring

Description of Scenario Outcome

- **a.** Minimal/no property damage. Slight BI due to system check and restart.
- . . .
- **f.** Extreme PD and BI due to total loss of building.

Severity Calculation

- **a.** Estimate of Property Damage | **a.** Estimate of days downtime | **a.** BI value = days down multiplied by daily contribution margin
- . . .
- **f.** PD Value | **f.** Downtime | **f.** BI value

Risk Value

- **a.** Expected Value Calculation: (PD+BI)* (a. branch line probability)
- . . .
- **f.** Expected value

Total Event Tree Annual Risk Value: **Sum of a to f** Expected value

Cost Benefit Analysis

	Scenario	Total Annual Risk Value	Expected Life of Equipment (years)	Life Cycle Risk Cost
Event Tree A	Paint Booth Fire WITH sprinklers at Roof level	$ 843,779	20	$ 16,875,589
Event Tree B	Paint Booth Fire WITHOUTsprinklers at Roof level	$ 2,452,485	20	$ 49,049,701

Life Cycle Cost Difference	$ 32,174,113
Initial Capital Cost of Roof-Level Sprinklers	$ 6,000,000
Decision: GO or NO GO	**GO**

- Ignores time value of money
- Assumes expected useful life of paint shop is 20 years

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Questions?