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GO WITH THE FLOW:Using HL7 Messaging and Diagnosis-Related Groups to Characterize Inpatient Flow

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Using HL7 Messaging and Diagnosis-Related Groups to Characterize Inpatient Flow

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Overview

- Context- Resource Allocation in Hospitals
- Problem Statement -Modeling Patient Flow
- Methodology
- Preliminary Results
- Impact

Decision Making & Resource Allocation

Decisions at the organization level

Decisions at the unit level

…can have a serious implications

Virtual Hospital

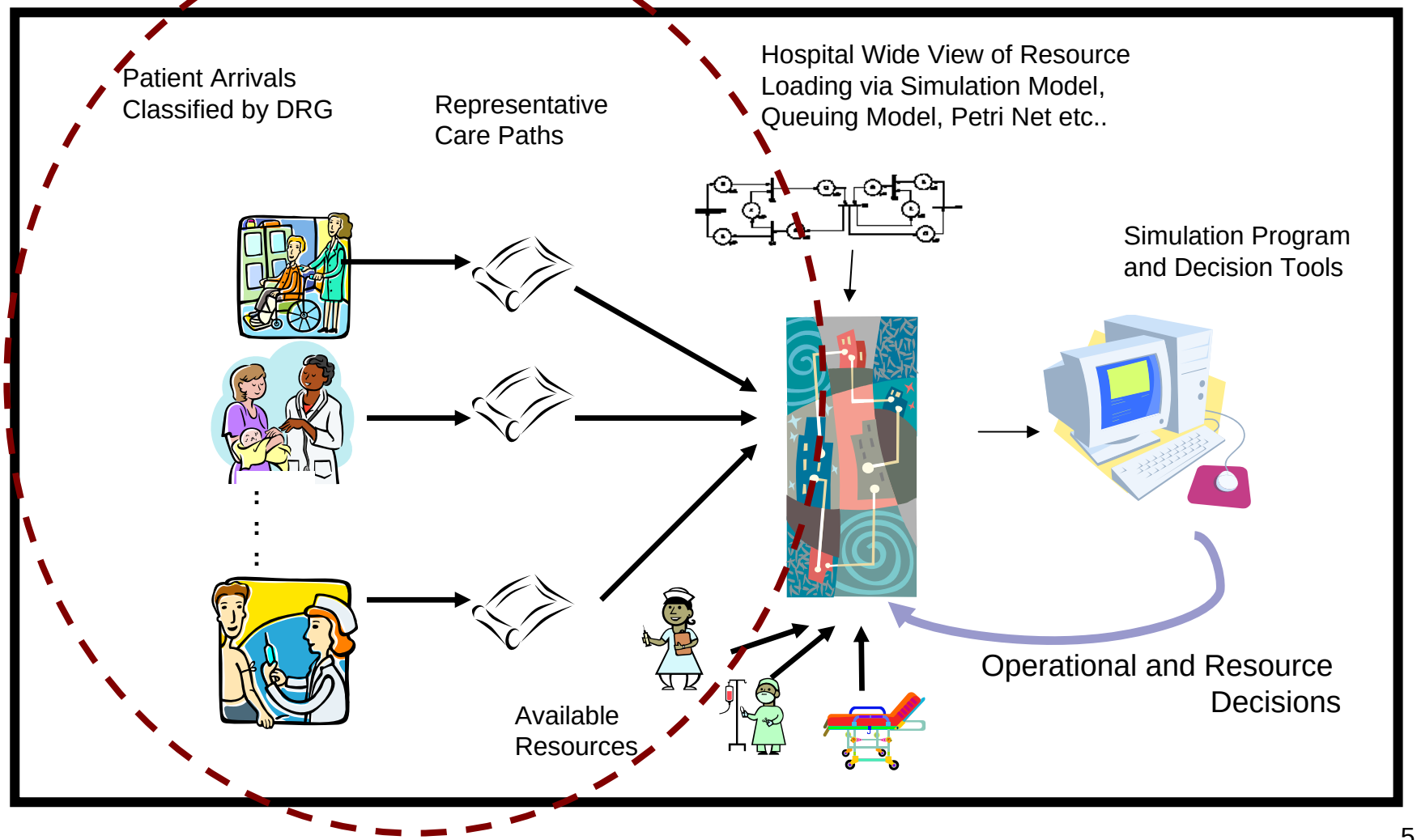
The question shouldn't be
'How do we take a department and optimize it?',
but
'How do we support the optimization of a whole system?'

Dr. Peter Woodbridge- VA Indianapolis

It is the little things that we are missing. [It] isn't a black box!

Dr. Imtiaz Munshi- VA Indianapolis

Focus


Patient Arrivals
Classified by DRG
Representative
Care Paths
Hospital Wide View of Resource
Loading via Simulation Model,
Queuing Model, Petri Net etc..
Simulation Program
and Decision Tools
Operational and Resource
Decisions
Available
Resources

Objective

1. Make explicit the expected resource requirements a patient presents upon admission
2. Devise a method of incorporating these flow requirements into decision support models

Challenge: the Underlying Data Basis

Necessary Condition for this work:

Large quantities of real time admission, diagnosis and flow data for different patient types

- Much of what happens to the patient occurs as a result of information system *message passing*
- Each patient *generates a set* of such messages during their hospital stay
- These patient specific message sets can be *mined* for flow data (including resources used and timing information)
- These message sets can be archived and rapidly *accessed* electronically

Challenge: Developing a Data Construct

Can I represent patient flow potential as a function of patient type from the workload perspective?

- Possible to classify patient events according to resources needed

- Sequence Analysis methods can be used to examine a succession of expected resources

Methodology

1. Data Preparation
2. Data Synthesis
3. Data Modeling
4. Model Validation

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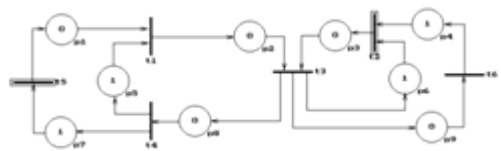
PID|||PATID1234^5^M11||JONES^WILLIAM^A^III||19610615|M||C|1200
    N ELM STREET^^GREENSBORO^NC^27401-1020|GL|(919)379-
    1212|(919)271-3434||S||
    PATID12345001^2^M10|123456789|987654^NC|
NK1|JONES^BARBARA^K|WIFE||||||NK^NEXT OF KIN
PV1|1|I|2000^2012^01||||004777^LEBAUER^SIDNEY^J.|||SUR||||ADM|
    A0|
```

Patient	Sequence
6	*1*14*7*10*6*6*6*6*6*0*1*6*6*6*6*6*14*7*CLC*6*6*6*7*1
7	*1*14*6*6*6*14*6*6*6*7*6*6*14*CLC*6*6*7*7*1
8	*1*14*6*6*6*6*7*CLC*1*0*1*6*6*6*6*7*1



Methodology 1: Data Preparation

5 DRGs

1. DRG 544: Major Joint Replacement Or Reattachment Of Lower Extremity
2. DRG 558: Percutaneous Cardiovascular Procedure with Drug-Eluting Stent without major complications
3. DRG 14: Intracranial Hemorrhage Or Cerebral Infarction
4. DRG 182: Esophagitis, gastroenteritis and miscellaneous digestive disorders with complications
5. DRG 183: Esophagitis, gastroenteritis and miscellaneous digestive disorders without complications

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PV1|1|I|2000^2012^01||||004777^LEBAUER^SIDNEY^J.|||SUR||||ADM|A0|
```

Health Information Systems messages in HL7 format

Source: www.hl7.org (hypothetical data)

Individual Care Paths

Patient	Segment	Message	Time	Event	Order Number	Location
DRG558_6	ORM	O01	0.50	Culture, MRSA Screen	36404009	MIC^
DRG558_6	ORM	O01	1.95	OXYGEN	36404147	MIC^
DRG558_6	ORM	O01	2.90	PX CHEST 1V	36403812	
DRG558_6	ORM	O01	7.75	Prothrombin Time	36407750	MIC^
DRG558_6	ORM	O01	7.88	CL ORDER CODE HEART CATH, LEFT	36407986	
DRG558_6	ORM	O01	13.17	CK TOTAL W/REFLEX MB FRACTION	36413114	SR5M
DRG558_6	ORM	O01	13.17	TROPONIN	36413116	SR5M
DRG558_6	ORM	O01	13.17	12 LEAD EKG - 5 MAIN	36413118	SR5M
DRG558_6	ORM	O01	13.17	CK w/Refex CKMB	36413114	S5M^
DRG558_6	ORM	O01	13.18	BASIC METABOLIC PROFILE	36413135	SR5M

Each patient has a list of all orders which includes the description of the order, the time since admission, the status of the order (e.g. Scheduled, Completed) and location

Idea of ‘Resource Bundles’

		Required Resource						
Visit Event	Event Key	RN	Tech	Lab	Clerk	MD	RAD	Procedure
Arterial Blood Gas	ABG		1			1		
Admit	ADT				1			
Basic Metabolic Panel	BMP	1		1				
UREA NITROGEN, BLOOD (BUN)	BUN	1		1				
Complete Blood Count, Auto w/Diff	CBC	1		1				
CK TOTAL W/REFLEX MB FRACTION	CKT	1		1				
CL HEART CATH, LEFT	CLC	1	1			1		1
COMPREHENSIVE METABOLIC PROFILE	CMP	1		1				

Snapshot of Resource Bundles for DRG 558- Percutaneous Cardiovascular Procedure with Drug-Eluting Stent without Major complication

Patient Paths with Resources..

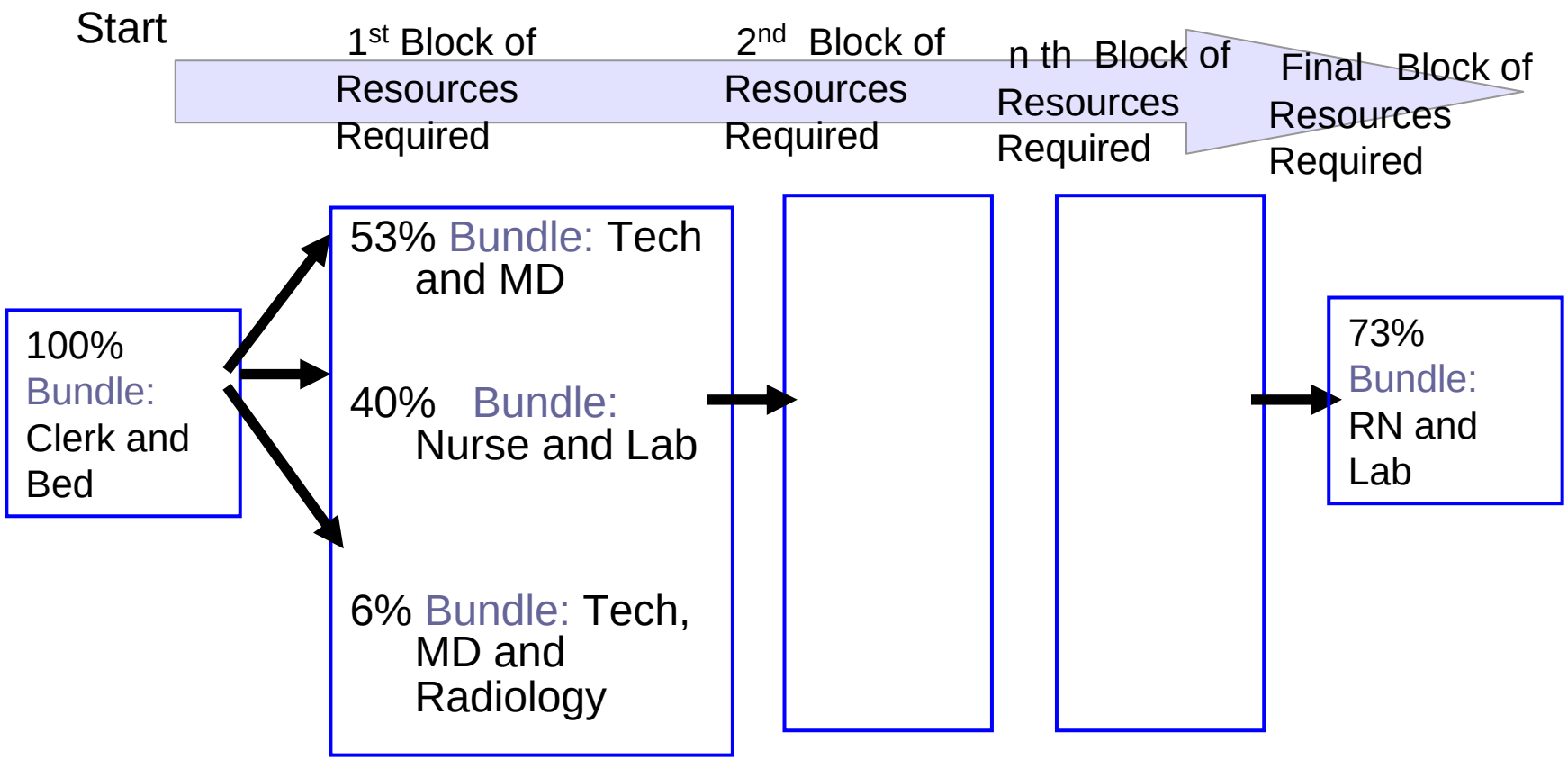
Patient Num	Time since admission	Event	Resources	
DRG558_6	0.00	Admit	Clerk	1
DRG558_6	0.63	Culture, MRSA Screen	RN, Lab	6
DRG558_6	5.70	Troponin I	RN, Lab	6
DRG558_6	10.57	Transfer	Bed	14
DRG558_6	13.17	12 LEAD EKG - 5 MAIN	Tech, MD	7
D		DER CODE HEART CATH, LEFT	RN, Tech, MD	15
D		AD EKG - E/D TEAM HEALTH	Tech, MD	7
D		PX CHEST 1V	Radiology, MD	10
D		Basic Metabolic Panel	RN, Lab	6

Summarized patient paths with resources required, events, time of occurrence

Paths for DRG 558

Patient_ID	aggpath
1	*1*1*14*7*6*6*6*6*6*10*6*14*6*6*6*6*6*6*6*6*6*6*6*6*7*PFT*10*CLC*14*7**6*6*6*7*1
2	*1*14*7*6*6*6*6*6*CLC*0*6*PTA*6*6*7*7*6*6*6*6*6*1
3	*1*1*14*7*10*6*6*6*6*6*6*7*14*6*7*CLC*0*6*6*6*7*1
4	*1*1*14*7*6*6*6*6*6*6*6*10*14*10*6*6*6*6*6*6*6*6*6*7*CLC*14*0*6*0*0*7*6*6*6*6*6*6*6*PTA*6*6*6*1
5	*1*1*14*7*6*6*6*6*6*10*0*6*6*6*6*6*14*7*CLC*PTA*6*6*7*7*14*6*1
6	*1*1*14*7*10*6*6*6*6*6*0*6*6*6*6*6*14*7*CLC*6*6*6*6*7*1
7	*1*1*14*6*6*6*6*14*6*6*6*7*6*6*6*14*CLC*6*6*7*7*1
8	*1*14*6*6*6*6*6*7*CLC*6*6*6*6*6*7*1
9	*1*14*7*6*6*6*6*6*6*CLC*7*6*6*6*6*6*1
10	1*14*6*6*6*6*6*6*6*6*6*6*6*6*6*6*14*CLC*14*6*7*6*6*6*7*1*
11	1*14*7*CLC*0*7*6*6*6*1*6*6*6*6*6*1*
12	*1*14*6*6*6*6*6*7*CLC*7*0*7*6*6*6*6*6*6*1
13	*1*14*6*6*6*6*6*7*0*CLC*7*6*6*6*6*6*6*6*1
14	*1*14*6*6*6*6*6*7*PTA*7*6*6*6*1
15	*1*14*7*6*6*6*6*6*CLC*7*7*6*6*6*1

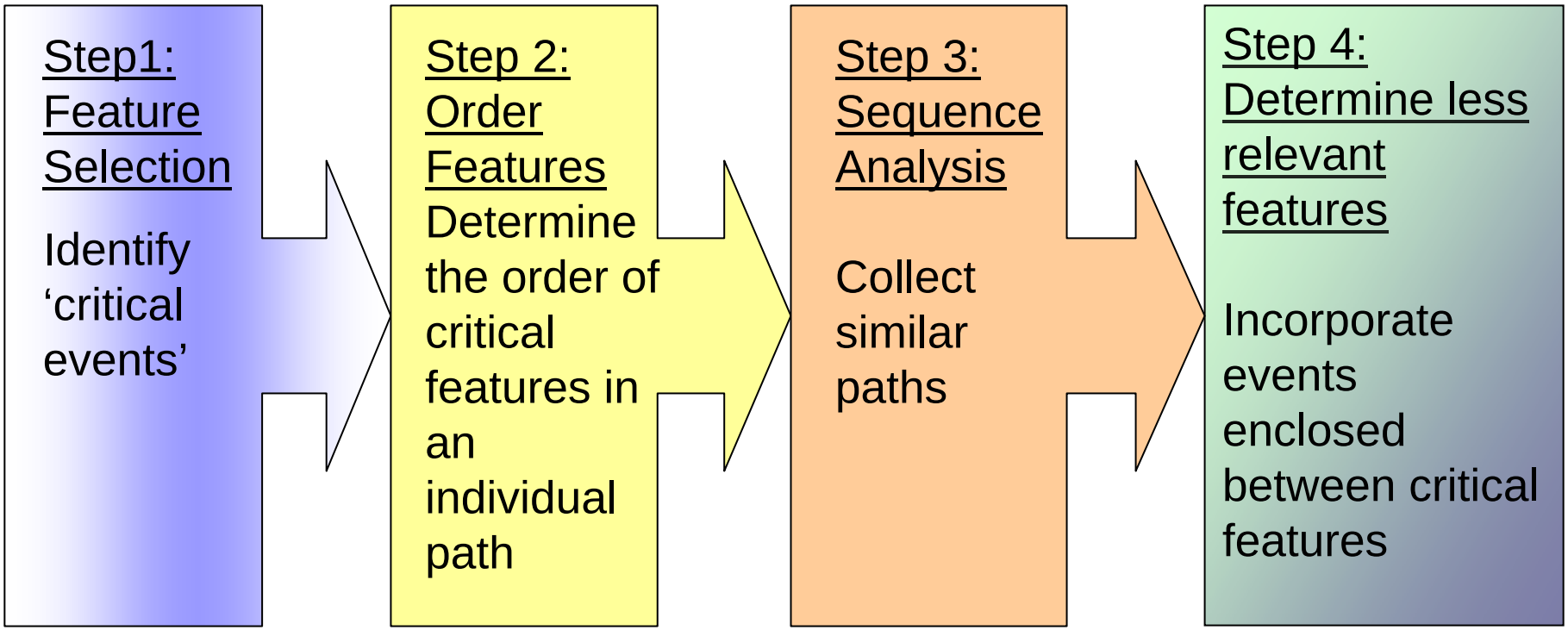
Methodology 2:Data Synthesis



Looking at the skeleton of a path….

Patient_ID	aggpath
1	*1*1*14*7*6*6*6*6*6*10*6*14*6*6*6*6*6*6*6*6*6*6*6*6*7*PFT*10*CLC*14*7**6*6*6*7*1
2	*1*14*7*6*6*6*6*6*CLC*0*6*PTA*6*6*7*7*6*6*6*6*6*6*1
3	*1*1*14*7*10*6*6*6*6*6*6*7*14*6*7*CLC*0*6*6*6*6*7*1
4	*1*1*14*7*6*6*6*6*6*6*6*10*14*10*6*6*6*6*6*6*6*6*6*7*CLC*14*0*6*0*0*7*6*6*6*6*6*6*6*PTA*6*6*6*1
5	*1*1*14*7*6*6*6*6*6*10*0*6*6*6*6*6*14*7*CLC*PTA*6*6*7*14*6*1
6	*1*1*14*7*10*6*6*6*6*6*0*6*6*6*6*14*7*CLC*6*6*6*7*1
7	*1*1*14*6*6*6*14*6*6*6*7*6*6*14*CLC*6*6*7*7*1
8	*1*14*6*6*6*6*7*CLC*6*6*6*6*7*1
9	*1*14*7*6*6*6*6*6*CLC*7*6*6*6*6*1
10	1*14*6*6*6*6*6*6*6*6*6*6*6*14*CLC*14*6*7*6*6*7*1*
11	1*14*7*CLC*0*7*6*6*1*6*6*6*6*1*
12	*1*14*6*6*6*6*7*CLC*7*0*7*6*6*6*6*6*1
13	*1*14*6*6*6*6*7*0*CLC*7*6*6*6*6*6*6*1
14	*1*14*6*6*6*6*7*PTA*7*6*6*1
15	*1*14*7*6*6*6*6*CLC*7*7*6*6*1

Data Synthesis Algorithm



Example

Bundles

7, 10, PTA

Pat 1: 7, 10

Pat 2: 7,10, PTA

Pat3: 10, PTA

[7 10] xxxx [10 PTA]xx [PTA]

Preliminary Results using Index of Similarity (Delesie & Croes)

Patient	LOS (hrs)	Admit	Paths
4	135	ED	*1*14*7*6*6*6*6*6*6*10*14*10*6*6*6*6*6*6*6*6*7*CLC*14*6*7*6*6*6*6*6*6*PTA*6 *6*6*1
5	61	ED	*1*14*7*6*6*6*6*10*6*6*6*6*14*7*CLC*PTA*6*6*7*14*6*1
Similarity Score		1.00	

Patient	LOS (hrs)	Admit	Paths
2	32	Direct Admit	*1*14*7*6*6*6*6*6*CLC*0*6*PTA*6*6*7*7*6*6*6*6*6*1
3	50	Direct Admit	*1*14*7*10*6*6*6*6*6*7*14*6*7*CLC*0*6*6*6*7*1
Similarity Score		0.491	

Preliminary Results using SAM

Patient	LOS (hrs)	Admit	Paths
4	135	ED	7 10 14 CLC PTA
5	61	ED	7 10 14 CLC PTA

Patient

	DRG558_1	DRG558_4	DRG558_5	DRG558_6
DRG558_1	-	1	1	0
DRG558_4	-	-	0	1
DRG558_5	-	-	-	1
DRG558_6	-	-	-	-

Patient

Preliminary Results using SAM

Patient	LOS (hrs)	Admit	Paths
2	32	Direct Admit	*1*14*7*6*6*6*6*6*CLC*6*PTA*6*7*7*6*6*6*6*6*1
3	50	Direct Admit	*1*14*7*10*6*6*6*6*6*14*6*7*CLC*6*6*6*6*7*1

Patient

Patient	DRG558_2	DRG558_3	DRG558_7	DRG558_8
DRG588_2	-	4	3	3
DRG558_3	-	-	1	2
DRG558_7	-	-	-	1
DRG558_8	-	-	-	-

Recap: The Big Picture

MSH|^~\&|ADT|MCM|LABADT|MCM|198808181126|SECURITY|ADT^A01|MSG00001|P|2.3|
EVN|A01|198808181123||
PID|||PATID1234^5^M11||JONES^WILLIAM^A^III||19610615|M||C|1200 N ELM STREET^^GREENSBORO^NC^27401-1020|GL|(919)379-1212|(919)271-3434||S|| PATID12345001^2^M10|123456789|987654^NC|
NK1|JONES^BARBARA^K|WIFE||||||NK^NEXT OF KIN
PV1|1||2000^2012^01||||004777^LEBAUER^SIDNEY^J.|||SUR||||ADM|A0|

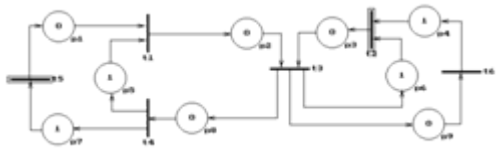
1. Health Information Systems Data……

2. Sequences of Resources an Individual Patient Uses

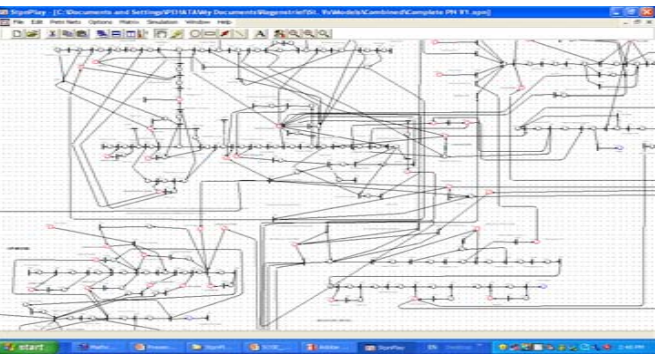
Patient	Sequence
6	*1*14*7*10*6*6*6*6*6*0*1*6*6*6*6*6*14*7*CLC*6*6*6*7*1
7	*1*14*6*6*6*14*6*6*6*7*6*6*14*CLC*6*6*7*7*1
8	*1*14*6*6*6*6*7*CLC*1*0*1*6*6*6*6*7*1

[7 10] xxxx [10 PTA]xx [PTA]

3. Synthesized Representation of Resources by DRG



4. “Submodels” of Patient Flow



5. Organization Decision Support

Potential Impact

Refined Decision Support

Variation in Clinical Practice

Flow Optimization

Intellectual Content

- Develop Data Sources
- Develop methodologies and data sources to capture flow patterns
- Create healthcare models able to represent resources required for patient flow by patient type
- Wide- reaching applicability

Thank You

EXTRA SLIDES

Index of Similarity

		Column k				Sum of K columns
Row i		p_{ik}				1
Row j		p_{jk}				1
Average of pair of rows		P_{i+jk}				1

Where p_{ik} and p_{ik} are the proportion of row quantities *i* and *j* in column *k* and

$$SP_{ij} = 1/2 \sum_{k} \left(\underset{(1)}{p_{ik}} \log_2 \frac{p_{ik}}{p_{i+j,k}} + p_{ji} \log_2 \frac{p_{jk}}{p_{i+j,k}} \right)$$

and

$$P_{i+j,k} = \frac{p_{ik} + p_{jk}}{2}$$

Source: Delesie and Croes (2000)

Previous Approaches

- Queueing
  - Majority access capacity requirements or outpatient scheduling (Preater, Green)

  Most Relevant: Koizumi et al (2005) show effects of *bed obstruction*

- Markov
  - Capture movement between units

  Most Relevant: Lin et al (2005) - Hidden Markov Models used to discover clinical pathways for Delivery patients

- Simulation
  - Majority focus on reducing length of stay within a single unit (Jun et al)

  Most Relevant: Cohen et al (1980)- modeled blocked transfers through the entire hospital

- Petri nets
  - Hospital wide

  Most Relevant: Maruster et al (2002)- proposed algorithm to create acyclic workflow nets from hospital data

Definition of Flow

The word “Flow” encompasses:

1. The number of events during a patient’s stay
2. The precedence/sequence of events
3. The timing of events
4. Resources required to execute these event

Petri Nets

- Graphical and mathematical tool for describing systems **characterized** as: concurrent, asynchronous, distributed, parallel, nondeterministic

- The major strength of Petri nets is their support for analysis of many properties and problems associated with concurrent systems
  - Behavioural Properties (depend on initial marking)
    Reachability, Boundedness, Liveness, Fairness, etc.

  - Structural Properties (depend on the topological structure)
    Structural Liveness, Controllability, Structural Boundedness

- Analysis Methods:
  Covertablity trees, incidence matrix, decompostiion

- Petri Nets have a rich literature