



Charles E. Dorgan, P.E., Ph.D.

Professor Emeritus

University of Wisconsin - Madison

Principal – Farnsworth Group, Inc.

Madison, Wisconsin



Best Practices of Building Commissioning

**The “The Total Building Commissioning Process” for
Delivery of Quality Constructed Projects**



Total Building Commissioning Process (TBCxP)

- A process that improves the delivery of constructed projects
 - Time
 - Cost
 - Owner's Project Requirement
 - Clear design and basis of design
 - No Punchlists
 - No change orders
 - Achieve new challenging goals
 - Everyone's profit
 - Continuous Improvement

June 3, 2002

TBCxP, Part 2, 10:30

3



Best Practice of the Building Commissioning Process

- is a quality delivery process for constructed projects
- that improves owners defined project requirements,
- eliminates waste and reduces rework,
- speeds construction and decisions, and
- improves operations and maintenance of the facility

June 3, 2002

TBCxP, Part 2, 10:30

4



Best Practice of TBCxP

- Further it makes the planning, design, construction and operations more FUN!
- Improves everyone's profit and satisfaction
- Allows and provides continuous improvement
- Benchmarks whatever is important, including productivity of the facility!!

June 3, 2002

TBCxP, Part 2, 10:30

5



Must Know Your TBCxP Mission

- Do not go into the **Total Building Commissioning Process** blindly
- Define it's **mission** for you
- Adopt **a process** that you can evaluate
- Do not just add another **"expert"** to your team, without knowing or defining the benefits and expectation

June 3, 2002

TBCxP, Part 2, 10:30

6



Is this the new concept?

The TBCxP is an **“expert” system**

Not a

System of **“experts” !!!TM**

TM by Chad Dorgan



First Steps in Implementing

- Define the Mission of the TBCxP
- Define benefits
- Define barriers
- Define benchmarks



What is Total Building Commissioning Process (TBCxP)?



A **quality process**
to VERIFY and DOCUMENT
that **building systems**
meet the needs of
BUILDING OWNERS and OCCUPANTS.

June 3, 2002

TBCxP, Part 2, 10:30

9



Why Should **YOU** be Interested in TBCxP?

- The best can always get better.
- The old can get younger.
- Profitability can always improve.
- We can do more with less.
- More management is not better.
- Quality works!

June 3, 2002

TBCxP, Part 2, 10:30

10



Why Should *You* be Interested in TBCxP?

- We love to change!!!,
- Please, no status quo!!!!
- Change is easy!!!!!!
- We have the current process down pat, time to change!!!!!!!!!!!!!!
- LET'S HAVE FUN and go to a conference and learn about TBCxP- - - -

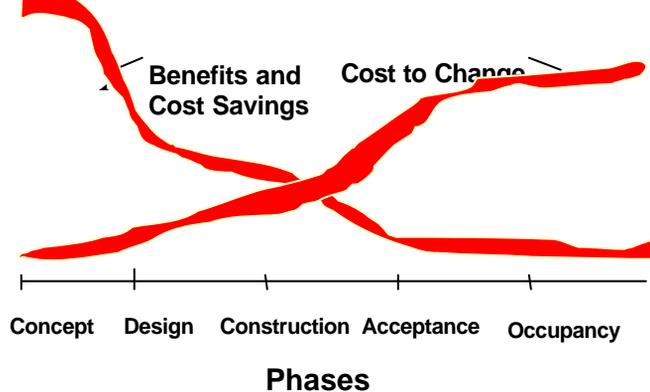
June 3, 2002

TBCxP, Part 2, 10:30

11



Benefits and Cost Savings Potential Vs. Cost to Implement or Change



June 3, 2002

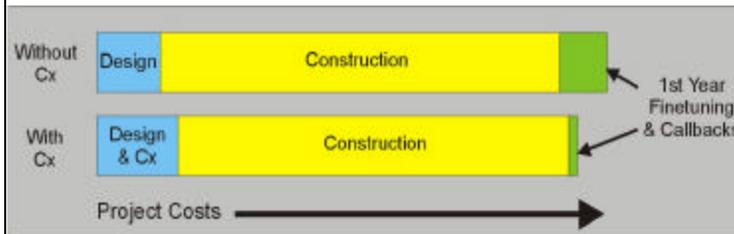
TBCxP, Part 2, 10:30

12



A Shift in Project Costs?

- CxP shifts cost from the end of the project to the beginning
- Reduces overall investment



June 3, 2002

TBCxP, Part 2, 10:30

13



The Commissioning Authority A New Entity

- Owner's advocate
- Primary focus is on the process
- Background
 - Design
 - Construction
 - Operation
 - Quality process control
- Augments, but does not replace programming, architect, engineers, construction manager and operators

June 3, 2002

TBCxP, Part 2, 10:30

14



Trademark and Copyright

The following PUZZLE CONCEPTS™©

Are copyrighted and trademarked by the Farnsworth Group, Inc. and use or reproduction should be given appropriate credit.



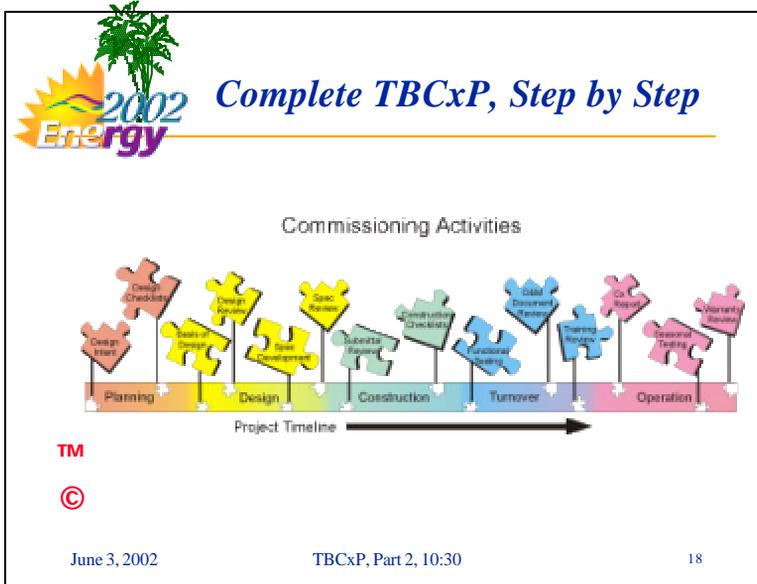
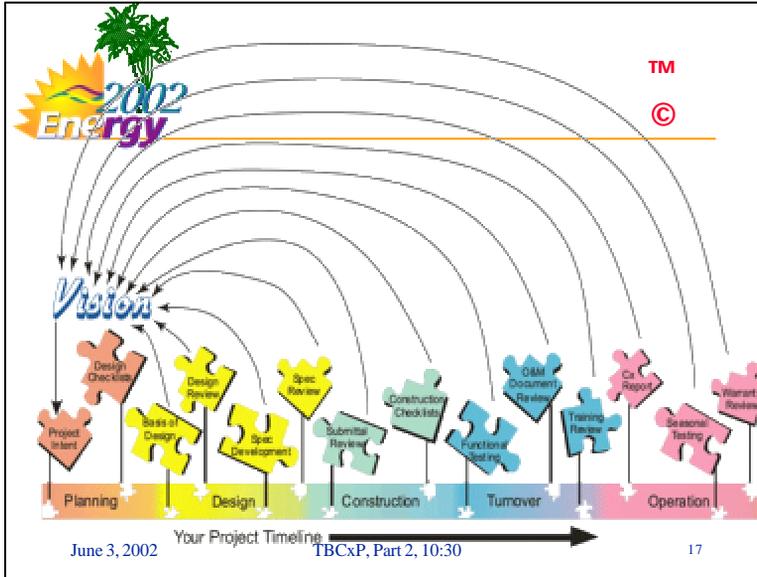
The Current Process

Vision



Your Project Timeline 

TM ©





TBCxP During Planning or Pre-Design



- ☒ Document the owner's Design or Project Intent (Owner's Project Requirements)
- ☒ Develop design checklists for the designers
- ☒ Develop initial Commissioning Plan

June 3, 2002

TBCxP, Part 2, 10:30

19



Question F: How will you determine the success of this project?

Page 7

Response #	Responses	Facility Users	User Score	A/E Score	Overall Score
F-3	IMPROVED HEATING AND COOLING	0.00	8.30	0.00	8.30
	ADEQUATE SPACE	0.00	6.00	0.00	6.00
	WORK AREA COMFORTABLE FOR STAFF AND CUSTOMERS	0.00	5.83	1.00	6.83
F-2	FUNCTIONAL WORK SPACE	0.00	5.20	1.33	6.53
F-4	SECURITY UPGRADES	0.90	4.25	0.00	5.15
F-20	MORALE AFTER SEVERAL MONTHS	0.00	4.00	5.33	9.33
F-7	PRIVACY	0.00	3.93	0.00	3.93
F-18	CREATE A PROFESSIONAL IMAGE	0.00	2.40	5.50	7.90
F-6	BETTER PUBLIC ACCESS	0.00	1.58	0.00	1.58
F-22	SHOWCASE BUILDING	2.00	1.35	1.83	5.18
F-10	IMPROVED LIGHTING	0.00	1.33	0.00	1.33
F-29	MINIMAL EFFORT FOR FUTURE CHANGES	1.13	1.30	1.25	3.68
F-17	ADEQUATE STORAGE	0.00	1.25	0.00	1.25
F-12	USERS ARE PLEASED	0.00	0.00	13.33	13.33
F-15	SUCCESSFULLY BID AND CONSTRUCTED TO AVOID COMPROMISING END PRODUCT	0.00	0.00	7.77	7.77
F-19	ON BUDGET ON TIME	2.25	0.00	3.47	5.72
F-9	REDUCED ENERGY AND MAINTENANCE COST	2.33	0.00	3.00	5.33
F-27	DOCUMENTATION FOR LIFE OF BUILDING	1.50	0.00	2.50	4.00
F-23	RELIABLE UTILITIES	1.20	0.00	2.13	3.33
F-16	KUDOS TO TEAM	2.00	0.00	0.40	2.40
F-14	WORKSPACE EFFICIENCY AND COMFORT	0.00	0.00	1.50	1.50
F-24	MAINTENANCE STAFF LIKES DESIGN	0.00	0.00	1.50	1.50
F-21	COMMON USE AREAS	0.00	0.00	1.13	1.13
F-25	REPEAT BUSINESS	0.00	0.00	0.90	0.90

June 3, 2002

TBCxP, Part 2, 10:30

20



Question F: How will you determine the success of this project?

Page 7

Response #	Responses	Facility Users	User Score	A/E Score	Overall Score
F-3	IMPROVED HEATING AND COOLING	0.00	8.30	0.00	8.30
F-1	ADEQUATE SPACE	0.00	6.00	0.00	6.00
F-8	WORK AREA COMFORTABLE FOR STAFF AND CUSTOMERS	0.00	5.83	1.00	6.83
F-2	FUNCTIONAL WORK SPACE	0.00	5.20	1.33	6.53
F-4	SECURITY UPGRADES	0.90	4.25	0.00	5.15
F-20	MORALE AFTER SEVERAL MONTHS	0.00	4.00	5.33	9.33
F-7	PRIVACY	0.00	3.93	0.00	3.93
F-18	CREATE A PROFESSIONAL IMAGE	0.00	2.40	5.50	7.90
F-6	BETTER PUBLIC ACCESS	0.00	1.58	0.00	1.58
F-22	SHOWCASE BUILDING	2.00	1.35	1.83	5.18
F-10	IMPROVED LIGHTING	0.00	1.33	0.00	1.33
F-29	MINIMAL EFFORT FOR FUTURE CHANGES	1.13	1.30	1.25	3.68
F-17	ADEQUATE STORAGE	0.00	1.25	0.00	1.25
F-12	USERS ARE PLEASED	0.00	0.00	13.33	13.33
F-15	ENHANCEMENT OF THE BUILDING	0.00	0.00	3.33	3.33



TBCxP During Design

Commissioning Activities



- Document each designer's Basis of Design
- Review the design for compliance with the owner's Design Intent
- Develop TBCxP portion of specifications
- Review complete specifications before bidding



2002 TBCxP During Construction



- Review submittals for compliance with the owner's Design or Project Intent
- Develop and track completion of construction checklists
- Verify all aspects of the construction process, using **statistical quality sampling**

June 3, 2002 TBCxP, Part 2, 10:30 23



2002 TBCxP During Turnover



- ⌚ Complete functional performance testing
- ⌚ Review O&M documentation
- ⌚ Review training plans
- ⌚ Verify codes, project intent, and certifications have been met

June 3, 2002 TBCxP, Part 2, 10:30 24



TBCxP During Operation



- ✦ Complete and submit Commissioning Report
- ✦ Perform any seasonal testing
- ✦ Ensure the systems are being operated to meet project intent
- ✦ Review equipment performance prior to warranty expiration

June 3, 2002

TBCxP, Part 2, 10:30

25



Lessons Learned Workshop

- During first year or after end of project
- This is the “Continuous Improvement” of the TBCxP
- Lets do an illustrative workshop question?

June 3, 2002

TBCxP, Part 2, 10:30

26



Lessons Learned Workshop

- During first year or after end of project
- This is the “Continuous Improvement” of the TBCxP
- Key input to the final commissioning report
- Lets do an illustrative workshop question?

June 3, 2002

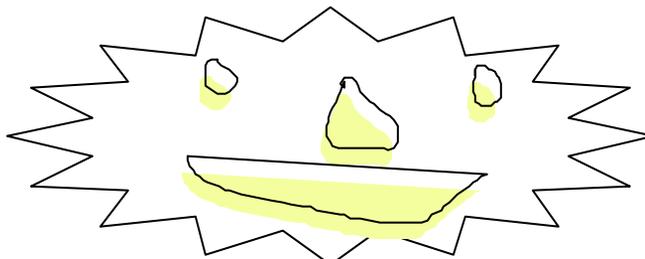
TBCxP, Part 2, 10:30

27



WORKSHOP EXERCISE

- Write down your reaction to this question?
“What did you learn that could have improved your preparation for this conference”?



June 3, 2002

TBCxP, Part 2, 10:30

28



- Turn to the 4 to 7 people around you and compare answers.
- In five minutes develop a list of 7 good answers. Or just the ask for the best from each of your members.
- Each, rank best from 7, find consensus?
- **Do not make this difficult! Just collect ideas and rank!!**

June 3, 2002

TBCxP, Part 2, 10:30

29



Your Input to Improving the Trip to the Energy 2002

- What answer do you want published in the LA Time tomorrow morning?

June 3, 2002

TBCxP, Part 2, 10:30

30



2002 Training/Education Resources

- Building Commissioning Association
 - bcxa.org
- University of Wisconsin – Madison
 - epdweb.egr.wisc.edu
- ASHRAE
 - ashrae.org



2002 Case Studies

Outpost Store



Information from a Commissioning Process Case History

Joy E. Altwies, MSME, EIT
Commissioning and Green Building Specialist
Farnsworth Group



Basis of Calculations	
Scenario 1	Higher cost option
Scenario 2	Lower cost option
Cost of Labor	\$50 / hour
Cost of Professional Time	\$75 / hour
Average Store Sales	\$16,000 / day
Productivity Loss	5% per worker, per day
Sales Loss	2% per shopper
Employee Labor Cost	\$7 / hour, 8 hour work day
Time Period for Recurring Costs	20 years, 355 working days per year (10 holidays)

June 3, 2002 TBCxP, Part 2, 10:30 35

Issue	Cost Avoided	
	Scenario 1	Scenario 2
Rooftop Cooling Capacity	\$62,160	\$51,200
Outdoor Air Intake Location	\$326,600	\$5,660
Store Relative Humidity	\$61,750	\$26,500
Diffuser Selection	\$153,360	\$1,766
Total Avoided Cost	\$603,870	\$85,126

June 3, 2002 TBCxP, Part 2, 10:30 36



Cost Benefit of Cx

- Commissioning: 1.3% of project budget
- Minimum projected savings due to Cx Process: \$85,000 (triple the Cx fee)
- Estimated savings could be as high as \$600,000, including long term operations
- Majority of savings due to catching issues early (inexpensive fixes on paper)

June 3, 2002

TBCxP, Part 2, 10:30

37





1st Year Lessons Learned

- Challenges in connection between refrigeration system and HVAC
- Daylighting sensor calibration problems
- On-going team communication +/-

June 3, 2002

TBCxP, Part 2, 10:30

39



Participant Feedback

- General Manager - without commissioning would not have received required system and would not have known the system would not meet their goals

June 3, 2002

TBCxP, Part 2, 10:30

40



City Schools of Hammond

- General Benefits from six projects

June 3, 2002

TBCxP, Part 2, 10:30

41



Benefits of TBCxP

- Reduced Punchlist on schools at turnover from 257 to 6
- Reduced cost of change orders by 87%
- Reduced first year call backs by 90%
- Reduced cost of construction by ?, goal should be 10-20%, but currently more like 4-9%, still very good.

June 3, 2002

TBCxP, Part 2, 10:30

42



Benefits of TBCxP

- Received project I wanted
- Received more value than expected, and would not have known than I could get this much for our budget
- Great Documentation and Training
- Accurate Drawings

June 3, 2002

TBCxP, Part 2, 10:30

43



Benefits of TBCxP

- * Sure, you may achieve some of these without commissioning, however you are probably doing many of the tasks of the TBCxP.
- * TBCxP formulizes your best process and insure repeatability for quality
- * Provides a cost effective quality means to delivery a constructed project or building

June 3, 2002

TBCxP, Part 2, 10:30

44



Air Force Academy

- Major Renovation (or reconstruction)
- For each \$80,000 for the commissioning team, the project cost benefits were \$500,000
- Not a bad payback and in addition there were many quality issues related to occupants and the operations and maintenance of the rehab of the building, including ESM

June 3, 2002

TBCxP, Part 2, 10:30

45



TBCxP Benefits

- Reduced typical startup of university research laboratories from 2-3 years to zero!! University of Washington (John Heinz, P.E.)

June 3, 2002

TBCxP, Part 2, 10:30

46



Retro-Commissioning Case Studies

June 3, 2002

TBCxP, Part 2, 10:30

47



The Retro-commissioning Process

- Focus on the quality process
 - Modifications are to ensure system meets owner's design intent
 - Verification methodology uses statistical sampling
- Integrate the commissioning concepts into the daily routine (systems manual)

June 3, 2002

TBCxP, Part 2, 10:30

48



Case Studies

- Thermal energy storage (TES) system
- Medical facility

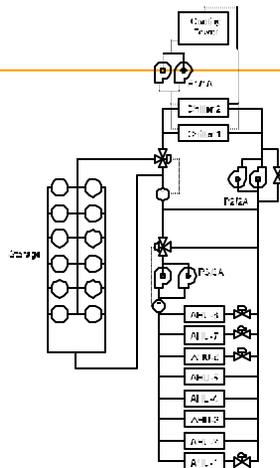
June 3, 2002

TBCxP, Part 2, 10:30

49



TES System Layout



June 3, 2002

TBCxP, Part 2, 10:30

50



TES System - Opportunities Identified

- TES differential temperature increase
 - Install VSD on secondary pumps and control valves on air handling units
 - \$20,400/year savings at a cost of \$17,500
- Control system adjustments
 - Adjust set points and control outdoor air
 - \$2,400/yr. savings with in-house labor

June 3, 2002

TBCxP, Part 2, 10:30

51



TES System - Opportunities Identified

- TES tank piping insulation/repair
 - Insulate branch piping to tank
 - Install larger band clamps on branch piping
 - \$800/year savings at a cost of \$500
- Overall system improvements
 - Modify operating sequence
 - Add discriminator control (minimize reheat)
 - \$10,050/year savings at a cost of \$14,600

June 3, 2002

TBCxP, Part 2, 10:30

52



Systems Manual

- Provides overview of TES system and its interface with building systems
- Documents sequence of operation clearly showing different modes of operation
- Is a living document
- Change in personnel soon after completion of commissioning

June 3, 2002

TBCxP, Part 2, 10:30

53



TES System Results of Retro-commissioning

- Increased storage capacity by approximately 40%
- Reduction in energy use by approximately 20% (reheat)
- Verified operation of system through field test
- Developed useful Systems Manual

June 3, 2002

TBCxP, Part 2, 10:30

54



Medical Center - Background

- New medical center with out-patient surgery and offices
- Construction was completed two years after design completed (all new people hired to operate facility)
- 60% occupied after two years
- Building was recommissioned at two year point

June 3, 2002

TBCxP, Part 2, 10:30

55



Medical Center - Opportunities Identified

- Modify steam system to match usage (5.7 year payback)
- Modify AHU control (1.4 year payback)
- Install active pressure control on surgery suites
- Modify lobby airflow pattern
- Implement commissioning procedures on tenant fit-out

June 3, 2002

TBCxP, Part 2, 10:30

56



Medical Center - Opportunities Identified

- Install computer interface with existing Trane Tracer system
- Modify hot water freeze protection procedures
- Implement smoking area policy/system

June 3, 2002

TBCxP, Part 2, 10:30

57



Medical Center Results of Retro -commissioning

- Most opportunities improved the space conditions and were not energy related
- Provided system documentation which was previously unavailable

June 3, 2002

TBCxP, Part 2, 10:30

58



Medical Center Results of Retro-commissioning

- Change in O&M personnel at completion of commissioning
- Would have avoided 2 years of problems if used commissioning process from the beginning
- But better late than never

June 3, 2002

TBCxP, Part 2, 10:30

59



TBCxP Benefits

- Successfully implements new concepts desired by owners, without trial and error
- No undone punchlist items

June 3, 2002

TBCxP, Part 2, 10:30

60



TBCxP Best Practice

- Cost effective
- Owner's Project Requirement orientated
- Team (commissioning process team)
- Quality tools used
- Not "expert-in-construction" driven
- Orientated on delivery of the constructed project for: owner, occupants, and O&M

June 3, 2002

TBCxP, Part 2, 10:30

61



Essential Concept of TBCxP

- It takes the **uncertainty** out of the delivery of a constructed projects
- Does as well as any other approach, but at a **lower cost**
- Has **means to use statistical tools**
- Has an element of **continuous improvement**
- **Transfers knowledge** from planning to operations

June 3, 2002

TBCxP, Part 2, 10:30

62



Essential Concept of TBCxP

- How you achieve the five essential concepts will vary for every organization,
- But shortcuts will fail and the cost and delivery needs of owners, occupants and O&M will not be achieved.
- These are attributes of the quality delivery process, regardless of what it is labeled!

June 3, 2002

TBCxP, Part 2, 10:30

63



Essential Concept of Implementing TBCxP

- Requires a change
- Change must be managed
- Time and resources must be allocated
- Need to develop a mission statement for the commissioning process
- Must have a designated commissioning authority, leader, consultant, manager?

June 3, 2002

TBCxP, Part 2, 10:30

64



Final Summary Thoughts

Elements of Commissioning

- Always implement early
- A process
- Specifically states the Owners Requirements
- Evaluation and Verification at all phases
- Team
- Continuous improvement
- Lower cost