8th Annual
Systems Engineering
Conference

Thursday, 27 October 2005

Using Commercial Simulation Software to Model Linear and Non-Liner Processes: US Military Academy Reception-Day Simulation and Optimization

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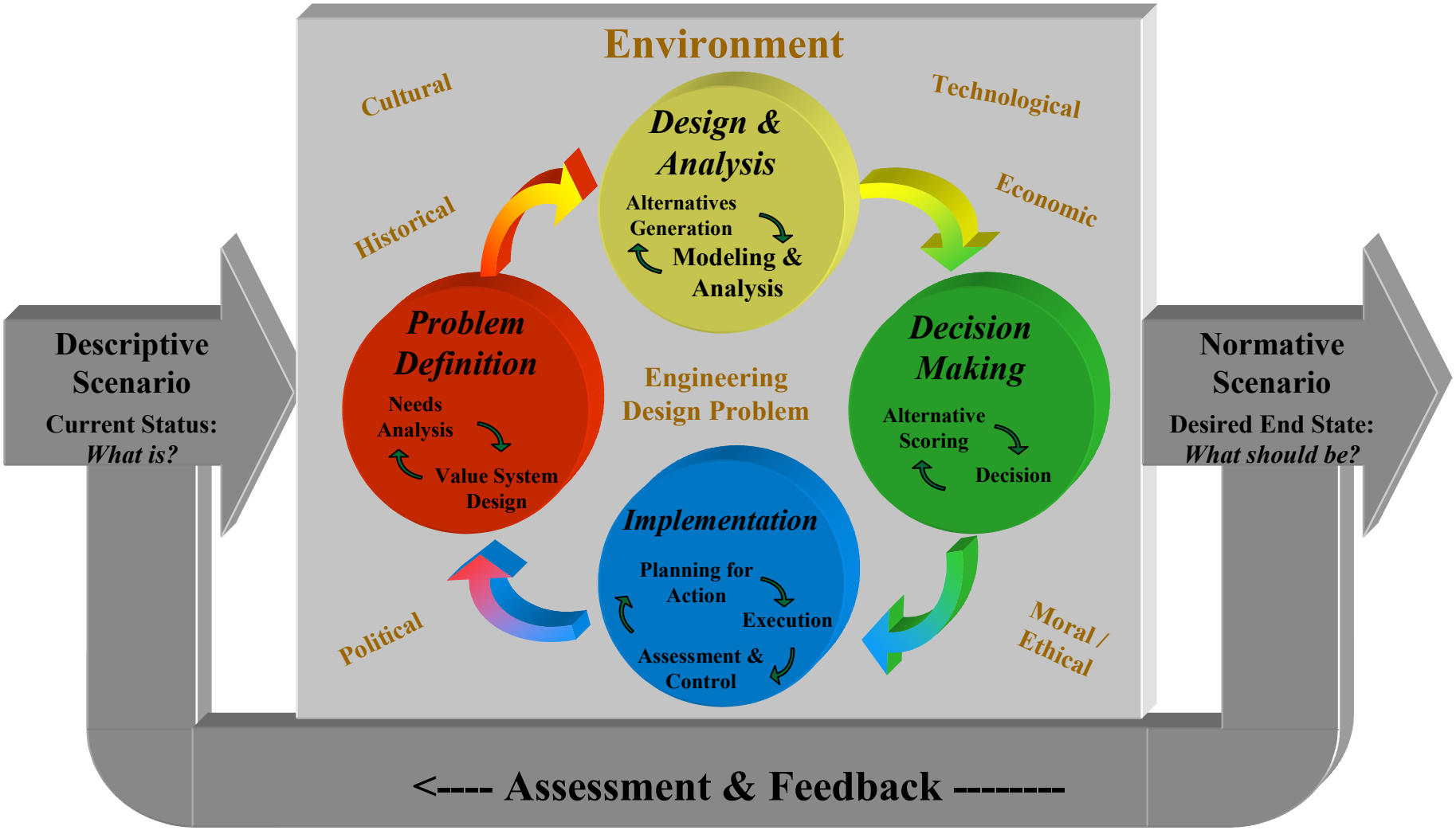
Operations Research Center of Excellence
Researching the Army's Future
Developing Tomorrow's Leaders

Agenda

- Systems Engineering Management Process
- Reception-Day Background
- Problem Statement
- Assumptions
- Overview of R-Day simulation in *ProModel*
- Initial analysis
- Alternatives
- *SimRunner* Optimization
- Study Conclusions
- Summary

Systems Engineering and Management Process



Reception-Day Background

- Process conducted annually in some form for over 200 years
- All tasks must be completed in one day between 0630 and 1730
- Over 1200 cadets in-processed annual for over 20 years
- Critical Reception-Day (R-Day) tasks
  - Thayer Hall (Linear)
  - United States Corps of Cadets (USCC) (Non-Linear)

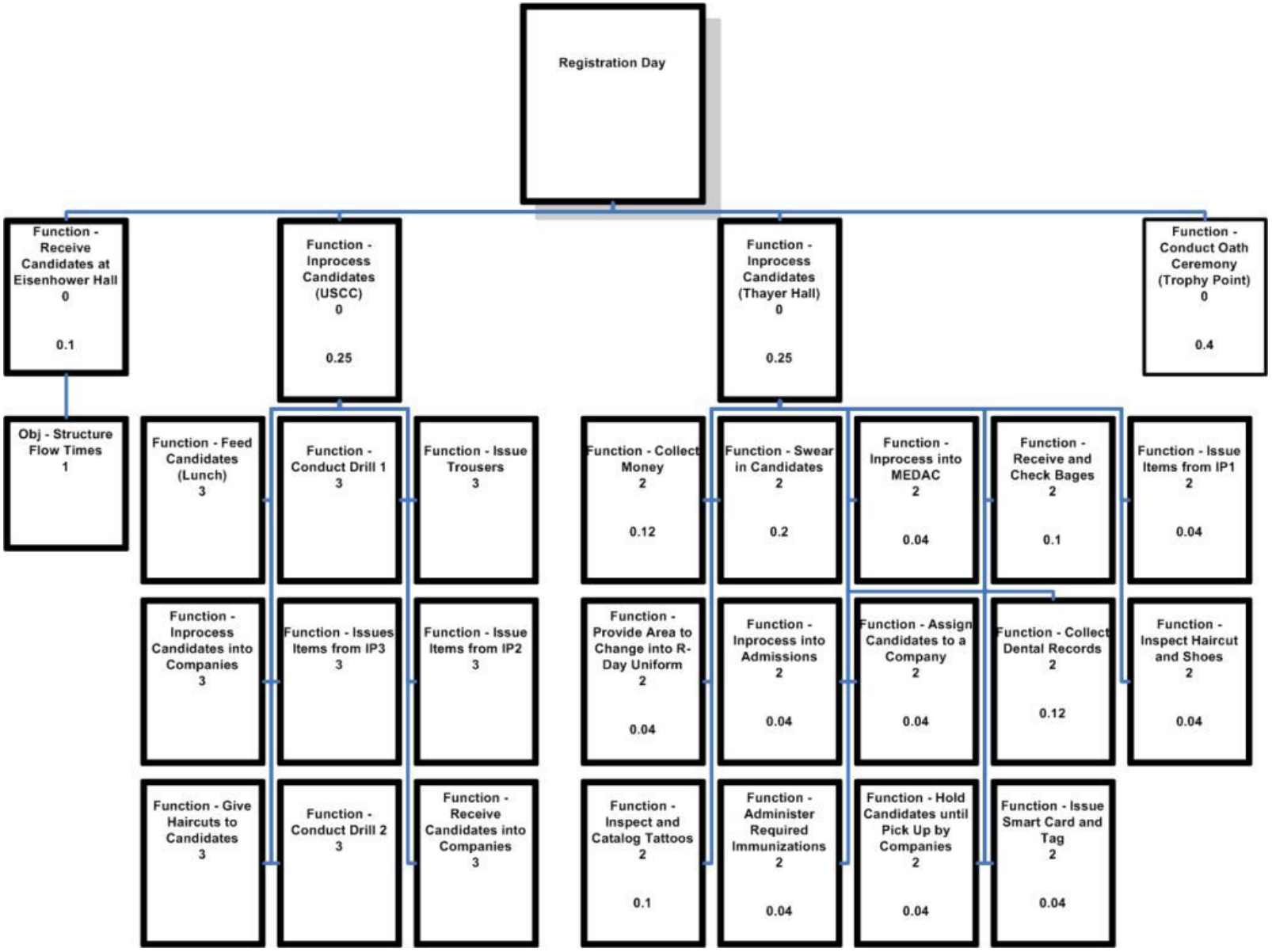
Problem Statement

- Stream line Reception-Day activities for in-processing new cadets into the Corps of Cadets from the initial arrival of candidates at Thayer Hall until the start of the Oath Ceremony to ensure all critical tasks and training are completed prior to the Oath Ceremony at 1745.

Information Resources

- Information Resources:
  - Admissions
  - “Beast” Company Commanders
  - Directorate of Logistics
  - Medical Department Activity
  - R-Day Director
  - Thayer Hall Non-Commissioned Officers
  - Treasurer
- Literature:
  - Operations Order (OPORDs) R-Day 2004
  - Data sets/maps from R-Day 2004
    - Data analysis implemented into model to greatest extent possible
  - Thayer Hall models form Academic Year 2004

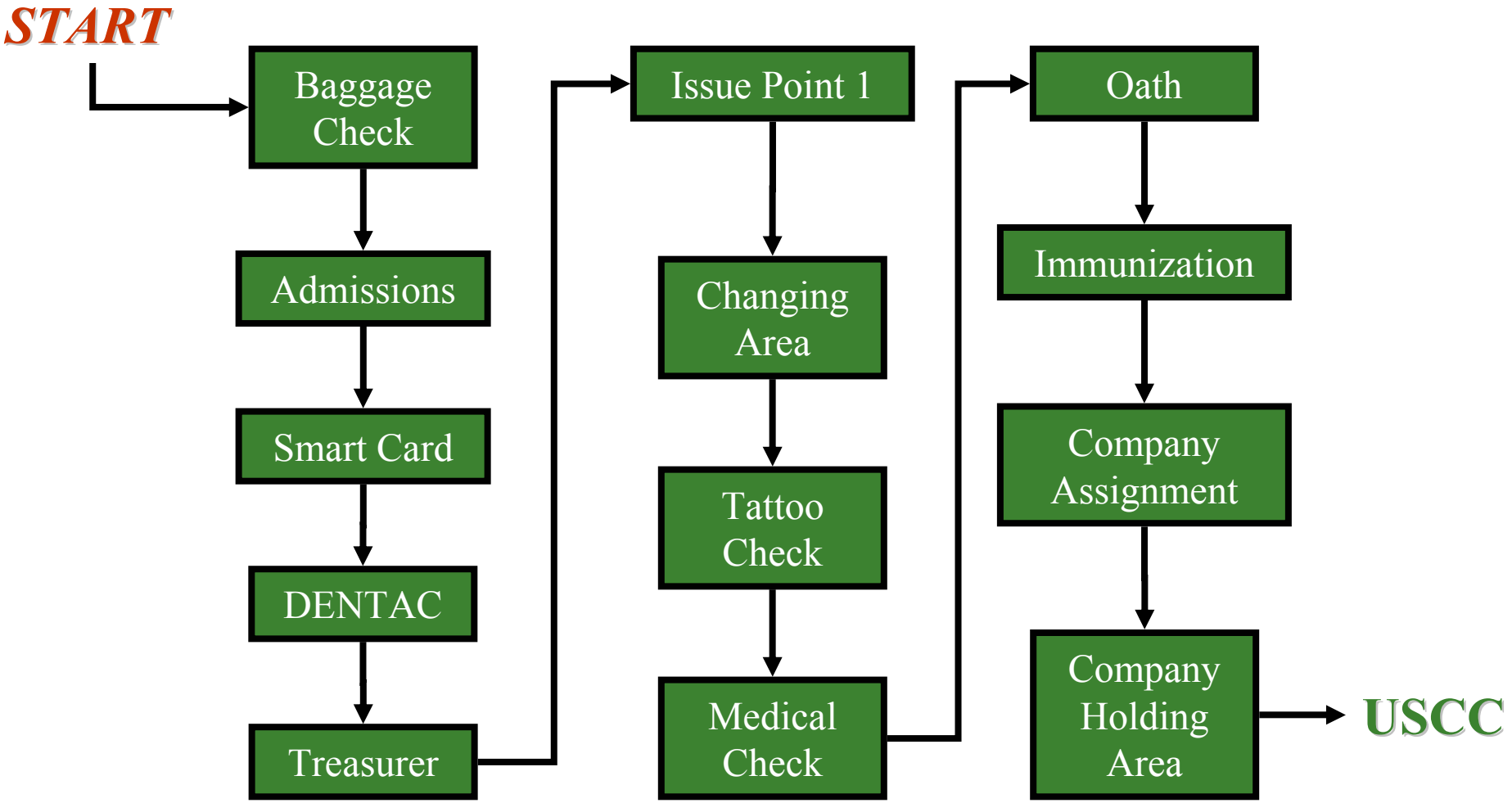
Value Hierarchy



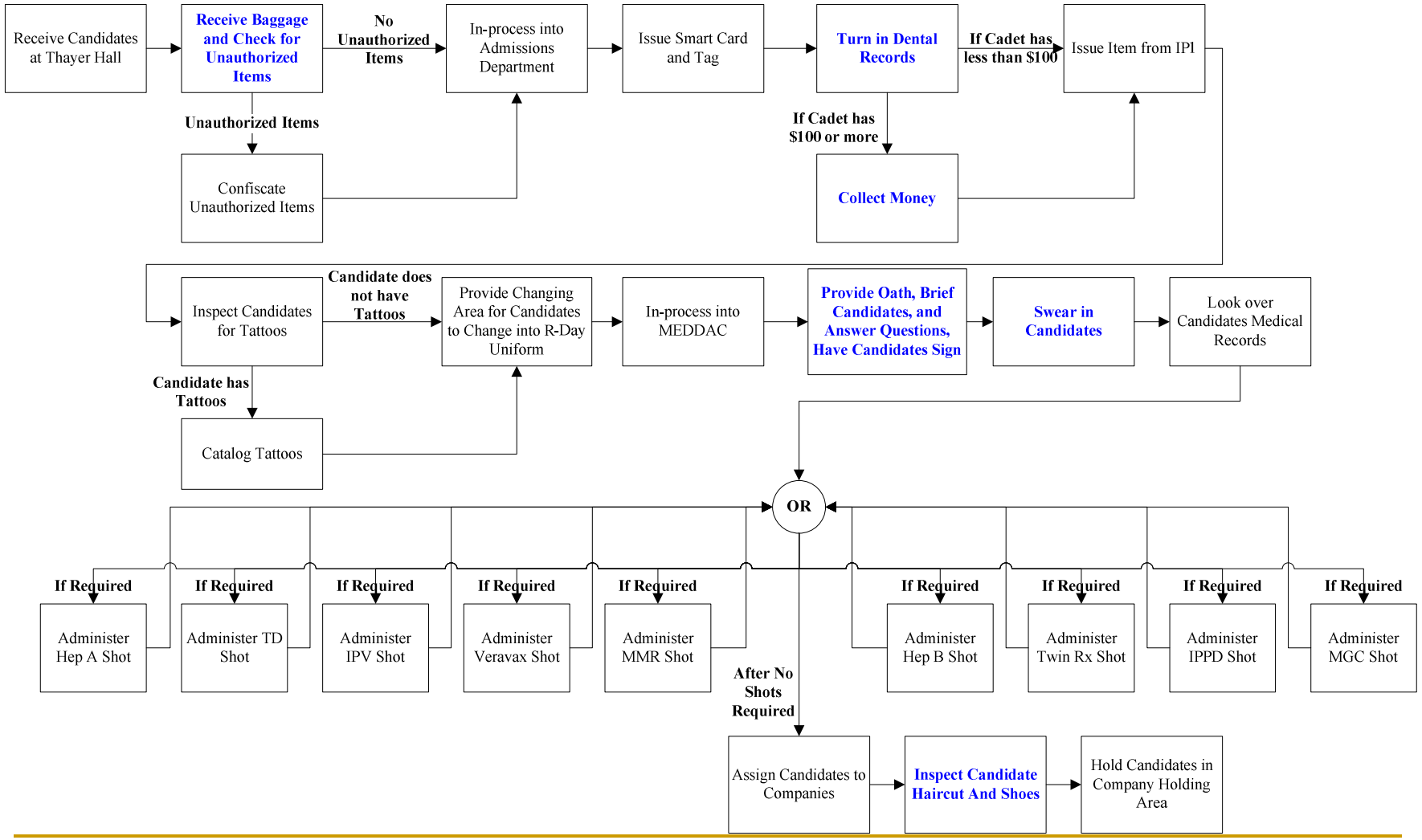
Assumptions

- Assumptions due to:
  - Modeling constraints
  - The need to account for imperfect data
- Examples:
  - Candidates return to Company Holding Area after each station
  - Candidates stay together as a single squad throughout the USCC portion of R-Day
  - All Candidates have trousers in hand when they leave Issue Point #2 (IP2)
  - Drill 1 and Drill 2 are combined
  - Every Candidate goes to the Barber Shop
  - IP3 and Company In-Processing grouped together

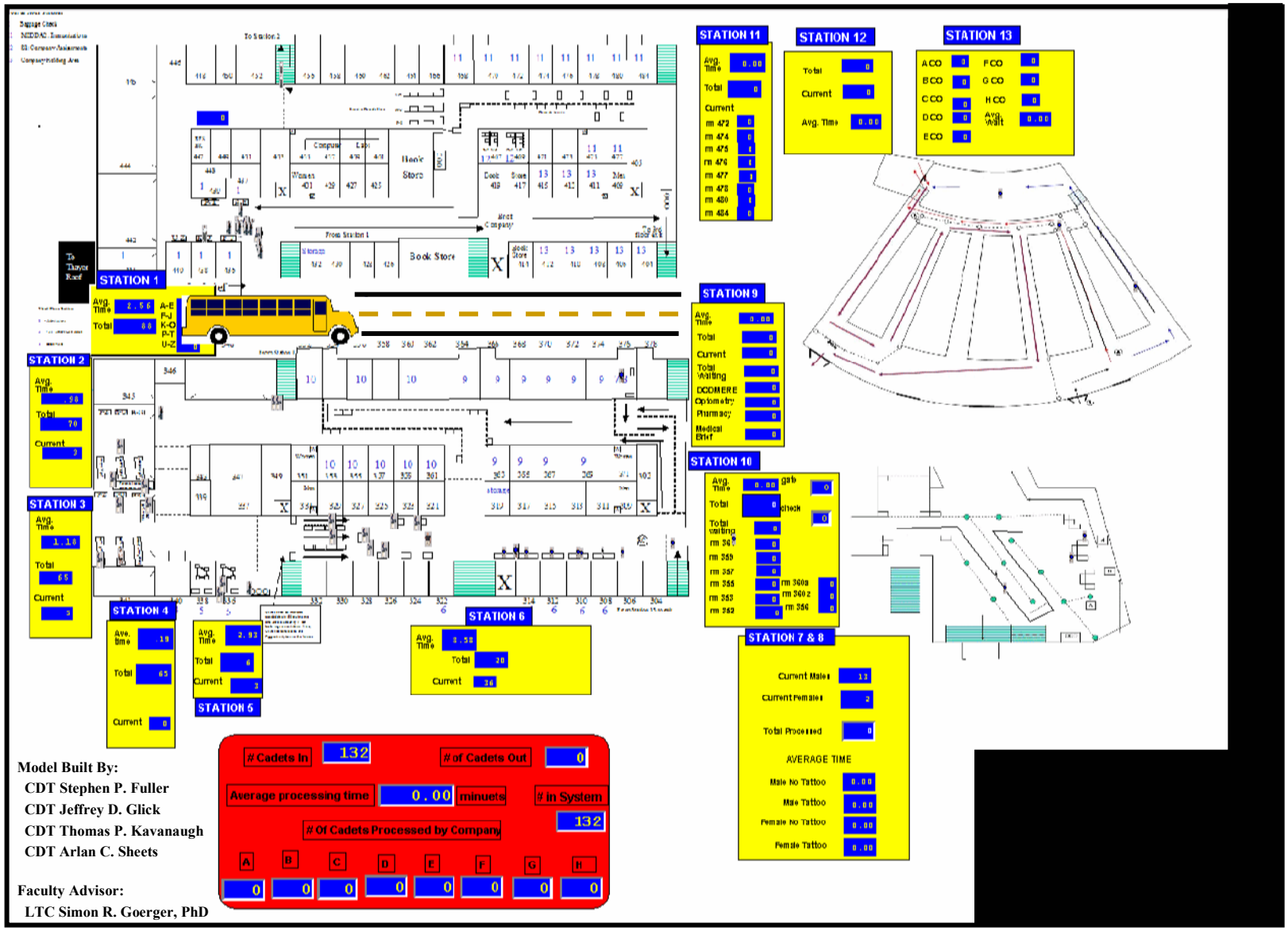
Process Flow: Thayer Hall



Functional Flow: Thayer Hall



ProModel: Thayer Hall



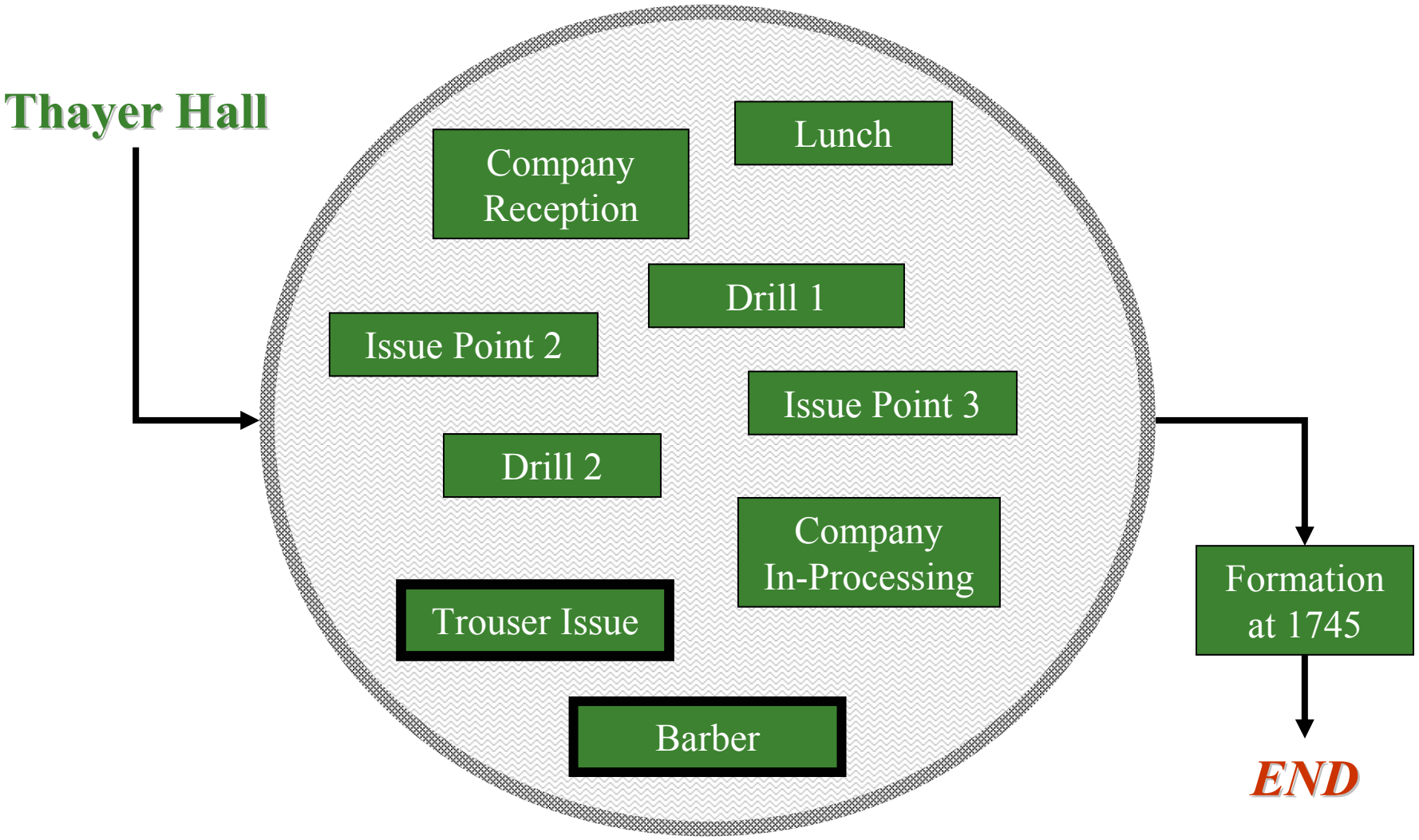
Model Built By:

CDT Stephen P. Fuller
CDT Jeffrey D. Glick
CDT Thomas P. Kavanaugh
CDT Arlan C. Sheets

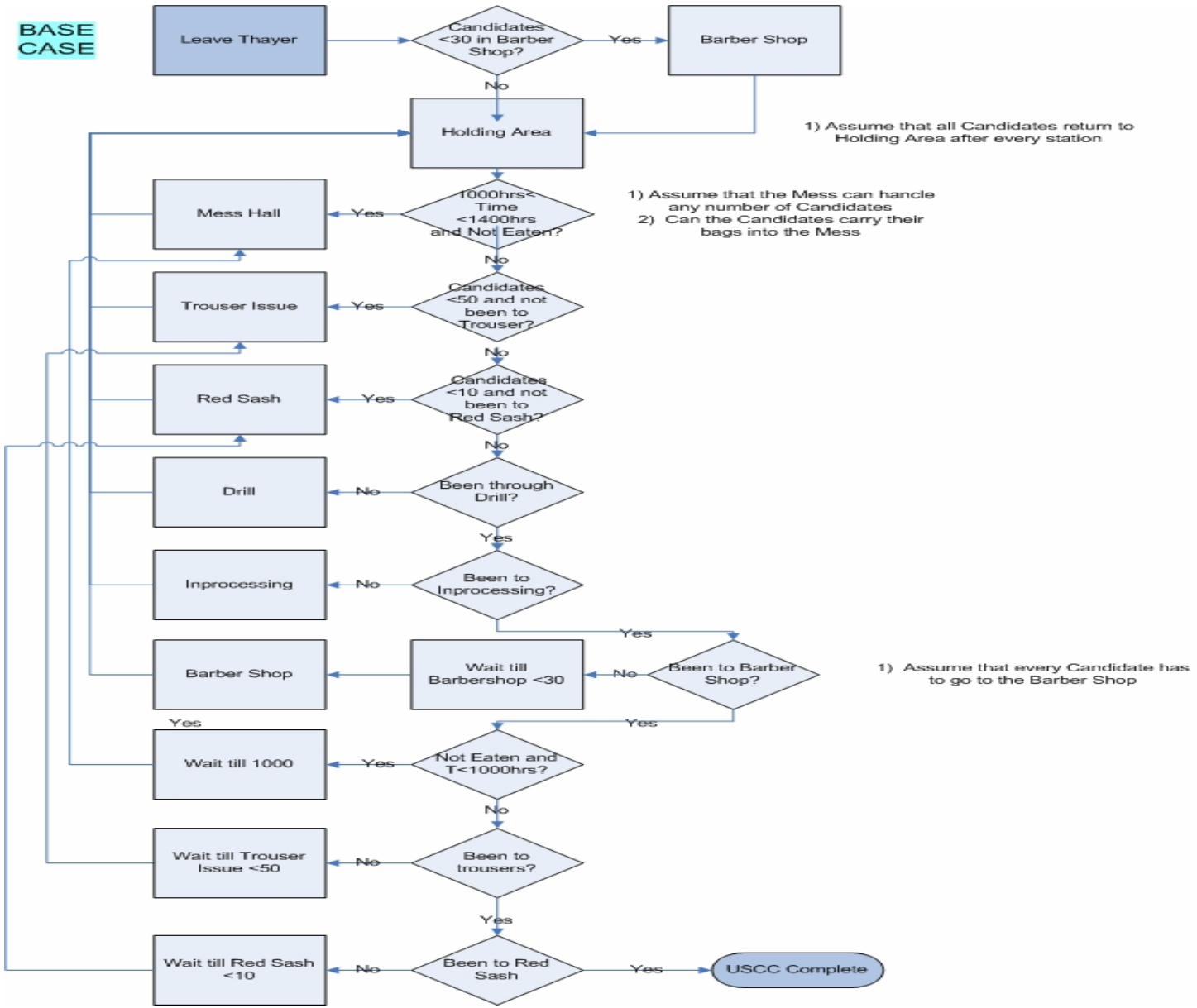
Faculty Advisor:

LTC Simon R. Goerger, PhD

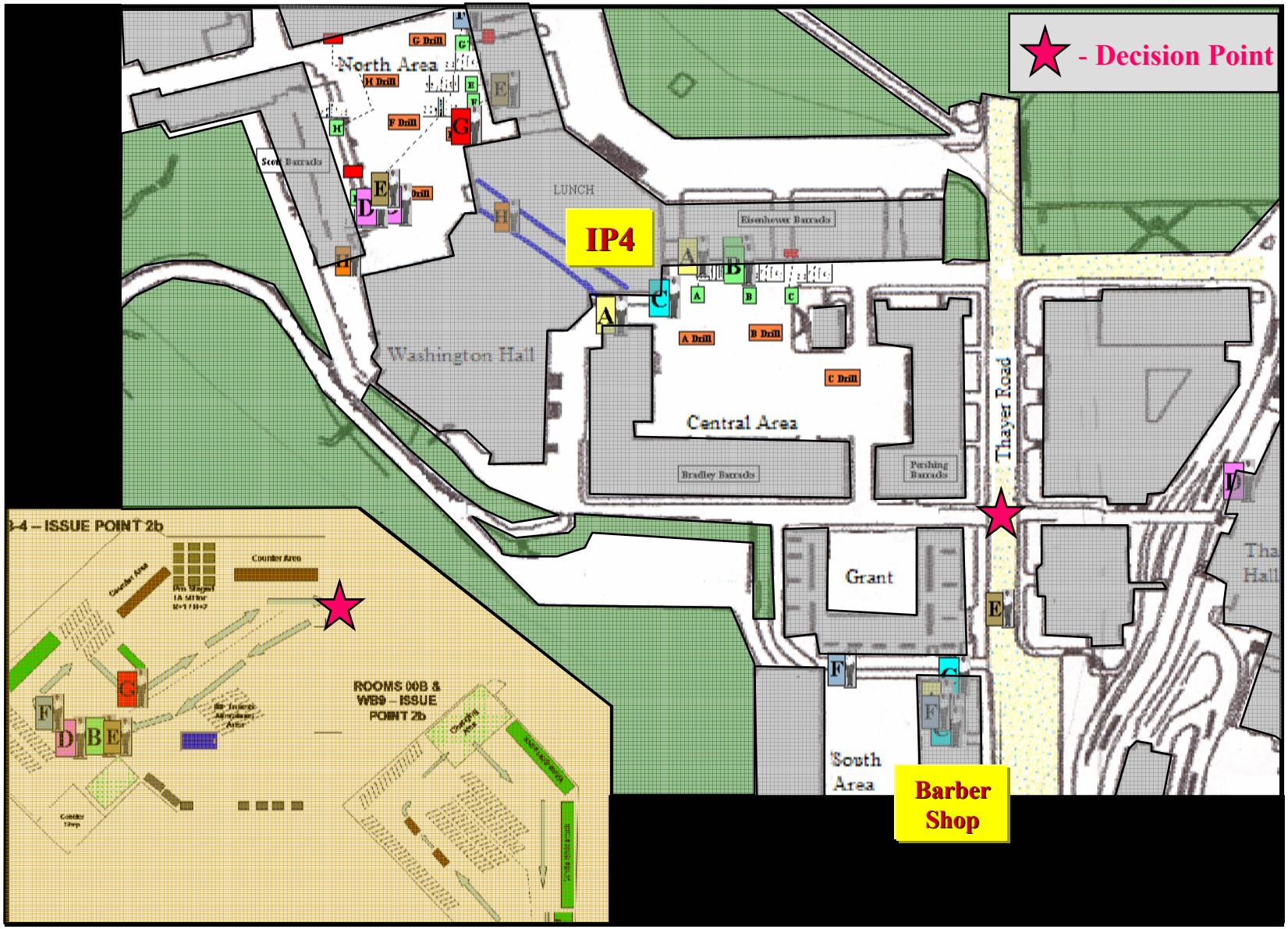
Process Flow: USCC



Functional Flow: USCC



ProModel: USCC



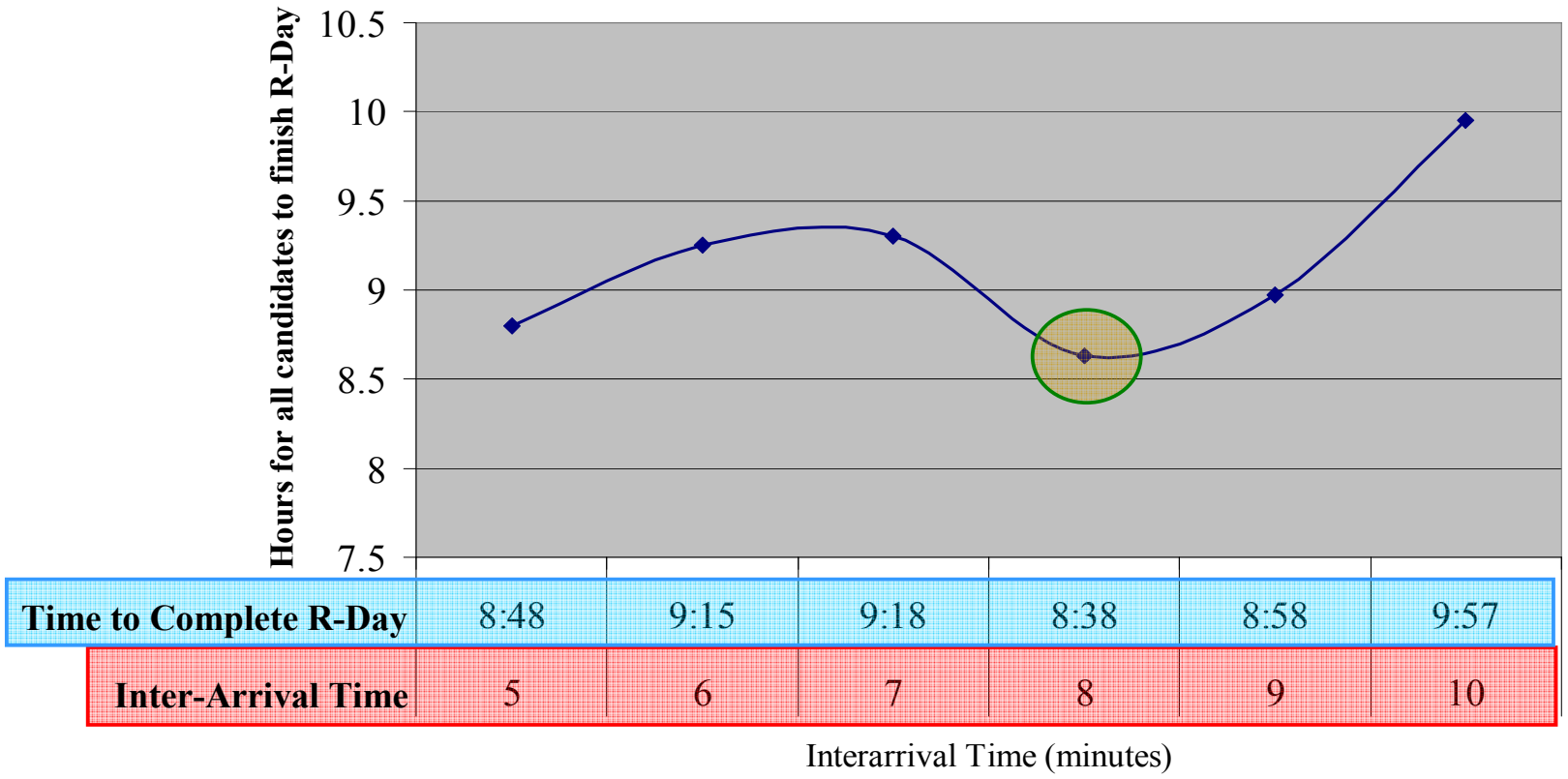
Alternatives/Issues

- Arrival rates of busses to Thayer Hall
- ***Pick-up rates of the candidates from Thayer Hall***
- Routing of candidates in order to reduce average wait times at the barbershop and delaying trouser issue
- Number of Squad Leaders available
- Number of barbers available

Alternatives

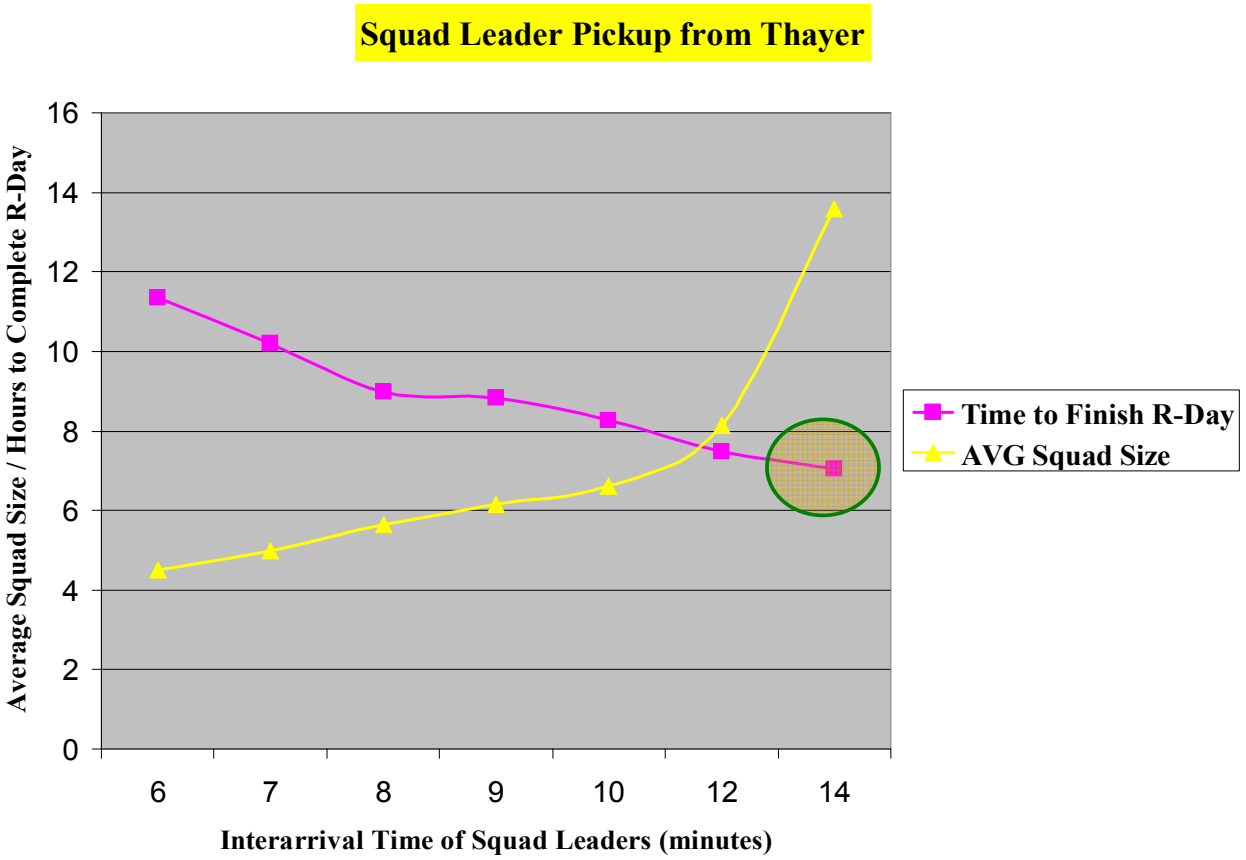
- Arrival rates of busses to Thayer Hall
- ***Bottom Line: Buses should arrive to Thayer Hall approximately every 8:30***

Arrival Times to Thayer



Alternatives

- Pick-up rates of the candidates from Thayer Hall
- ***Bottom Line: Longer inter-arrival time = larger squads = shorter R-day***



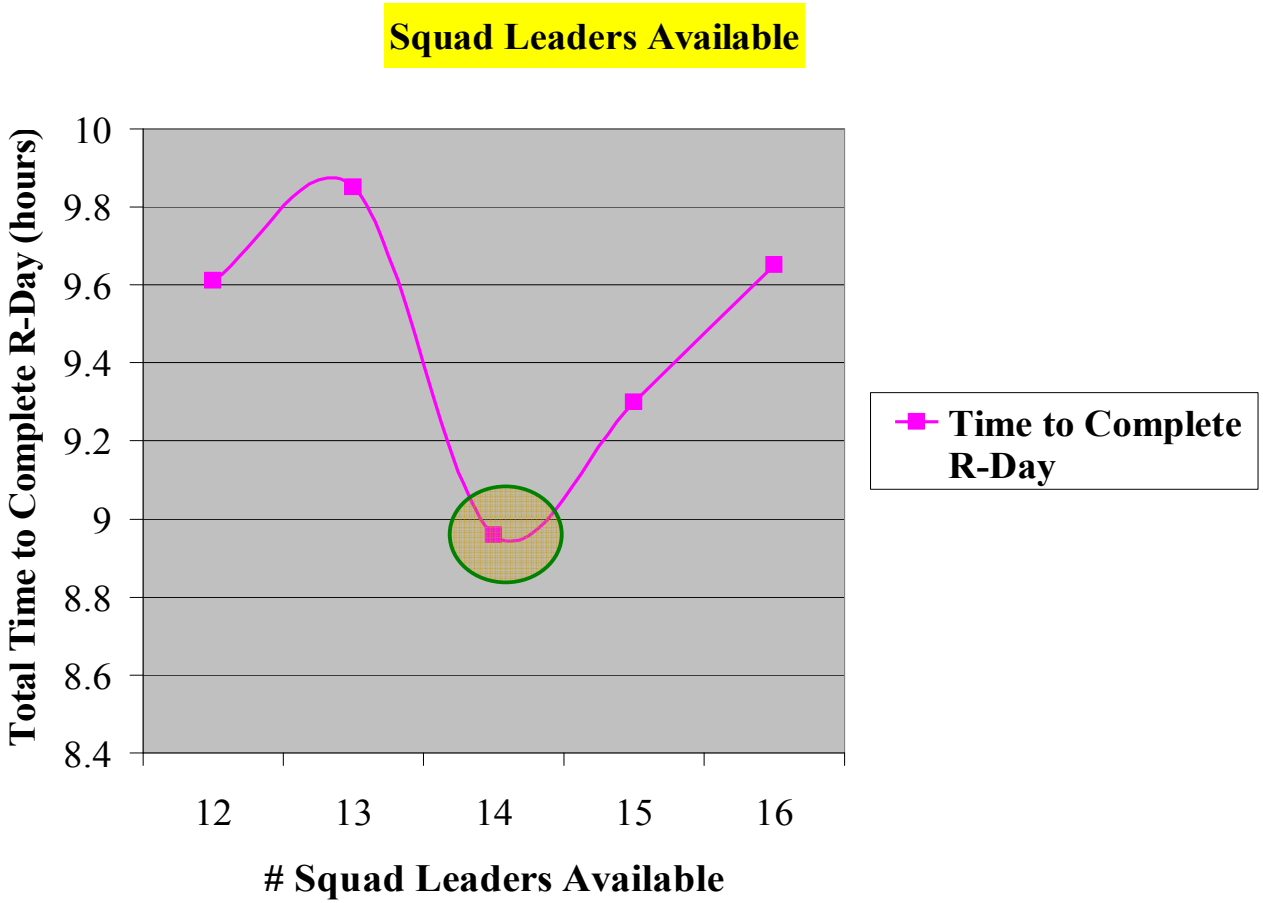
Alternatives

- Routing of candidates in order to reduce average wait times at the barbershop and delaying trouser issue
- ***Bottom Line: Limit the flow of cadets into the barber shop when trouser issue still incomplete***

Rule	Time to Complete R-Day
Haircut First	9:02
Trousers First	8:58

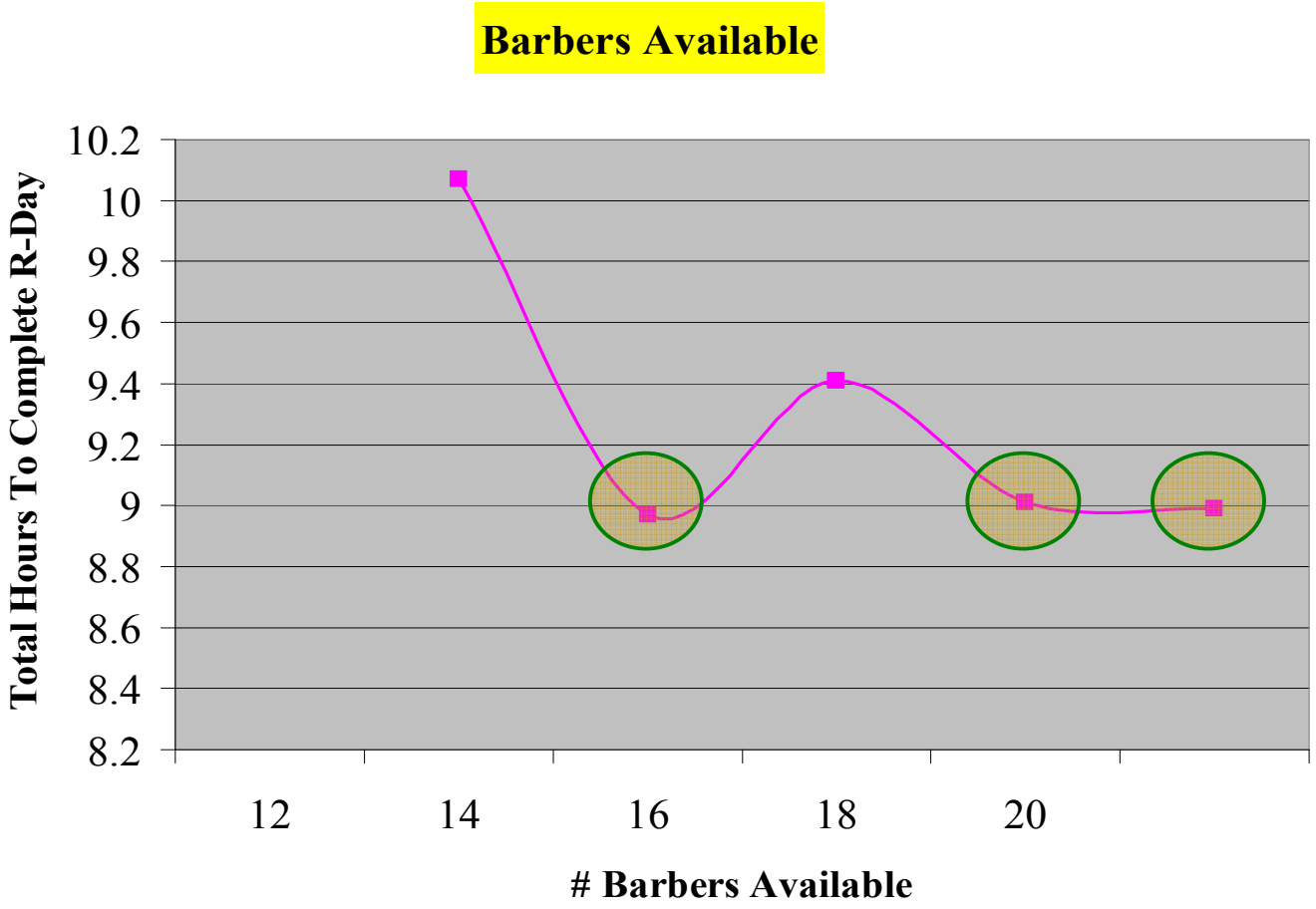
Alternatives

- Number of Squad Leaders available
- ***Bottom Line: Recommend 14 squad leaders; too many squad leaders creates too many (and smaller) squads moving in system***



Alternatives

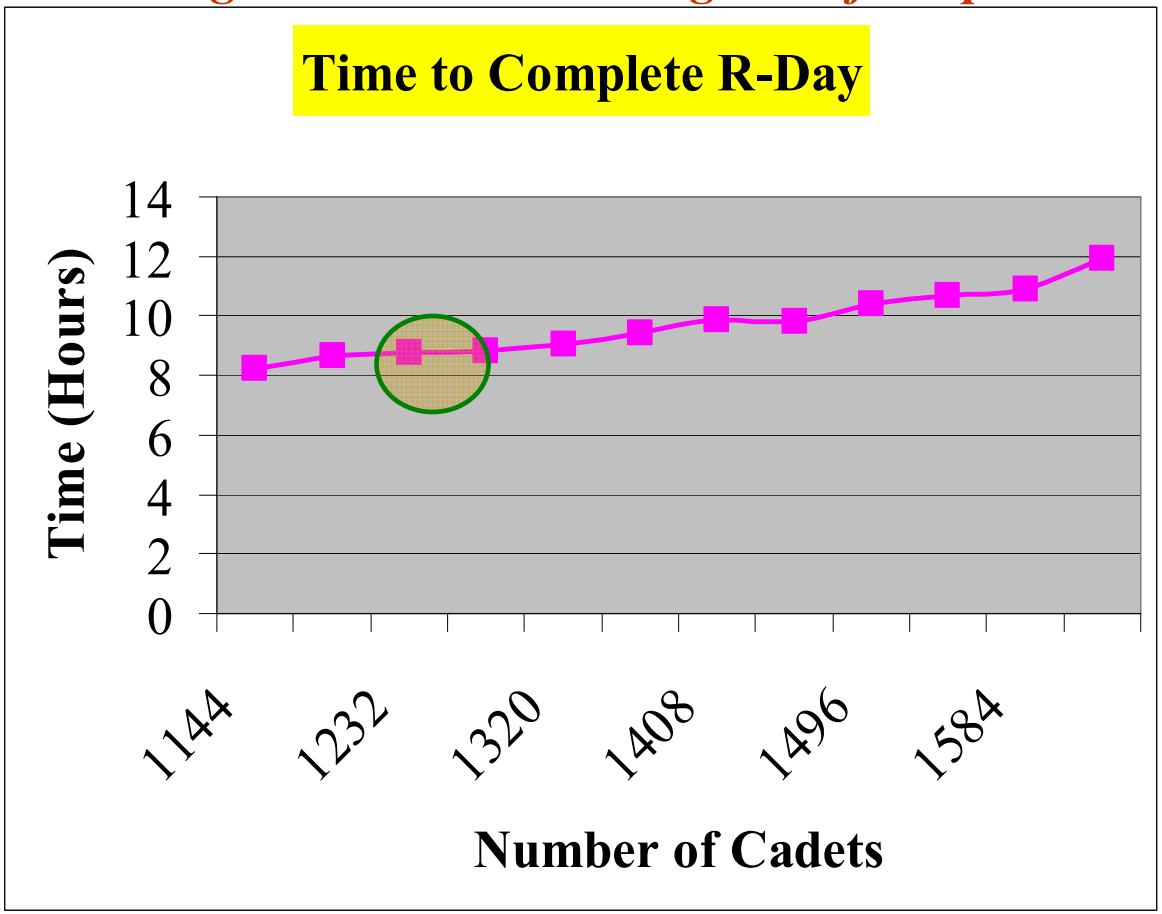
- Vary the number of carbers available
- ***Bottom Line: 16 Barbers cost effective***



Increase the Size of the Corps

Bus Trips	Cadets	Time to Complete R-Day
26	1144	8.25
27	1188	8.68
28	1232	8.78
29	1276	8.8
30	1320	9.05
31	1364	9.45
32	1408	9.85
33	1452	9.83
34	1496	10.42
35	1540	10.65
36	1584	10.9
37	1628	11.95

- ***Bottom Line: Time to complete R-day shows linear growth with increasing size of Corps***



Effect of Decreased Control Flow Measures

- When you decrease control flow measures, the amount of time needed to complete R-Day increases.
  - **SCENARIO**: Allow Squad Leaders to randomly decide where to take his/her squad until complete:

    RESULT: 25:16 hours (*Actual time = 7:46 AM, R-Day + 1*)
  - **SCENARIO**: Ignore the counters at the various stations:

    RESULT: Approximately 16:30 hours (*Actual time = 10:30 PM*)

SimRunner Optimization

- Picked four critical parameters
- Understand the interaction of:
  - Bus Arrival Rates
  - Squad Leader Pick-Up Arrival Rates
  - Squad Leaders Available
  - Barbers Available

SimRunner Optimization Function

x_i = average time at stations 1, 2,…i (a_i is the associated weight for each station)

x_j = number of minutes to complete R-Day (b_j is the associated weight for each station)

x_k = cost per bus driver, barber, and squad leader (c_k is the associated weight for each station)

x_l = % complete at stations 1, 2,…l (d_l is the associated weight for each station)

x_m = total throughput of the simulation (e_m is the associated weight for each station)

SimRunner Optimization Function

- Objective Function:

$$\text{Min } z_1 = \sum a_i x_i + \sum b_j x_j + \sum c_k x_k$$

$$\text{Max } z_2 = \sum d_l x_l + \sum e_m x_m$$

$$z_0 = z_2 - z_1$$

SimRunner Optimization Results

Bus Arrival Rates (Min)	Squad Leader Pick-Up Arrival Rates (Min)	Number of Squad Leaders Available (per Company)	Number of Available Barbers	Objective Function
7	14	13	12	27248.613
7	14	15	12	27248.613
7	14	14	12	27248.613
6	14	15	12	27245.455
6	14	14	12	27245.455
6	14	13	12	27222.004
6	14	12	12	27168.011
9	14	12	12	27116.028
8	14	12	12	27077.671
8	14	13	12	27077.671

SimRunner Optimization Results

Method	Bus Arrival Rates (Min)	Squad Leader Pick-Up Arrival Rates (Min)	Number of Squad Leaders Available (per Company)	Number of Available Barbers
Four Factor Optimization	7	14	13	12
One Factor Optimization	8	14	14	16
Actual for 2004	~9	~10	Average 13	Average 14
Actual for 2005	~8	~15	Average 13	Average 14

Study Conclusions

- Limited resources requiring non-linear utilization can be optimized by establishing flexible process thresholds which allow freedom of execution.
- Process thresholds need to be subjectively altered by a central command (operations center) throughout the day to maximize throughput.
- Real-time information of status of key areas is required to allow system administrators (squad leaders) and central command (operations center) to execute tasks in a timely manner.
- Impact to USMA and the Army:
  - Efficiency (*2005 process shaved nearly 30 minutes from 2004 time*)
  - Cost-savings

Summary

- Commercial simulation software such as ProModel can be utilized to model linear and non-linear processes to provide insight into system enhancements.

Questions

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