Predictive Modeling of Prefabrication Feasibility for the U.S. Electrical Contracting Firms

Hisham Said, Ph.D.

Santa Clara University

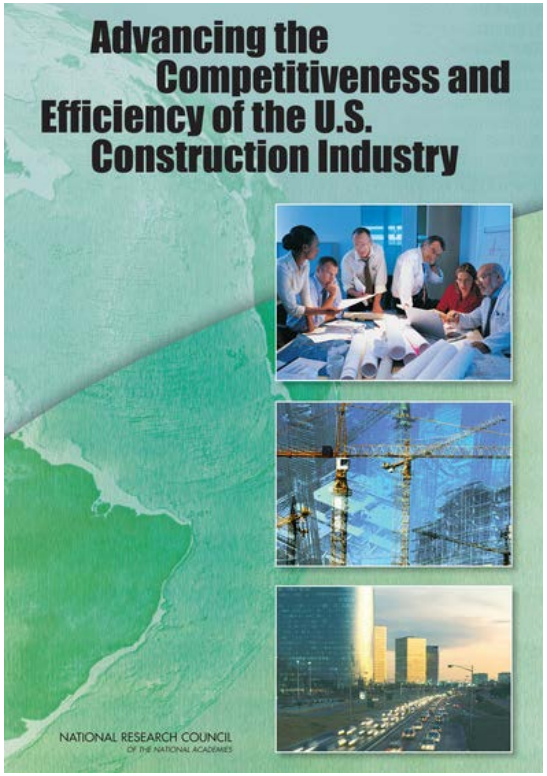
5th International/11th Construction Specialty Conference
June 10, 2015

Outline

- Overview
- Research Need and Objective
- Qualitative Data Collection
- Quantitative Data Collection
- Prefab Feasibility Binary Logistic Models
- Sensitivity Analysis
- Conclusion & Future Research

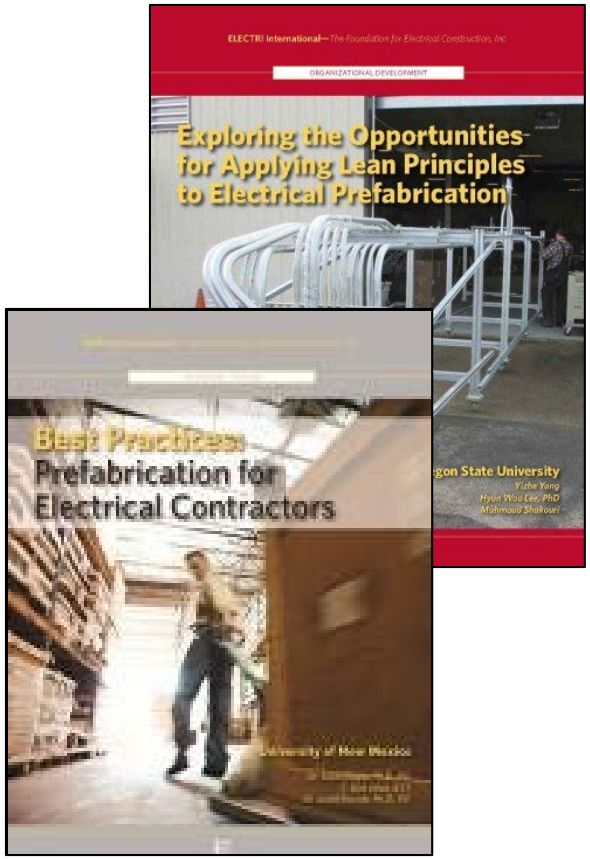
Overview

- Construction industry generally lacks behind other business sectors!
  - Productivity fell by 7% between 1995 – 2001 *(Triplett and Bosworth, 2004)*
  - 25 – 50% internal waste in labor and material *(Tulacz and Armistead 2007)*
- Need for improvement was recognized by national organizations (NIST & NRC).
- Recommended industry improvement approaches: to improving construction efficiency:
  1) Increased Interoperability.
  2) Effective Interfacing between project processes.
  3) **Modular Construction & Offsite Prefabrication**
  4) Use of demonstration installations
  5) Use of Effective Performance Measurement.



Overview

- MEP contractors have been early adopters of prefabrication.
- Previous Research Studies of Electrical Contraction:
  - Design/Build Considerations (Rowings 2000)
  - Financial evaluation (Jaselskis et al. 2002)
  - HR recruitment and detainment (Rojas 2013).
  - MEP trades coordination (Riley et al. 2005, Korman and Tatum 2006, Horman et al. 2006)
  - Planning and Control (Menches and Hanna 2006)
  - Change orders impact (Hanna et al. 2004),
  - BIM (Khanzode et al. 2008, Hanna et al. 2014).
  - Prefab Facility Best Practices (Bogus et al. 2009, Yang et al. 2014)

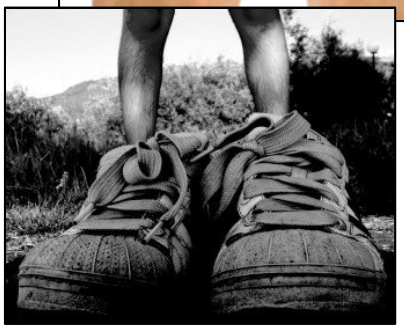


http://www.electri.org/research-project-archives

Research Need and Objective

- Prefab is not a one solution fits all!
- **No understanding of the determinants of prefabrication feasibility for EC's.**
- Research Objective:

  Develop a data-driven predictive model of prefabrication feasibility of electrical contractors.



Research Methodology

1. Qualitative Data Collection
2. Quantitative Data Collection
3. Logistic Regression Model Development/Validation
4. Sensitivity Analysis

Qualitative Data

Semi-Structured Interview

- ❑ Impact of project supply chain stakeholders (designer, general contractor, vendor, manufacturer)
- ❑ Impact of external environment (union relations, labor hourly rates).

Interviewed:

7 EC operation managers

1 vendor representative,

3 manufacturer sale managers

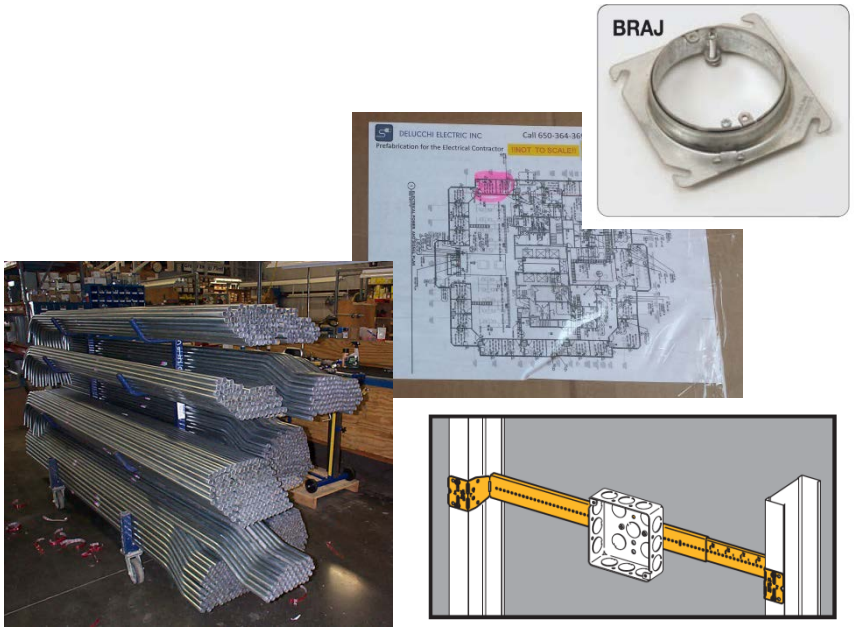
1 NECA executive director

Site Visits

- ❑ Visits to 2 EC prefabrication facilities
- ❑ Electric Roundtable meeting

Case Studies

- ❑ Projects, prefab assemblies



Quantitative Data

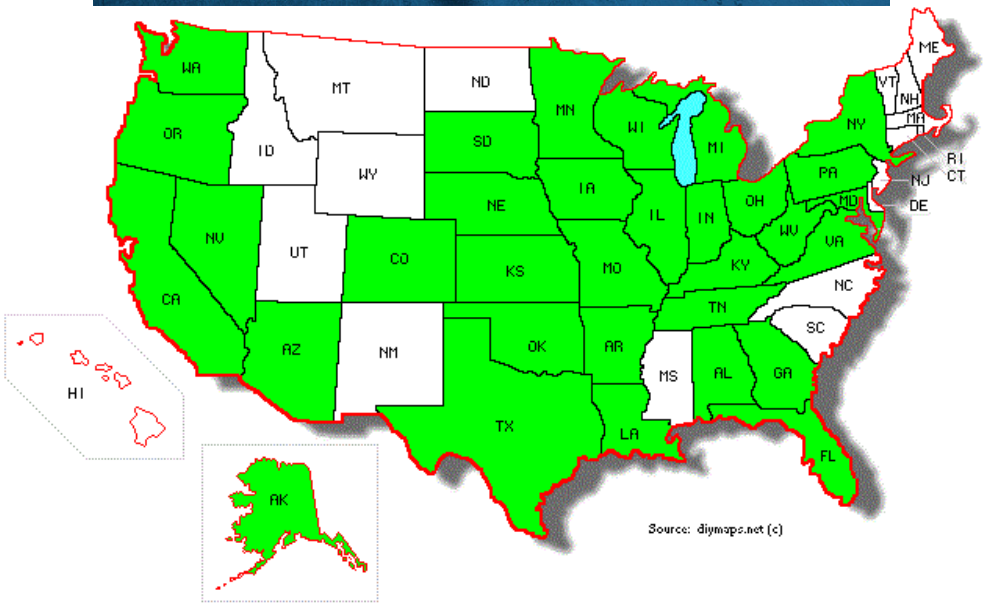
Web-based Questionnaire

Category	Question topics
Company characteristics	Work Volume , Prefab%, Zip Code, Lean Principles, Services (BIM, Engineering, Maintenance)
Vendor Relations	Vendor size, Vendor Partnership, Value-added services, Vendor Early Involvement
Manufacturer Relations	Manufacturer Services (*Training workshops, Products customization, Custom Packaging, Materials Logistics*)
Design Requirements	Flexibility of Design Code/Specs requirements
Labor Relations	Resistance to Prefab Resistance to Prefab outsourcing to vendors or manufacturers

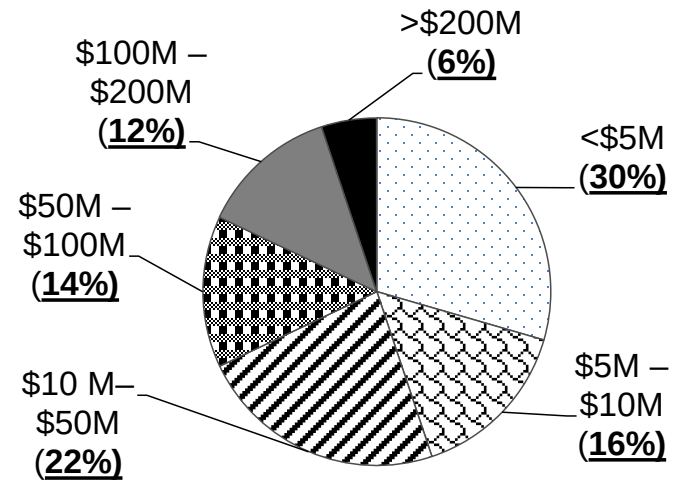
Quantitative Data

- ail list
- stry-

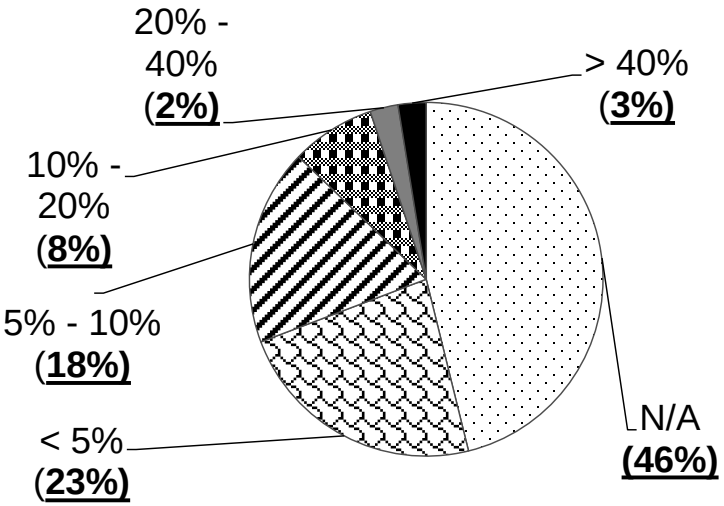
al. 2010)



States of Questionnaire Responses



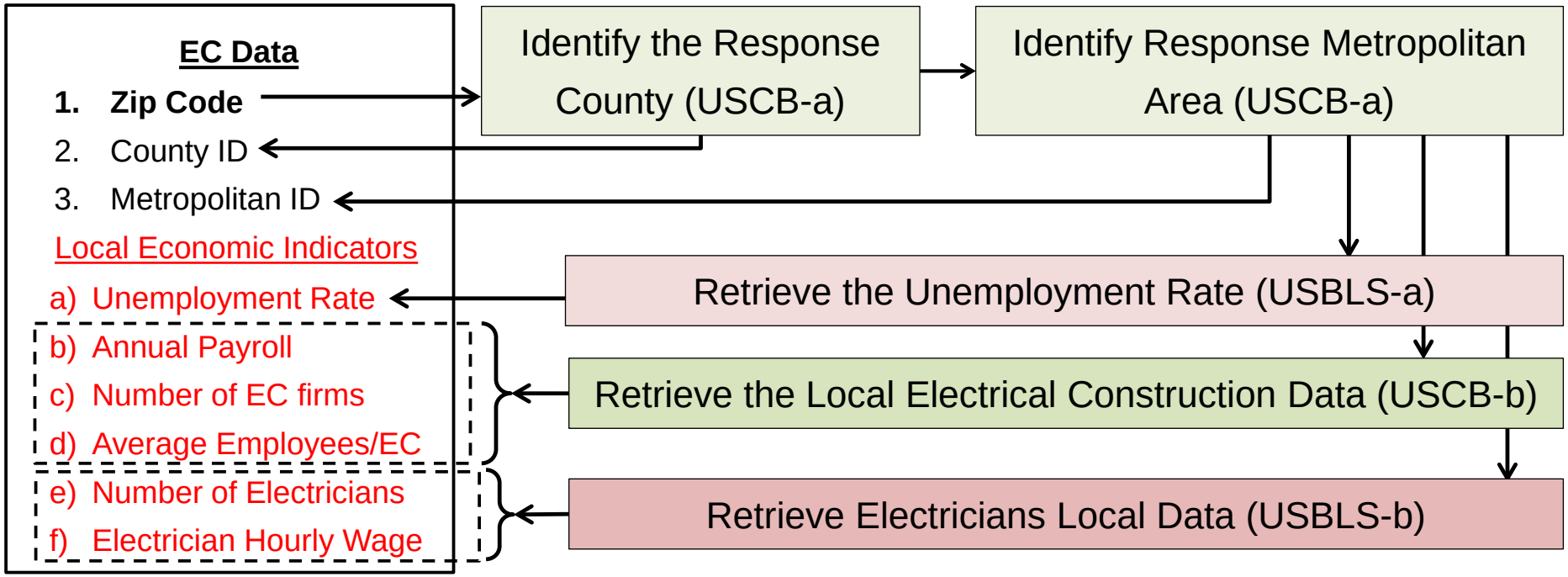
Work Volume



Prefab%

Quantitative Data

Industry Economic Data



USBLS-a: U.S. Bureau of Labor Statistics, Local Area Unemployment Statistics.

USBLS-b: U.S. Bureau of Labor Statistics, Occupational Employment Statistics (OES).

USCB-a: U.S. Census Bureau. Metropolitan and Micropolitan Statistical Areas

USCB-b: U.S. Census Bureau. County and Metropolitan Areas Business Patterns

Logistic Regression Models

Prefabrication feasibility (PF) is modeled as a binary dichotomous variable

0 = Prefab is a feasible operations model

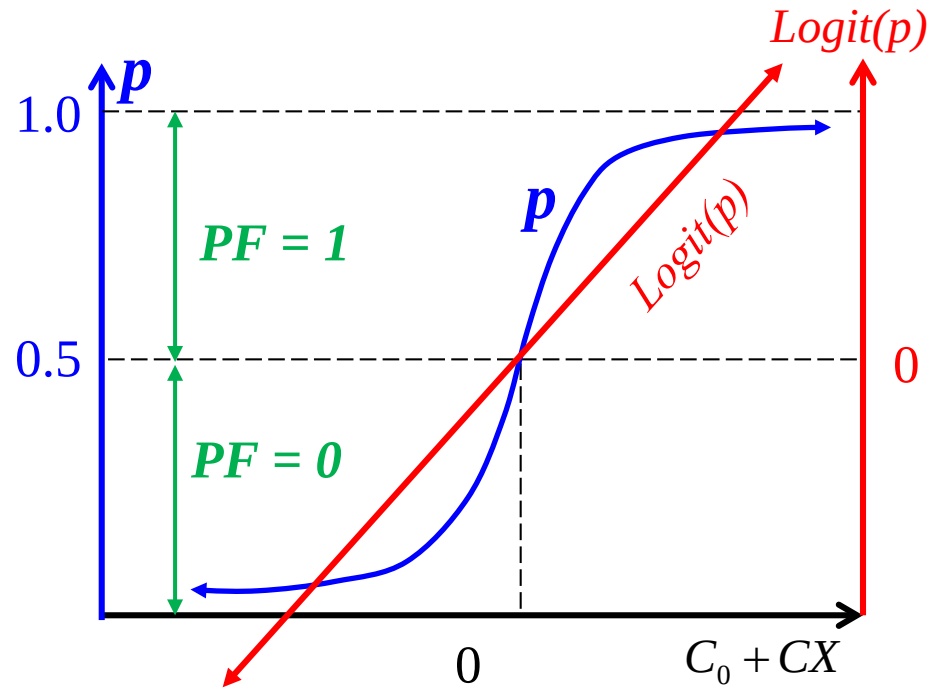
1 = Prefab is not feasible

Prefabrication Feasibility (*PF*)

$$PF = \begin{cases} 0 & if\ \ p < 0.5 \\ 1 & if\ \ p \geq 0.5 \end{cases}$$

Prefabrication Feasibility Probability (*p*)

$$p = \frac{1}{1 + e^{-(C_0 + C_1 X_1 + C_2 X_2 + \ldots\ldots + C_n X_n)}}$$



The Linear Logit Function

$$Logit(p) = \ln\left(\frac{p}{1-p}\right) = C_0 + C_1 X_1 + C_2 X_2 + \ldots\ldots + C_n X_n$$

X = Independent Variables (Prefab Determinants)

Logistic Regression Models

20 Prefabrication Determinants (Independent variables, X) were proposed.

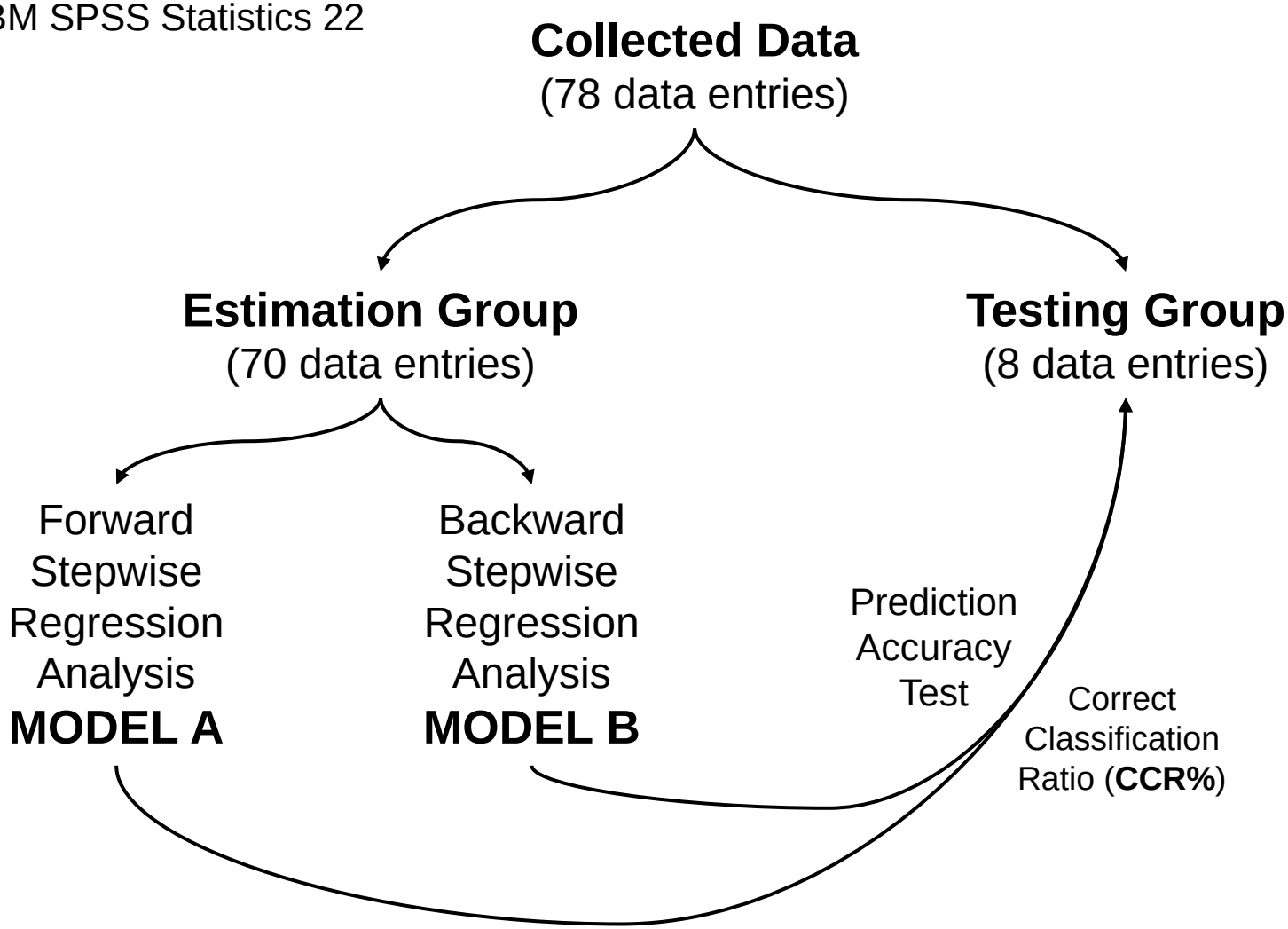
Metropolitan (local) Unemployment (***unemploy***)	Engineering/Design Services (***engDesign***)
~~Annual Payroll of Local Electrical Contracting Firms (***payroll***)~~	BIM Capabilities (***BIM***)
~~Number of Local Electrical Contracting Firms (***nFirms***)~~	Level of Lean Operations (***lean***)
Average Number of Employees per a Local Firm (***nEmploy***)	Vendor Partnership Existence (***vendorPartner***)
Electricians Employment (***electEmploy***)	Strength of Vendor Relationship (***vendorRel***)
Electricians Average Hourly Wage (***electWage***)	Existence of Material Blanket Prices (***blanketPrice***)
Union Acceptance of Prefab (***unionPrefab***)	Vendor Size (***vendorSize***)
Union Acceptance of Outsourcing (***unionOutsouce***)	Vendor Early Involvement (***vendorEarly***)
Firm's Work Volume (***workVolume***)	Strength of Manufacturer Relation (***ManufRel***)
Business Territory (***coverDistance***)	Prefabrication Flexibility of Electrical Specifications (***specsFlex***)

payroll and ***nFirms*** were not considered in the regression due to their high multicolinearity.

Logistic Regression Models

Regression Methodology

Using IBM SPSS Statistics 22



Logistic Regression Models

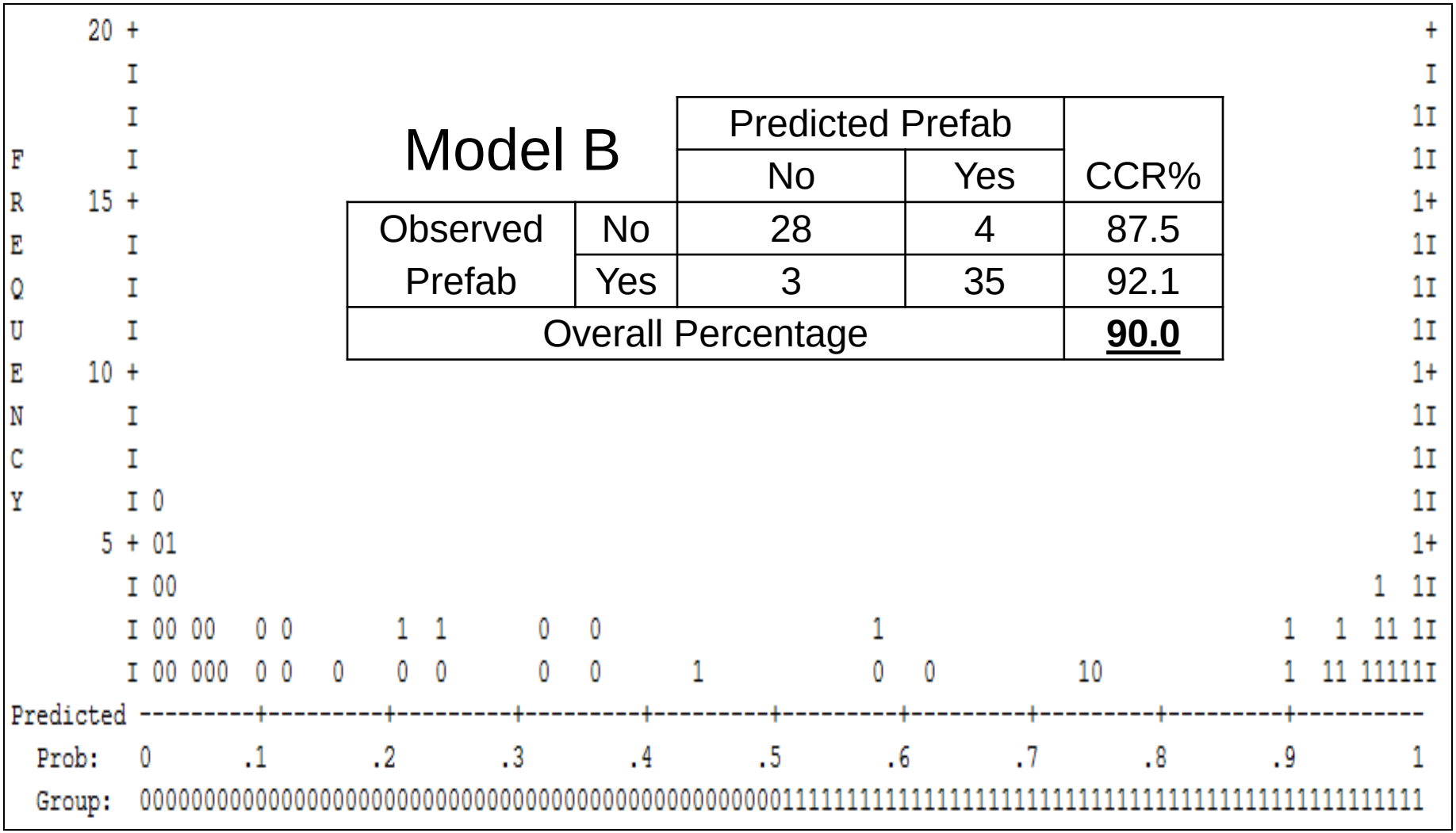
Variables*	Sample Average	Model A (Forward Stepwise)			Model B (Backward Stepwise)		
		B	S.E.	Sig.	B	S.E.	Sig.
Constant (C_0)	--	-1.890	0.994	0.057	-6.821	5.529	0.2173
unemploy	7.16	--	--	--	-0.784	0.4225	0.0633
nEmploy	12.77	--	--	--	0.3914	0.2107	0.0632
electWage	26.28	--	--	--	0.2407	0.1247	0.0536
unionOutsouce	-1.128	1.460	0.692	**0.035**	1.9687	0.988	**0.0464**
BIM	0.46	4.219	1.311	**0.001**	6.5916	1.8075	**0.0003**
vendorPartner	0.397	--	--	--	2.5773	1.3891	0.0635
vendorRel	4.70	0.547	0.245	**0.026**	--	--	--
Model Statistics							
Model Overall P-value		1.89E-13 (≅ 0.0)			2.6E-13 (≅ 0.0)		
Cox & Snell R^2		0.589			0.637		
Nagelkerke R^2		0.788			0.851		
CCR%		88.6%			90.0%		

logit(p_A) = -1.89 + 1.46 (unionOutsouce) + 4.219 (BIM) + 0.547 (vendorRel)

logit(p_B) = -6.821 -0.784(unemploy)+0.3914(nEmploy)+0.2407(electWage)+ 1.9687(unionOutsouce) + 6.5916 (BIM) +2.577(vendorPartner)

$$p = \frac{1}{1+e^{-\log it(p)}}$$

Logistic Regression Models



Model B

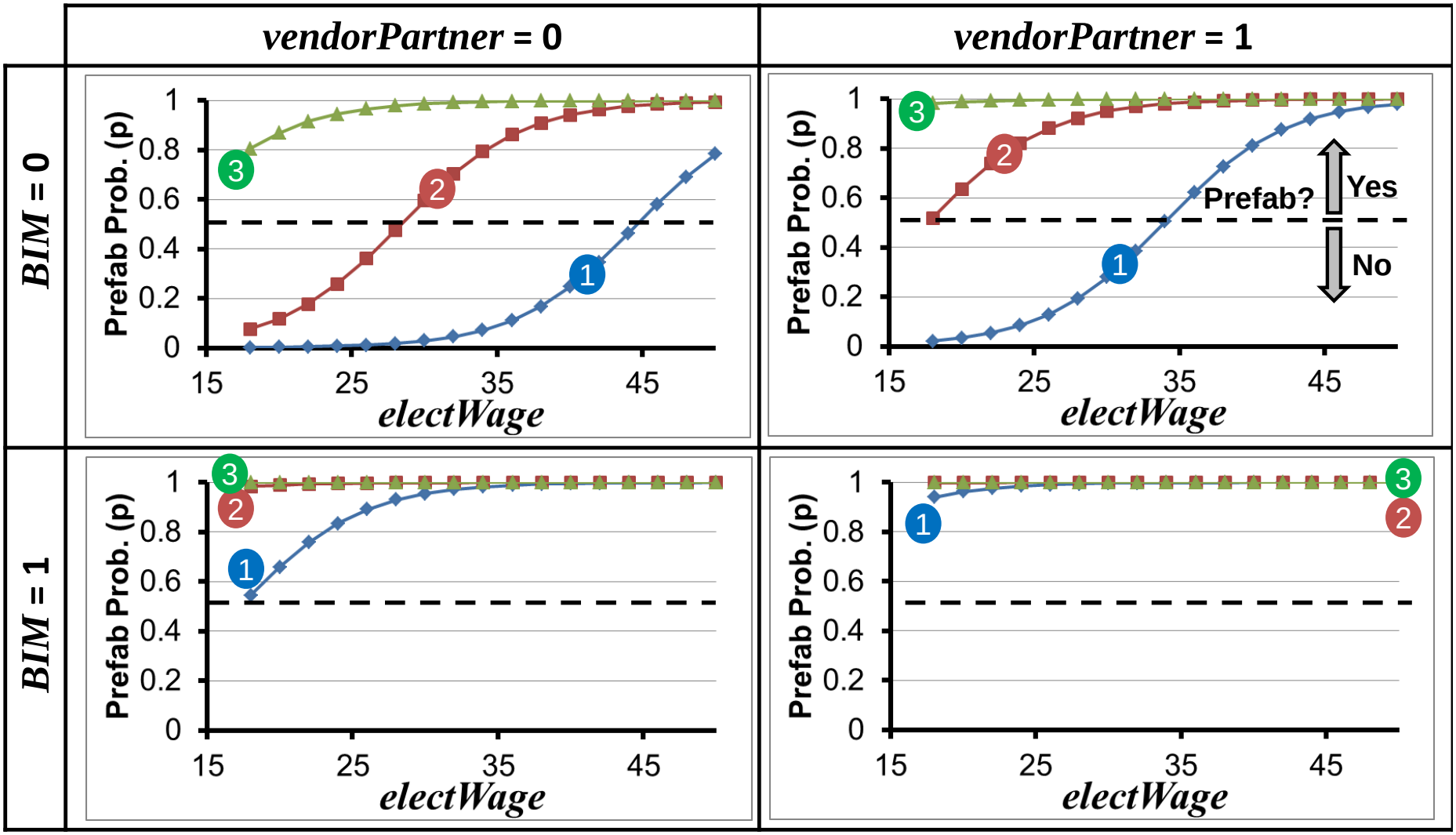
		Predicted Prefab		
		No	Yes	CCR%
Observed Prefab	No	28	4	87.5
	Yes	3	35	92.1
Overall Percentage				**90.0**

Logistic Regression Models

Prediction Accuracy Test

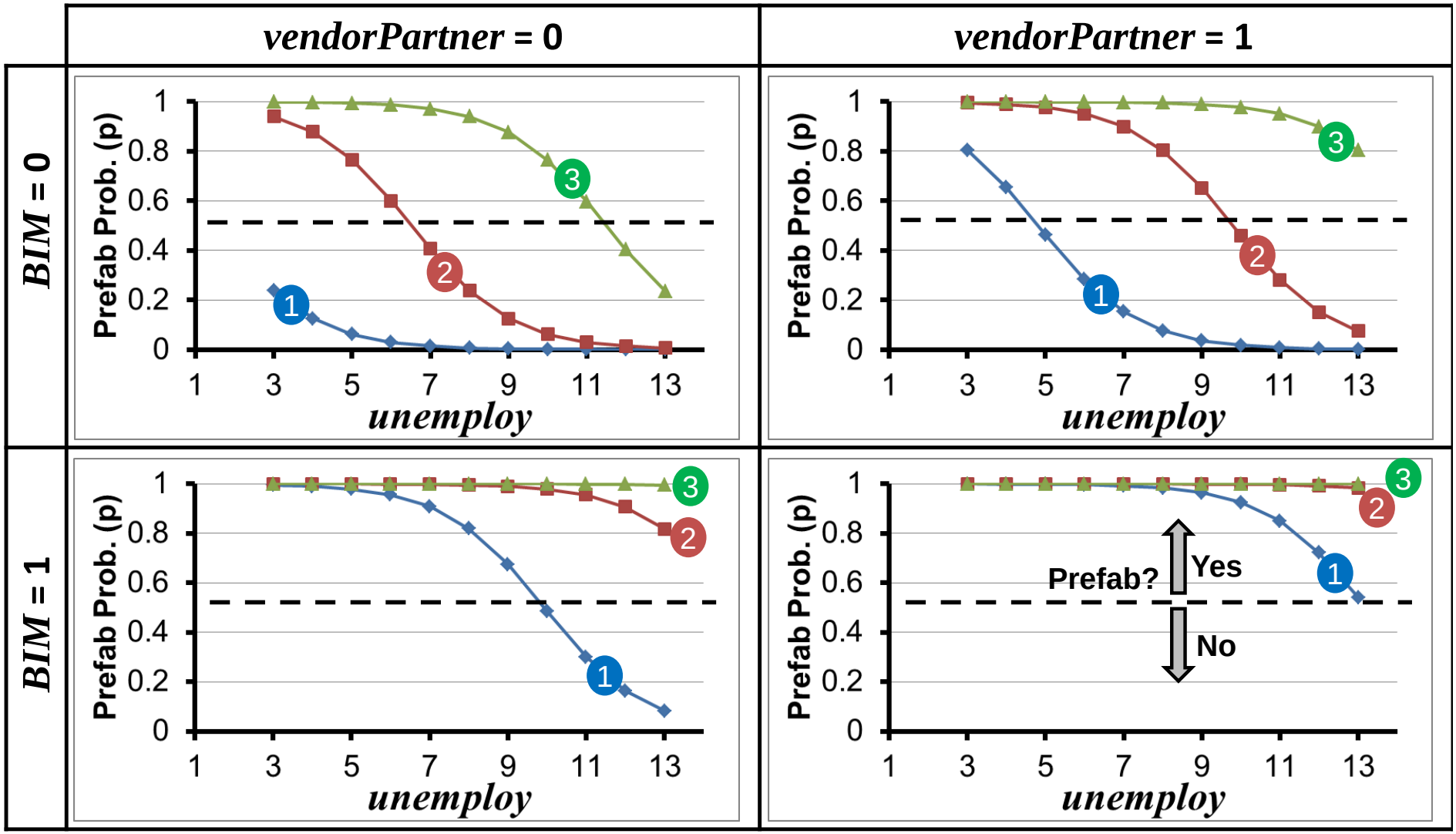
Variables	Validation Cases							
	1	**2**	3	4	5	6	7	**8**
BIM	0	**1**	1	1	0	1	1	**0**
vendorPartner	0	**0**	0	1	0	0	0	**0**
unemploy	9	**3.4**	4.5	8.3	6.1	3.5	8.1	**5.4**
nEmploy	14.7	**13.27**	13.5	14.74	9.4	11.25	13.17	**11.8217**
electWage	30.48	**20.71**	22.41	24.23	19.37	22.04	30.17	**40.01**
unionOutsouce	0	**0**	-2	-1	-1	-2	-2	**-1**
Observed Prefabrication State	No	**No**	Yes	Yes	No	Yes	Yes	**No**
Calculated Probability	0.312	**0.999**	0.952	0.996	0.0053	0.9425	0.869	**0.774**
Predicted Prefabrication Feasibility	No	**Yes**	Yes	Yes	No	Yes	Yes	**Yes**
CCR%	**75%**							

Sensitivity Analysis



Average employees/firm in the area (nEmploy): 1 10 2 20 3 30

Sensitivity Analysis



Average employees/firm in the area (nEmploy): 1 10 2 20 3 30

Conclusion and Future Research

- **BIM** and **Union Relations** have a significant impact on prefabrication feasibility for electrical contractors.
- Other prefab determinants: **vendor partnership**, **local competition**, and **labor cost**.
- <u>Future Research:</u>
  - Developing a **multinomial logistic regression analysis** to classify prefabrication feasibility into classes (high, medium, low).
  - Apply similar methodology to the prefabrication feasibility in **other building trades** (i.e. mechanical, plumping)
  - Develop a **web-based tool** to facilitate continuous collection of prefabrication data and dissemination of the results.

Predictive Modeling of Prefabrication Feasibility for the U.S. Electrical Contracting Firms

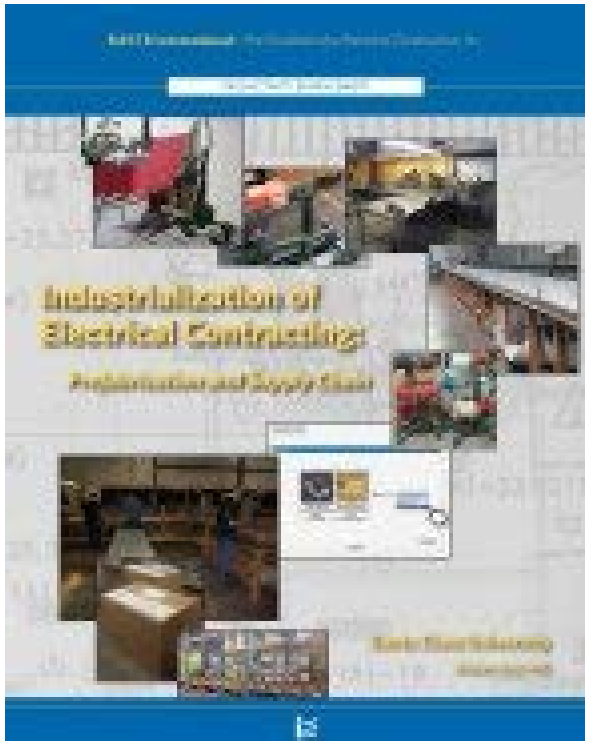
Hisham Said, Ph.D.

Santa Clara University

hsaid@scu.edu

ELECTRI INTERNATIONAL

THE FOUNDATION FOR ELECTRICAL CONSTRUCTION INC.



Thank you!

Your Questions and Feedback are welcomed!

SANTA CLARA UNIVERSITY 1912-2012 100 ENGINEERING