A STATISTICAL PROJECT CONTROL TOOL FOR ENGINEERING MANAGERS

2nd International Workshop on Engineering Management for Applied Technology
Joe C. Thompson Conference Center
Austin, TX

GARLAND T. BAUCH, PH. D.
INDUSTRIAL ENGINEERING
(SYSTEMS ENGINEERING/ENGINEERING MANAGEMENT)
NASA – JOHNSON SPACE CENTER
SPACE SHUTTLE DIVISION
SR&QA OFFICE
AUGUST 16, 2001

AGENDA

- Introduction
- Literature Review
- Problem Statement
- Research Methodology
- Research Results and Discussion
- Limitations of Study
- Contribution to the Body of Knowledge
- Future Research
- Conclusions

INTRODUCTION

- Use of Projects Increasing

  Meredith (1988), Badiru, (1991), Kharbanda & Pinto (1996), Pinto & Kharbanda (1996), and Shenhar, Levy, & Dvir (1996).

- Project Failures Increasing Globally

  Badiru (1995), Balachandra (1989), Gioia (1996), Morris (1988), Morris and Hough (1987), and Tishler, Dvir, Shenhar, and Lipovetsky (1996)

- Application to Project Management

LITERATURE REVIEW

- Project Success Definition
- Project Success Factors
- Project Control Tools (networking)
- Performance Measurement
- Statistical Process Control
- Continuous Assessment of Performance
- Statistical Project Control
- General Results

LITERATURE REVIEW

PROJECT SUCCESS DEFINITION

A Project Is Successful When the Cost, Schedule, Technical Performance, and Quality Satisfy the Customer.

LITERATURE REVIEW
PROJECT SUCCESS FACTORS

- Project Goals, Definition, & Mission
- Cost, Finance, & Schedule
- Technical Uncertainty & Performance
- Customer Satisfaction & Acceptance
- Environmental, Social, & Political Pressure
- Managerial & Organizational Factors
- Communications

[Morris (1988), Slevin & Pinto (1986), Tishler et. al (1996), Baker et. al. (1986), & Woodard (1988)]

LITERATURE REVIEW

TRADITIONAL PROJECT CONTROL TOOLS

- Gantt Charts

  Gantt (1911)

- WBS

  Kelley and Walker (1959)

- CPM

  Du Pont (1950s)

- PERT

  Navy Polaris (1958)

LITERATURE REVIEW

PERFORMANCE MEASUREMENT

- Actual Cost vs. Earned Value
- Planned (Budget) vs. Earned Value
- Technical Performance
- Required for > $25 Million

[Project Management Guide, JSC 61100, NASA-JSC]

LITERATURE REVIEW

STATISTICAL PROCESS CONTROL

- Shewhart Control Charts 1924

  [Emerson & Naehring (1985)] , [Montgomery (1985)], [Johnson's Miller & Freund (1994)]

- SQC Training/Deming, Et. Al.

  [Emerson & Naehring (1985)]

- Manufacturing Processes

- Tool Wear Model

  [Banks (1989), Grant (1952), McClave and Benson (1994)]

LITERATURE REVIEW

CONTINUOUS ASSESSMENT OF PROJECT PERFORMANCE (CAPP)

- Predictive Tools Task Force (1992)
- Quantitative Real-time Data Collected
- Questionnaire Used

LITERATURE REVIEW
STATISTICAL PROJECT CONTROL

- No Literature Found

LITERATURE REVIEW

GENERAL RESULTS

- Existing Tools Mostly Empirical & Subjective

  Slevin & Pinto (1986)

- Need for Better Dynamic Tools

  Balachandra & Raelin (1984), Christian (1993), Goldin (1998), Meredith (1988), Morris (1988), & Tadisina (1986)

- Consider Environmental Impact

  Might & Fisher (1985)

- Consider Customer Needs

  Lipovetsky, Tishler, Dvir, & Shenhar (1997)

PROBLEM STATEMENT

- Resources Becoming More Limited
- Projects Are Increasing in Numbers

  [Meredith (1988)]
- Project Failure Is Increasing

  [Morris (1989)]
- Systematic Methods Needed

  [Pinto & Slevin (1988)]
- Existing Methods Limited

OBJECTIVE

Provide a New
Statistical Project Control
Tool For
Project Managers

RESEARCH METHODOLOGY

- Data Search/Collection
- Research Population
- Data Transformation
- Validation Steps
- Comparison of SPC and SPCT Charts

RESEARCH METHODOLOGY

DATA SEARCH/COLLECTION

- NASA
- Military
- Consultants
- Professional
- Commercial
- Institutes

RESEARCH METHODOLOGY

RESEARCH POPULATION

- Construction Industry Projects
- 17 Companies
- 54 Projects
- 76 Variables

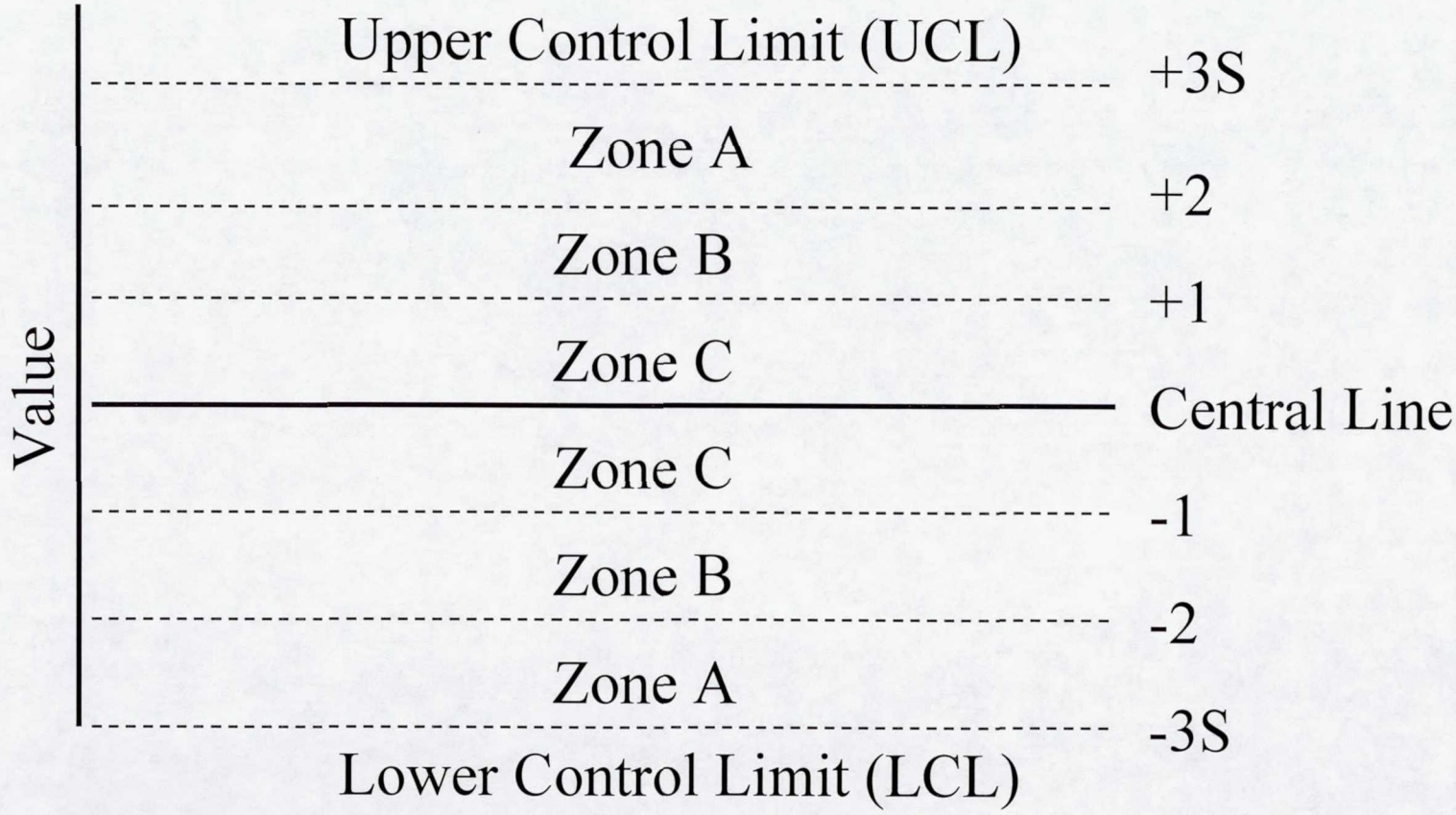
RESEARCH METHODOLOGY

DATA TRANSFORMATION

- Traditional Control Chart Features
- Compute Normalized Time and Variables
- Pattern Analysis Rules
- Validation Steps
- Comparison of SPC and SPCT Charts

RESEARCH METHODOLOGY

Traditional Control Chart Features



[McClave & Benson (1994)]

RESEARCH METHODOLOGY

DATA TRANSFORMATION

COMPUTE NORMALIZED TIME

Normalized

Original

RESEARCH METHODOLOGY

DATA TRANSFORMATION

COMPUTE NORMALIZED VARIABLE

- Ratio
- Moving Average
- Exponential Smoothing
- % Cumulative (Cum)
- Cum % Cum
- Average Cum % Cum

RESEARCH METHODOLOGY

DATA TRANSFORMATION

SPCT CHART

RESEARCH METHODOLOGY

DATA TRANSFORMATION

TRADITIONAL PATTERN ANALYSIS RULES

Rule 1: 1 point beyond Zone A

Rule 2: 9 points in a row in Zone C or beyond

Rule 3: 6 pts. in a row steadily incr. or decreasing

Rule 4: 14 points in a row alternating up and down

Rule 5: 2 out of 3 pts. in a row in Zone A or beyond

Rule 6: 4 out of 5 pts. in a row in Zone B or beyond

[McClave & Benson (1994)]

RESEARCH METHODOLOGY

DATA TRANSFORMATION
MODIFIED PATTERN ANALYSIS RULES

- Rule 1m: 1 pt. beyond Zone A

  Except for a slight exceeding in cost or design early in the project life cycle

- Rationale
  - —Initial start-up costs large sometimes
  - —Zero or low variable values
  - —Low values cause narrow control limits
  - —Insufficient trending data

RESEARCH METHODOLOGY

DATA TRANSFORMATION
MODIFIED PATTERN ANALYSIS RULES

- Rule 2m: 9 pts. in a row in Zone C or beyond

  Except below the CL early in the project life cycle for expenditures or construction and late in the life cycle for design.

- Rationale
  - —Expenditures and construction are historically low early in the project life cycle
  - —Design is historically low late in the life cycle

RESEARCH METHODOLOGY

DATA TRANSFORMATION

MODIFIED PATTERN ANALYSIS RULES

- Rule $3m_1$: 6 pts. in a row dec. rel. to the CL

  Except for design during the latter part of the project life cycle.

- Rationale

  Design historically decreases late in the project life cycle

RESEARCH METHODOLOGY

DATA TRANSFORMATION

MODIFIED PATTERN ANALYSIS RULES

- Rule $3m_2$: 6 pts. in a row inc. rel. to the CL

  Except for design during the early part of the project life cycle.

- Rationale

  Design historically increases early in the project life cycle

RESEARCH METHODOLOGY

Comparison of SPC and SPCT

FEATURE	TRADITIONAL	PROJECT
HISTORICAL		
TARGET LINE		
SAMPLE SIZE		
VALUE		
CENT. LINE		
UCL, LCL		

RESEARCH RESULTS

Chart Types

- Actual Owner Expenditure
- Actual % Design Complete
- Actual % Construction Complete
- Actual Cost of Change Orders

RESEARCH METHODOLOGY

QUANTITATIVE VALIDATION STEP

- Plot 3 Different Successful Projects

  Does Not Violate Pattern Analysis Rules

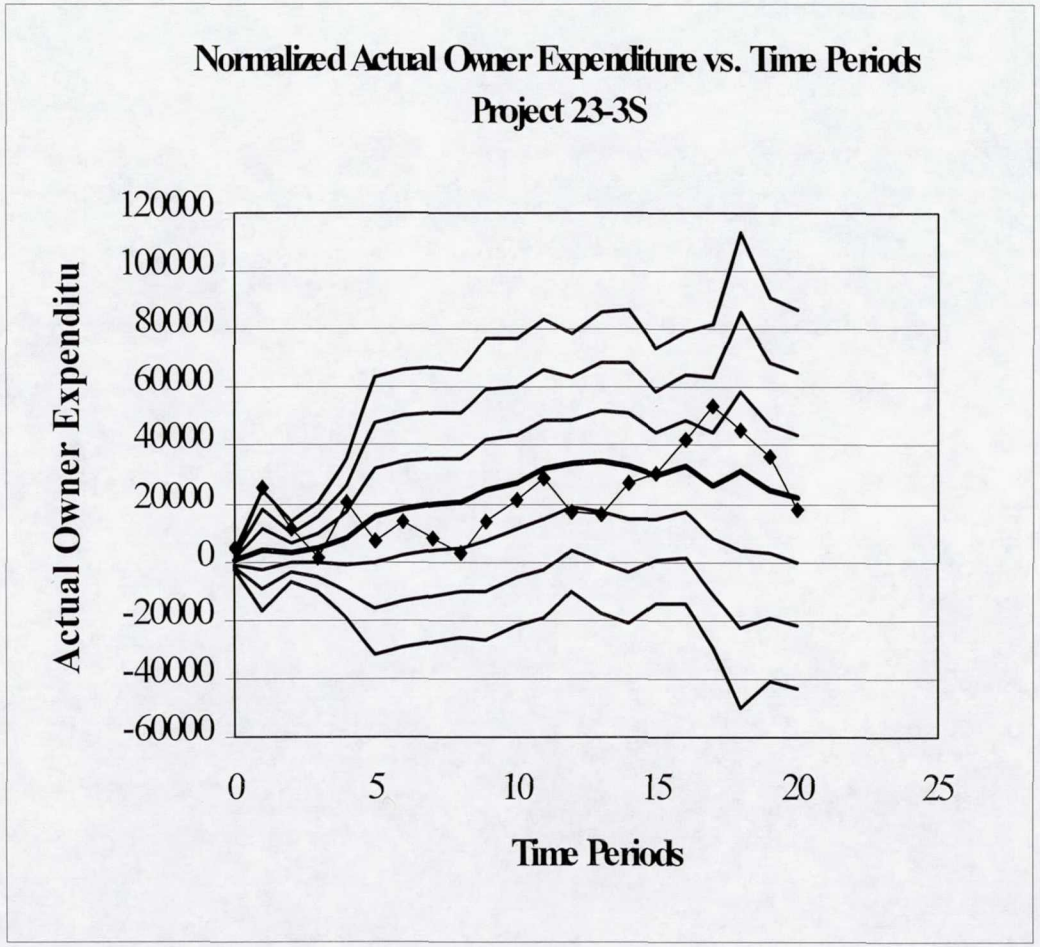
- Plot 3 Different Failed

  Violates Pattern Analysis Rules

- Success/Failure Defined By Owner

RESEARCH RESULTS

SPCT Validation Using Successful Project

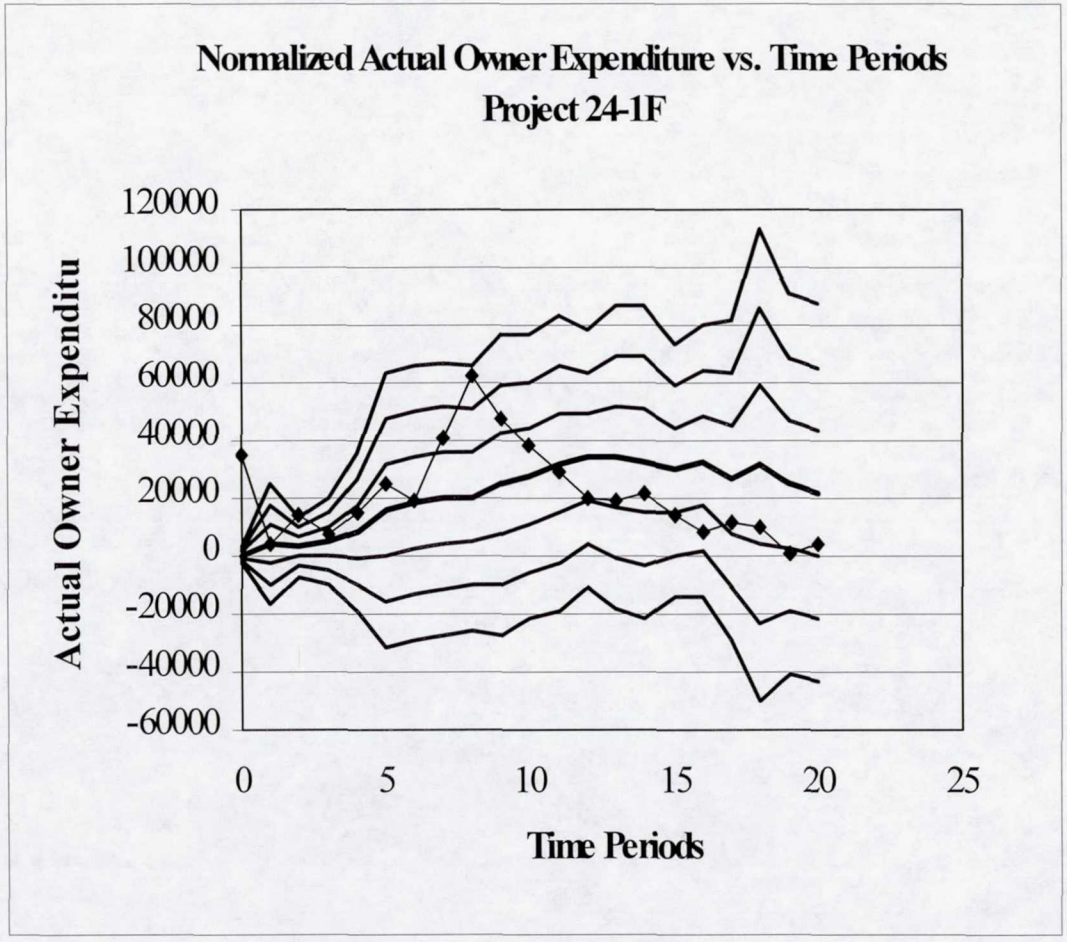


- Process industry
- In-control per Rules 1m & 2m
- Pattern validates control chart

TP	LCL	CL	UCL	23-3S
0	-2798	271	3340	4550
5	-31912	15862	63636	743
10	-21891	27427	76744	21432
15	-14300	29648	73597	30533
20	-43350	21872	87094	18079

RESEARCH RESULTS

SPCT Validation Using Failed Project

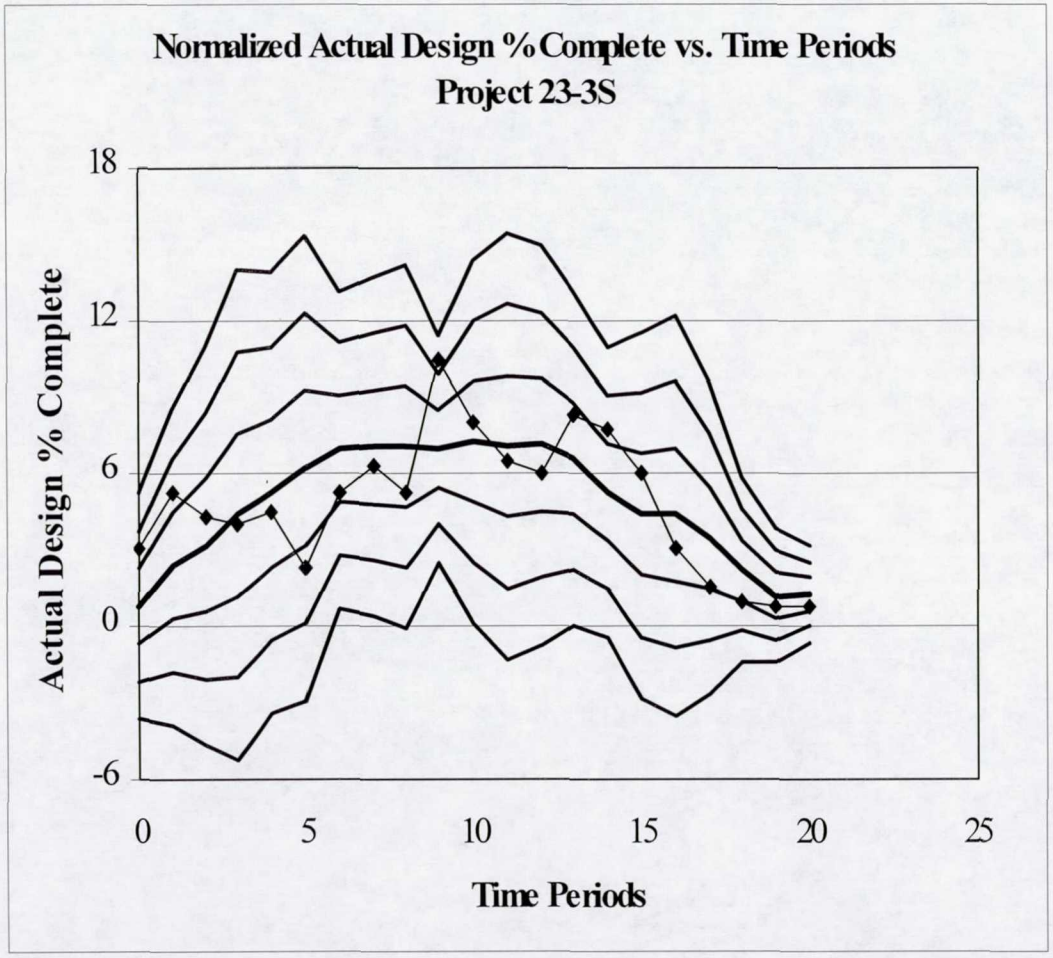


- Process industry
- Out-of-control per Rules 1, 2, & 3
- Pattern validates control chart

TP	LCL	CL	UCL	24-1F
0	-2798	271	3340	34769
5	-31912	15862	63636	25265
10	-21891	27427	76744	38152
15	-14300	29648	73597	13842
20	-43350	21872	87094	4057

RESEARCH RESULTS

SPCT Validation Using Successful Project

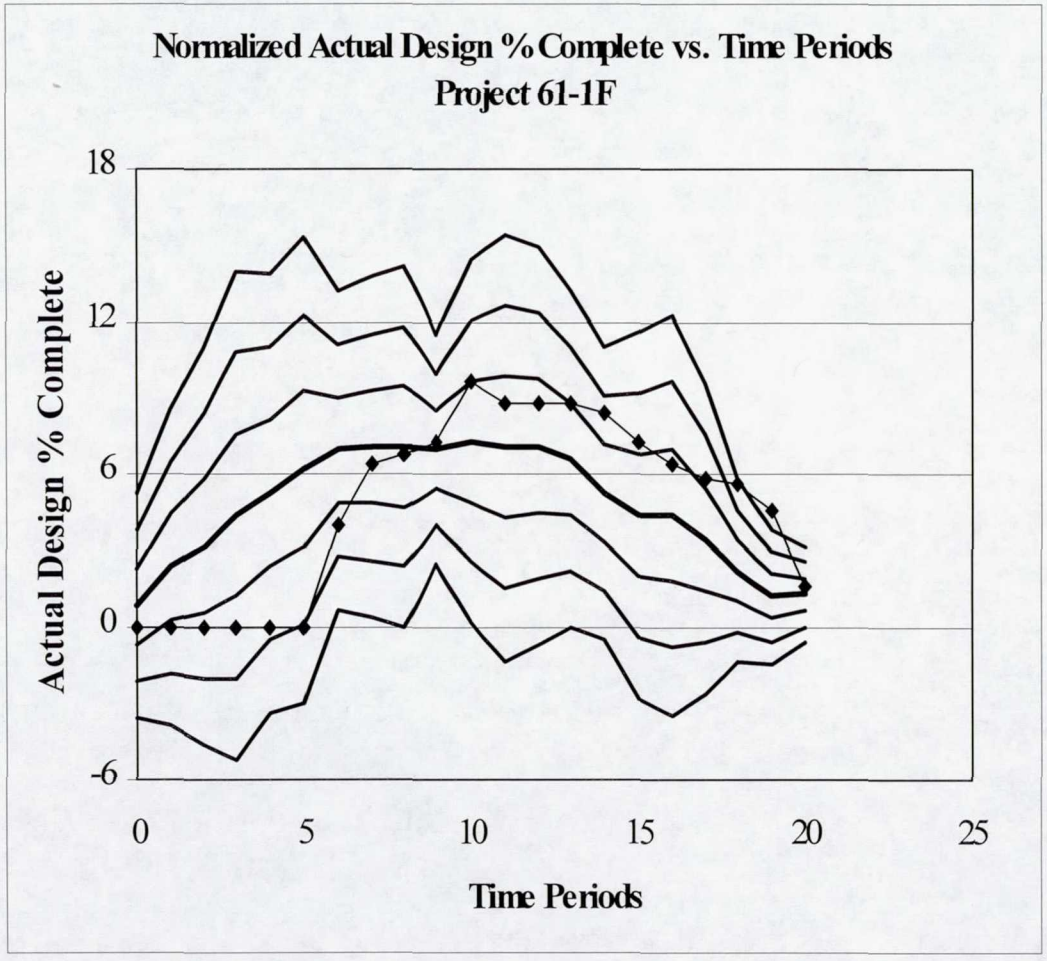


- Process industry
- Pattern in-control per Rule 3m
- Pattern validates control Chart

TP	LCL	CL	UCL	23-3S
0	-3.63	0.80	5.24	3.00
5	-2.99	6.17	15.33	2.25
10	0.12	7.27	14.41	8.00
15	-2.83	4.37	11.56	6.00
20	-0.65	1.25	3.16	0.75

RESEARCH RESULTS

SPCT Validation Using Failed Project

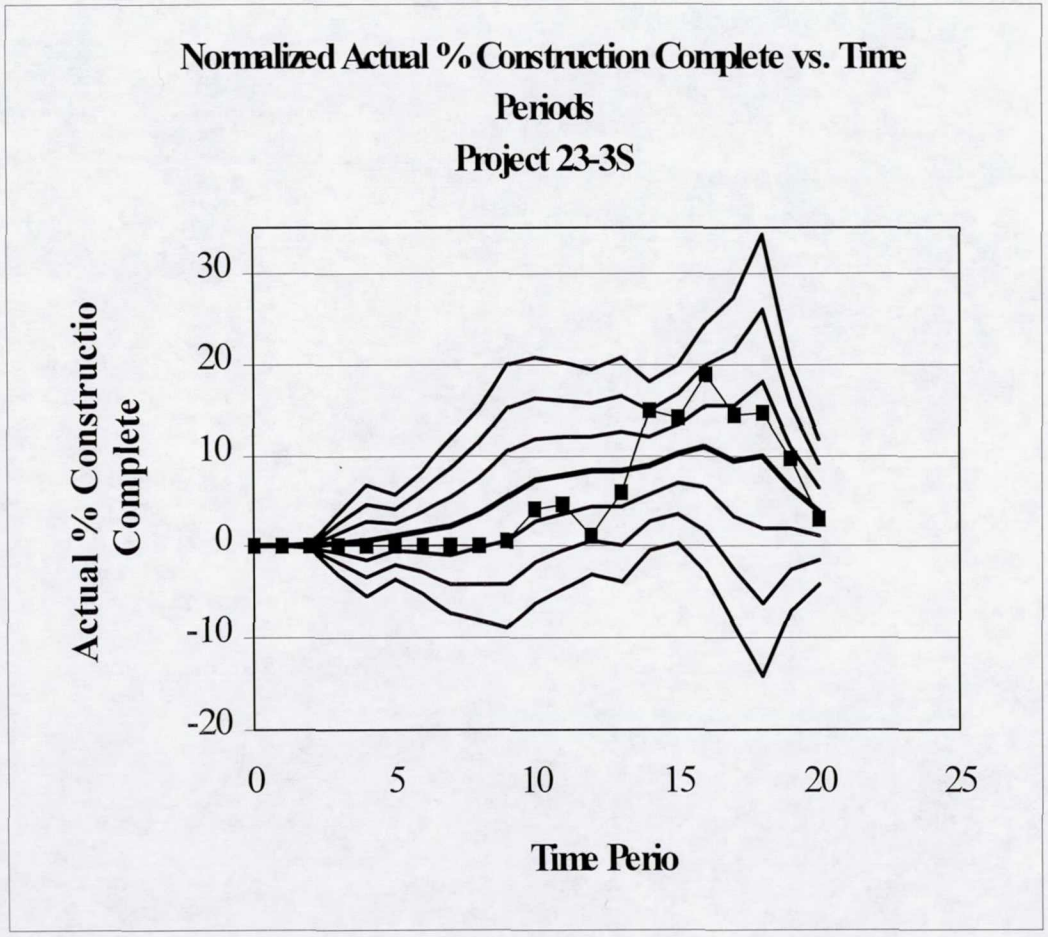


- Process industry
- Out-of-control per Rules 1, 3, & 6
- Pattern validates control chart

TP	LCL	CL	UCL	61-1F
0	-3.63	0.80	5.24	0.00
5	-2.99	6.17	15.33	0.00
10	0.12	7.27	14.41	9.60
15	-2.83	4.37	11.56	7.20
20	-0.65	1.25	3.16	1.60

RESEARCH RESULTS

SPCT Validation Using Successful Project

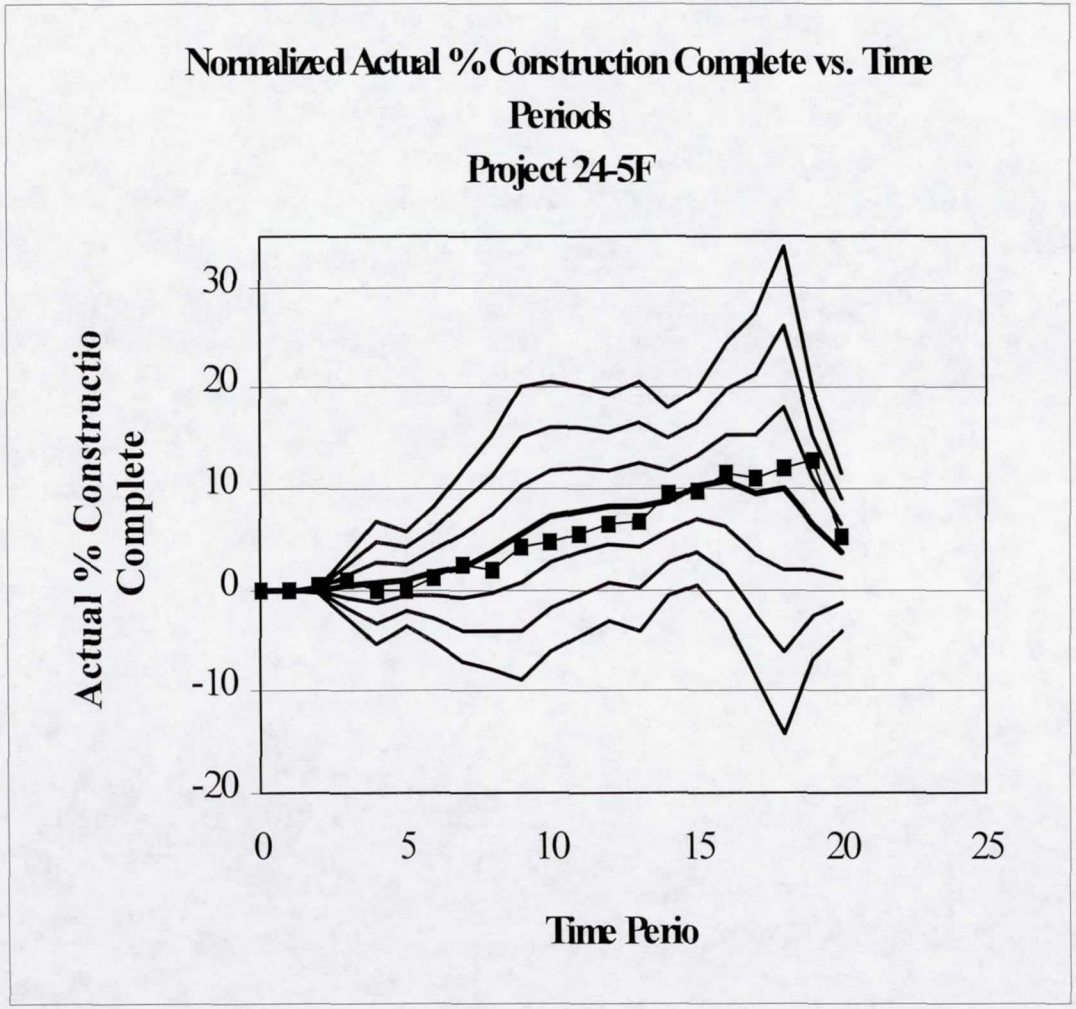


- Process industry
- Pattern in-control per Rule 2m
- Pattern validates control chart

TP	LCL	CL	UCL	23-3S
0	0.00	0.00	0.00	0.00
5	-3.61	1.02	5.65	0.00
10	-6.23	7.22	20.67	4.19
15	.41	10.16	19.90	14.20
20	-4.01	3.82	11.65	3.02

RESEARCH RESULTS

SPCT Validation Using Failed Project

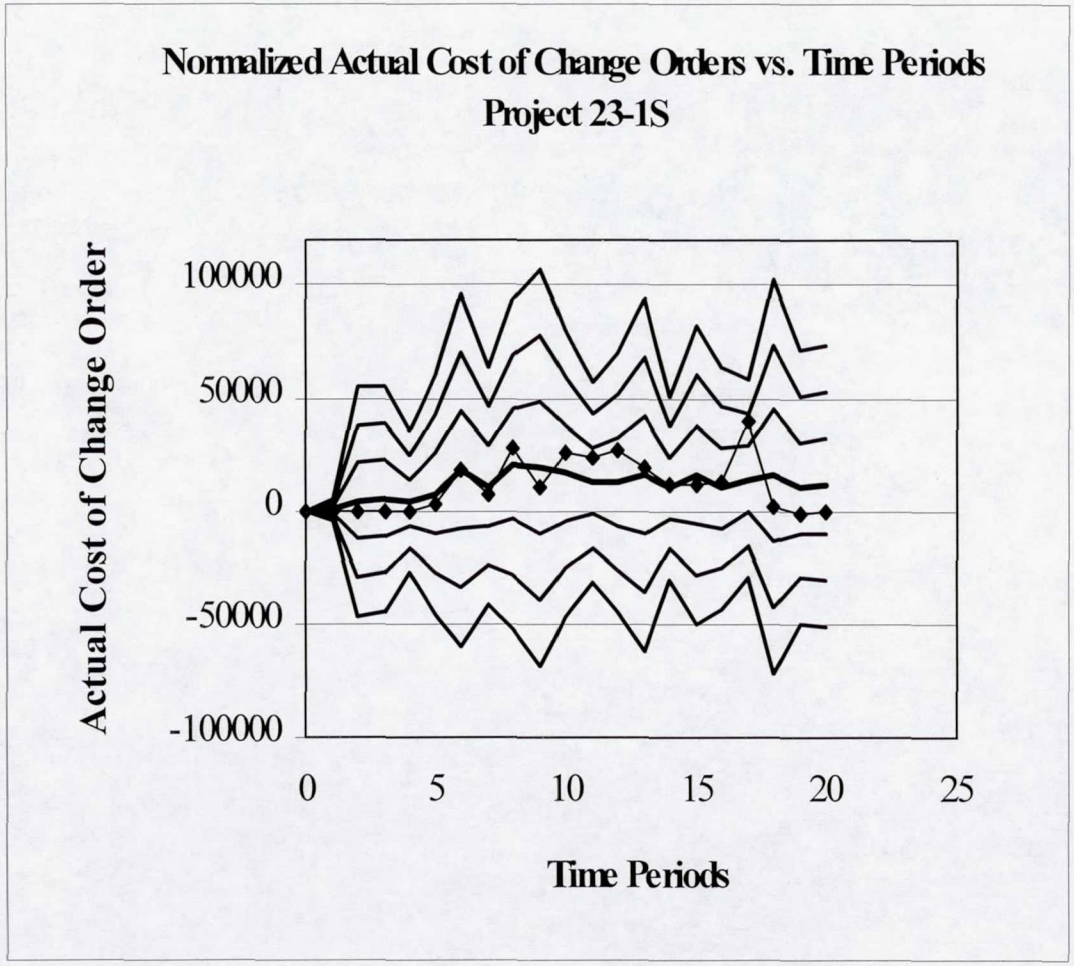


- Process industry
- Out-of-control per Rule 2
- Pattern validates control chart

TP	LCL	CL	UCL	24-5F
0	0.00	0.00	0.00	0.00
5	-3.61	1.02	5.65	0.00
10	-6.23	7.22	20.67	4.70
15	.41	10.16	19.90	9.89
20	-4.01	3.82	11.65	5.18

RESEARCH RESULTS

SPCT Validation Using Successful Project

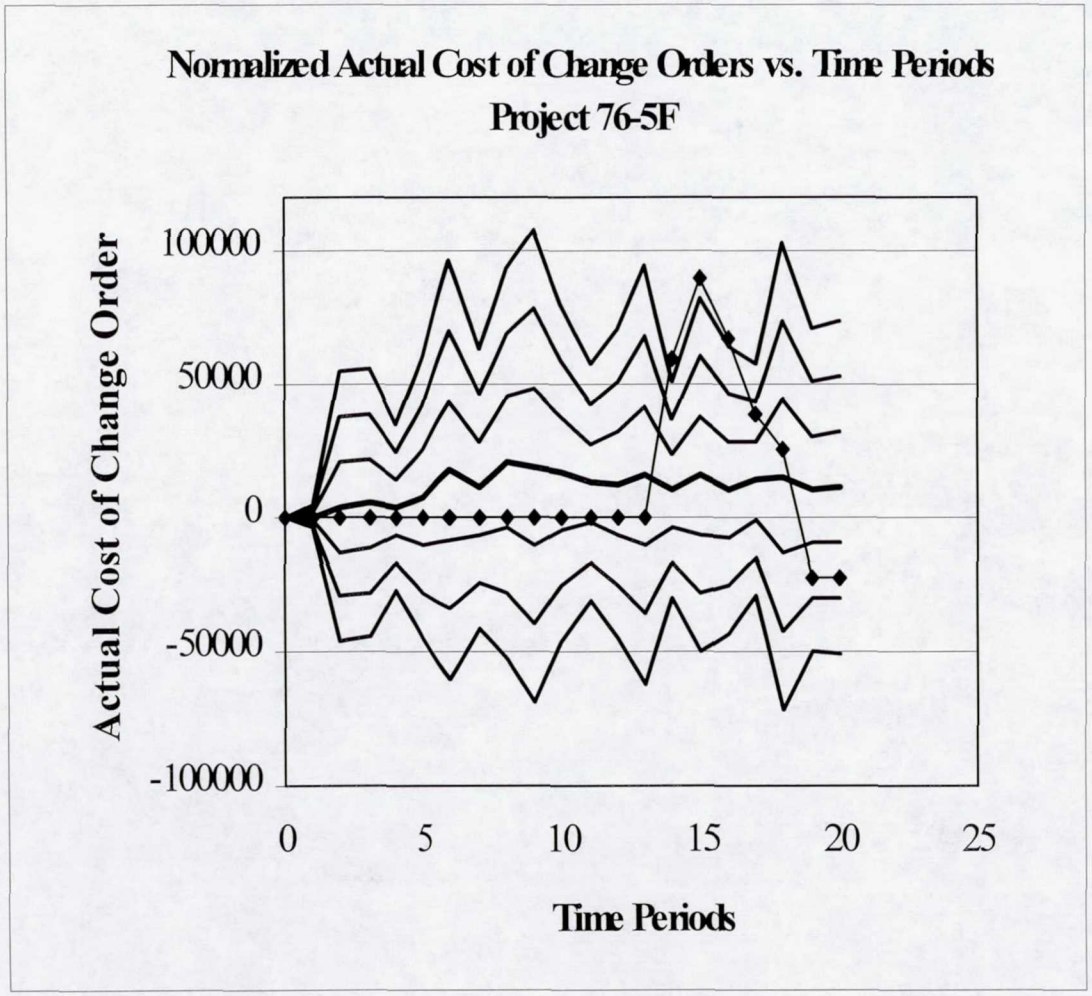


- Power industry
- Pattern in-control
- Pattern validates control chart

TP	LCL	CL	UCL	23-1S
0	0	0	0	0
5	-45536	7549	60635	2621
10	-46625	16620	79865	25403
15	-50258	15945	82149	11909
20	-51058	11182	73423	-725

RESEARCH RESULTS

SPCT Validation Using Failed Project



- General Building industry
- Out-of-control per Rules 1 & 5
- Pattern validates control chart

TP	LCL	CL	UCL	76-5F
0	0	0	0	0
5	-45536	7549	60635	0
10	-46625	16620	79865	0
15	-50258	15945	82149	89643
20	-51058	11182	73423	-22555

DISCUSSION

- Check for Normality Assumptions
- Comparison of Project Characteristics
- Control Chart Validation
- Problems Encountered
- Why Control Chart Works

DISCUSSION
Causes for "Out of Control" Patterns

- Rule 1: One Point Beyond Zone A
  - —Change in Corp. policy
  - —Design Change
  - —Design Step Omitted
- Rule 2: 9 Pts. in a Row in Zone C or Beyond
  - —New Manager
  - —New Metrics System Manager
  - —New Business Rules Instituted

DISCUSSION
Causes for "Out of Control" Patterns

- Rule 3_1: 6 Pts. in a Row Steadily Increasing
  - —Poor Team Morale
  - —Requirements not being met
  - —Manager or Team Fatigue
  - —Changes in External Environment
  - —Emergency or expedition declared
- Rule 3_2: 6 Pts. in a Row Steadily Decreasing
  - —Opposite causes as in Rule 3_1

LIMITATIONS OF STUDY

- Construction Industry Only
- Limited Amount of Data
- Variables Selected
- Effect of Project Characteristics
- Variable 4 Lack of Normality

CONTRIBUTION TO THE BODY OF KNOWLEDGE

- Quantitative Benchmarking Tool
- Dynamic Decision-Making (predictive)
- Industrial Engineering Method
- Environmental Factors
- Quality and Safety

CONCLUSIONS

- No Tool Like SPCT Presently Available
- Ratio Method Best
- Cumulative Plot Interpolation
- SPCT Chart Methodology Is Valid
- Can Indicate Health of Project
- May be applied to other industries

FUTURE RESEARCH

- Product vs. Process Success
- Study Lower Level Elements
- Study Other Industry Types
- Study Other Project Types

QUESTIONS