PRODUCTION FLOW ANALYSIS: A TOOL FOR DESIGNING A LEAN HOSPITAL

What is this presentation about?

- The use of Production Flow Analysis (PFA) to design the layout of a new hospital is discussed in this paper:
  - Karvonen, S., Korvenranta, H., Paatela, M. & Seppala, T. (2007). *Production Flow Analysis: A Tool For Designing a Lean Hospital*. World Hospitals and Health Services, Vol. 43, No. 1, 28-31.
- The use of the PFAST (Production Flow Analysis and Simplification Toolkit) software:
  1. validated the results reported in the original paper
  2. provided additional insights on hospital layout design beyond those reported in the original paper

Quotes about ***FLOW*** from Taiichi Ohno's Book

- (Page 11) "I was manager of the machine shop at the Koromo plant. As an experiment, I arranged the various machines in the sequence of machining processes"
- (Page 33) "We realized that the (kanban) system would not work unless we set up a production flow that could handle the kanban system going back process by process"
- (Page 39) "It is undeniable that leveling becomes more difficult as diversification develops"

Quotes about ***FLOW*** from Taiichi Ohno's Book (contd.)

- (Page 54) "Toyota's main plant provides an example of a smooth production flow accomplished by re-arranging the conventional machines after a thorough study of the work sequence"
- (Page 54) "It is crucial for the production plant to design a layout in which worker activities harmonize with rather than impede the production flow"
- (Page 100) "By setting up a flow connecting not only the final assembly line but all the processes, one reduces production lead time"

Quotes about ***FLOW*** from Taiichi Ohno's Book (contd.)

- (Page 123) "When work flow is properly laid out, small isolated islands do not form"
- (Page 125) "For the worker on the production line, this means shifting from being *single-skilled* to becoming *multi-skilled*"
- (Page 128) "The first aspect of the TPS…means putting a flow into the manufacturing process…Now, we place a lathe, a mill and a drill in the actual sequence of the manufacturing processing …"

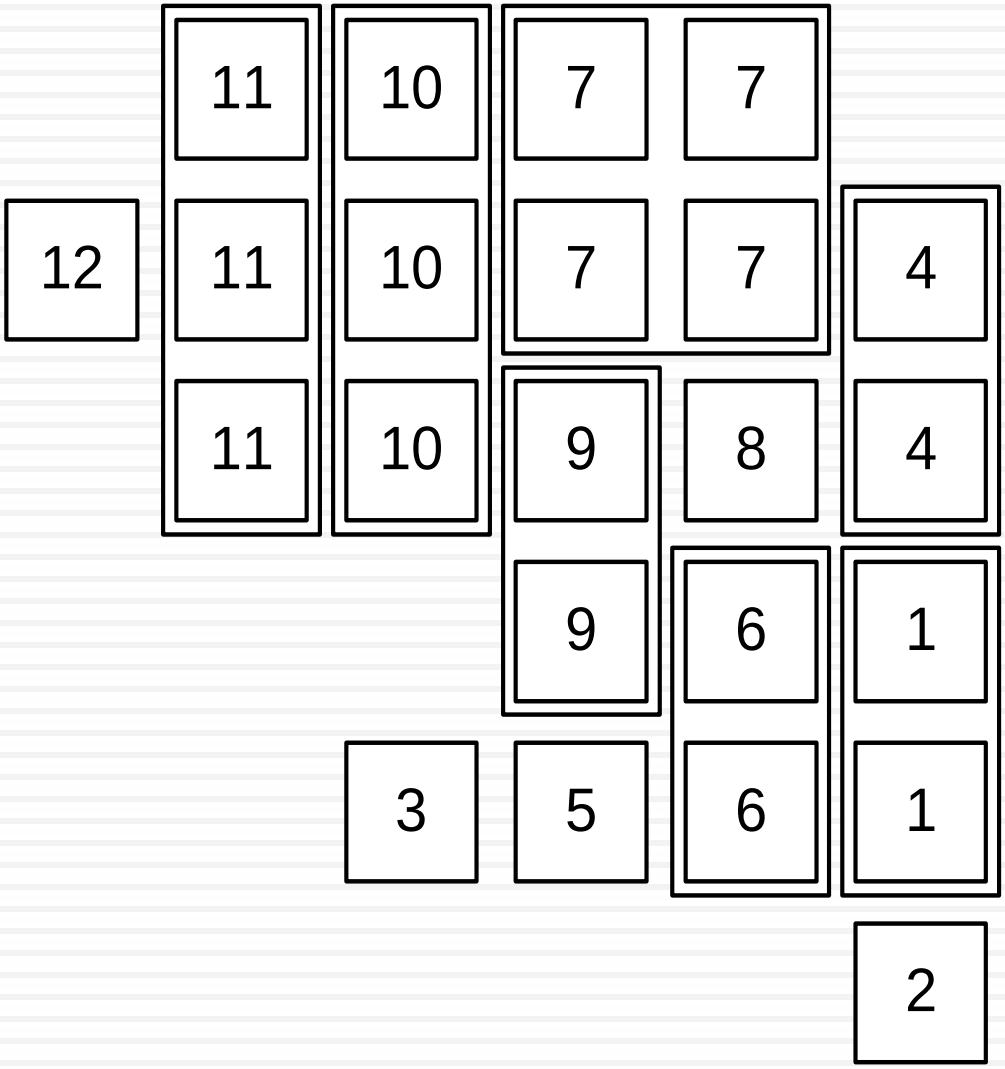
The Case ***Against*** Patient Transportation in ***Any*** Hospital

- Transportation
  - Anxiety for patient
  - Risk of injury to patient
  - Spread of infection to/from patient
- Transportation = NVA (non-value-adding) activity
  - = Cost of personnel hired to transport
  - = Travel delay between locations
  - = Queue delays at either "From" or "To" locations
  - = Queue delays in corridors, elevators, transport between buildings, etc.
  - = Increases total time taken to complete patient's treatment
- Travel reflects fundamental flaws in hospital design
  - Maximize asset utilization and departmental efficiencies
  - Increase payroll with transportation-related personnel
  - Invest in complex IT systems to manage the system
  - Persist with the functional organization of the entire hospital

Main Points in Paper

- Hospitals are organized by function ("Functional Layout")
  - Isolated departments (Laboratories, Radiology, OR's, ICU's, etc.)
  - Each department behaves like a "functional silo"
  - Each department is a single area where similar equipment is co-located --- The entire department specializes in "similar processes"
  - Each department seeks to maximize *their* efficiency and utilization
- Well-known disadvantages of a functional organization
  - Long patient throughput times
  - Poor overall process control and quality of care
  - Complex patient flow routes
  - Absence of "fluid" patient flows
  - Long transfer distances involving many multi-department visits
  - Complicated scheduling

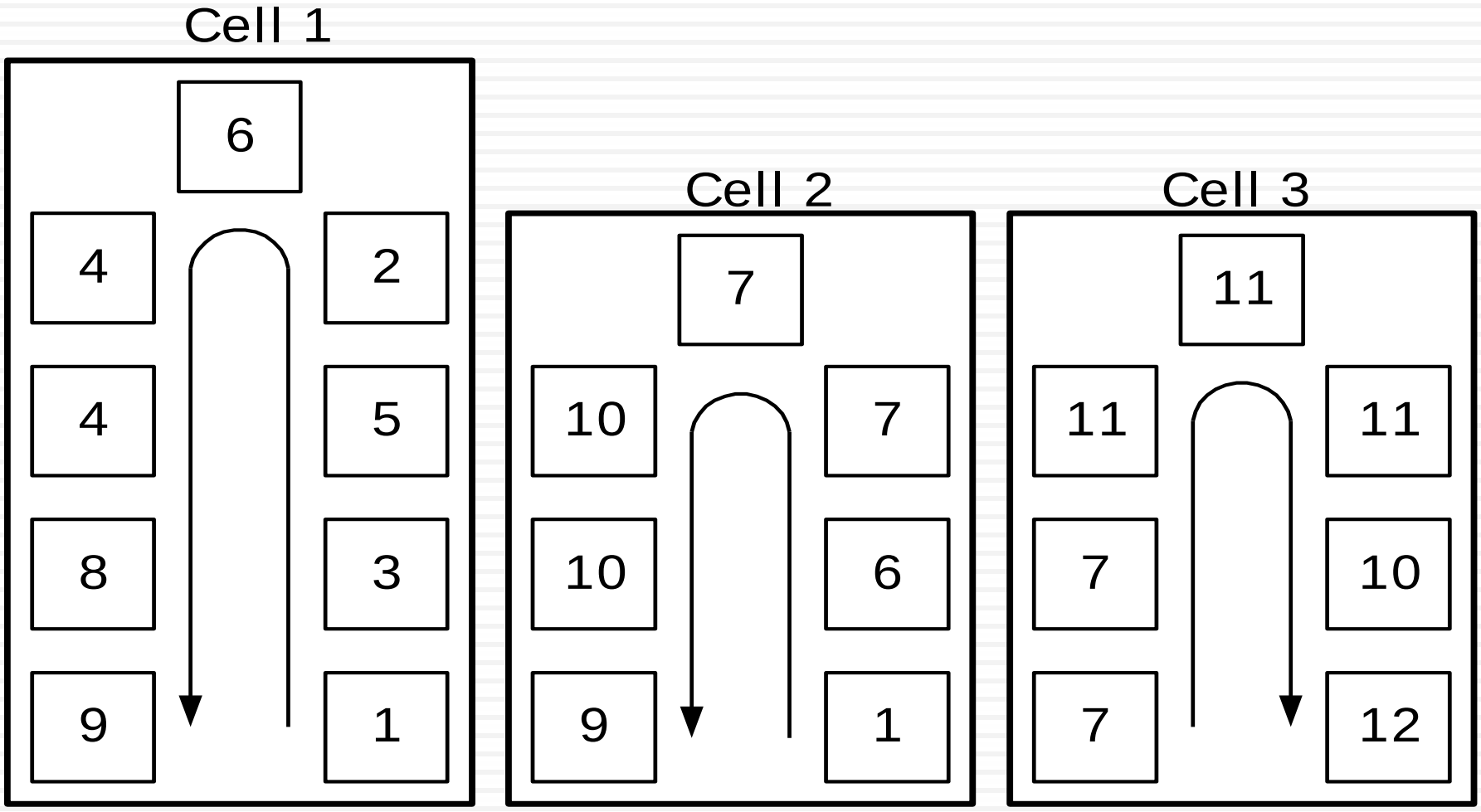
Process Layout/Functional Organization



Main Points in Paper (contd.)

- What does it mean to be a "product-focused hospital"?
  - ***The real product of a hospital is a treated patient***
  - All staff and equipment used in the treatment of a "family of illnesses" would work in one place as a multi-professional group
  - Each product-focused group completes end-to-end care of the patients it receives
- Proven benefits of a product (or cellular) organization
  - Fewer inter-department patient transfers = Quick throughput times = Less patient travel = Lower transfer delays
  - Quick response after error detection = Better quality of care
  - Lower inventories and inventory-carrying costs
  - Improved scheduling and end-to-end control of patient flows

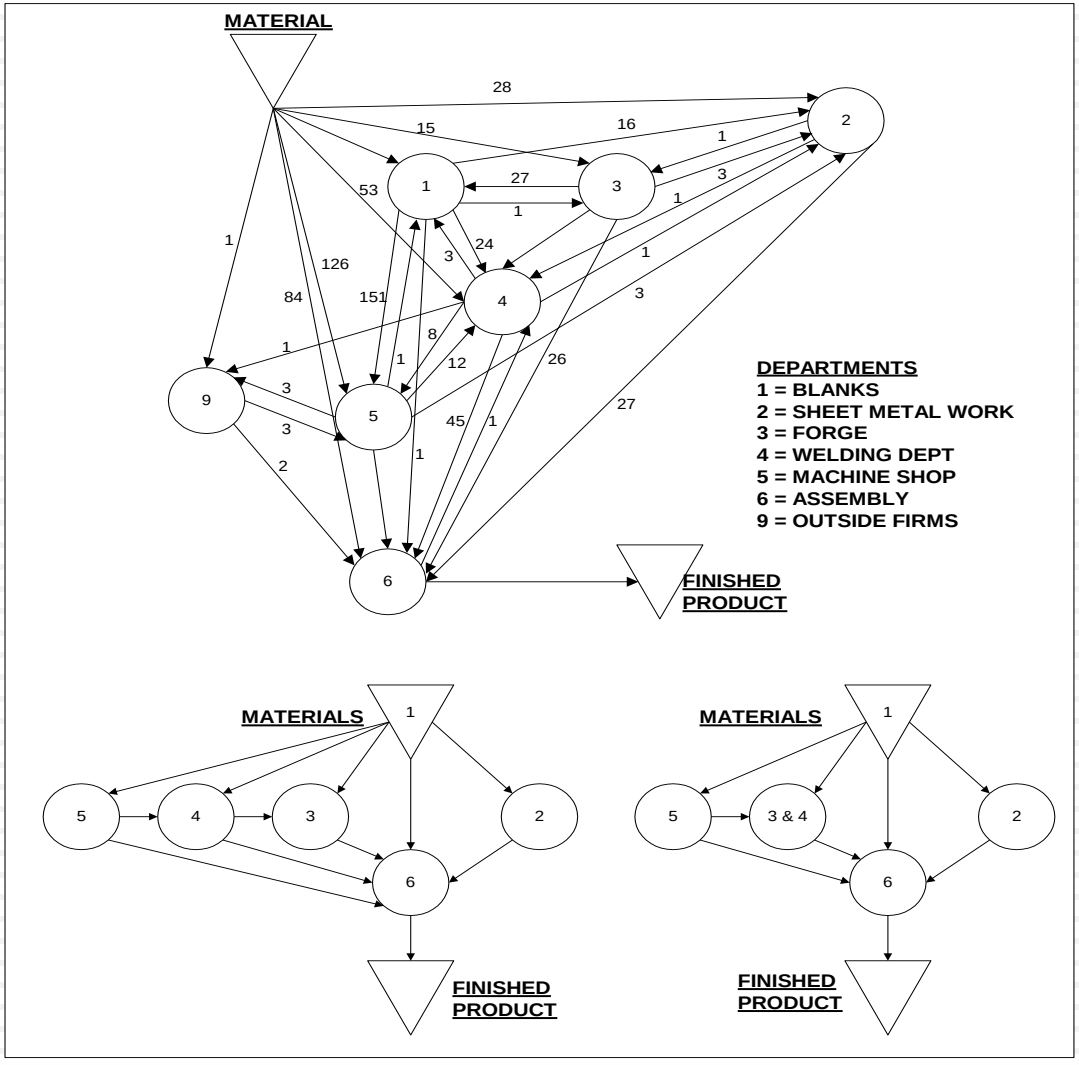
Cellular Layout/Product-focused Organization



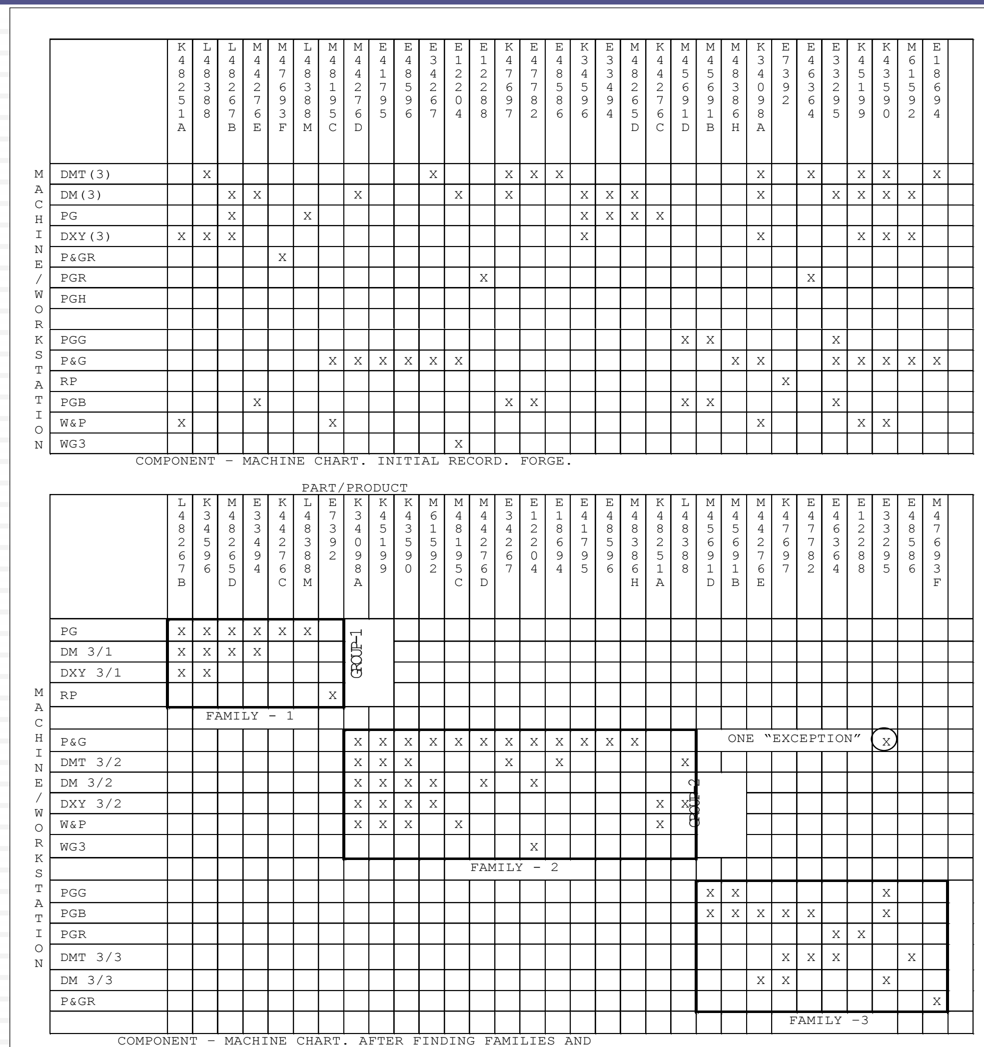
Main Points in Paper (contd.)

- Production Flow Analysis (PFA) was used to plan a new acute care hospital
- Four Stages in PFA
  - Factory Flow Analysis
    - Streamline and reduce flows across all departments/shops
  - Group Analysis
    - Streamline and reduce flows within each department/shop
  - Line Analysis
    - Streamline and reduce flows within each manufacturing cell inside each shop
  - Tooling Analysis (includes Setup Reduction)
    - Streamline and reduce flows at each workstation inside a cell
    - Focus *first and foremost* on the constraint w/c (Herbie!) ☺

Factory Flow Analysis



Group Analysis



MACHINE/WORKSTATION	K48251A	L48388	L48267B	M44276E	M47693F	L48388M	M48195C	M44276D	E41795	E48596	E34267	E12204	E12288	K47697	E47782	E48586	K34596	E33494	M48265D	K44276C	M45691D	M45691B	M48386H	K34098A	E7392	E46364	E33295	K45199	K43590	M61592	E18694
DMT(3)		X									X			X	X	X								X		X		X	X		X
DM(3)			X	X				X				X		X			X	X	X					X			X	X	X	X	
PG			X			X											X	X	X	X											
DXY(3)	X	X	X														X							X				X	X	X	
P&GR					X																										
PGR													X													X					
PGH																															
PGG																					X	X					X				
P&G							X	X	X	X	X	X											X	X			X	X	X	X	X
RP																									X						
PGB				X										X	X						X	X					X				
W&P	X						X																	X				X	X		
WG3												X																			

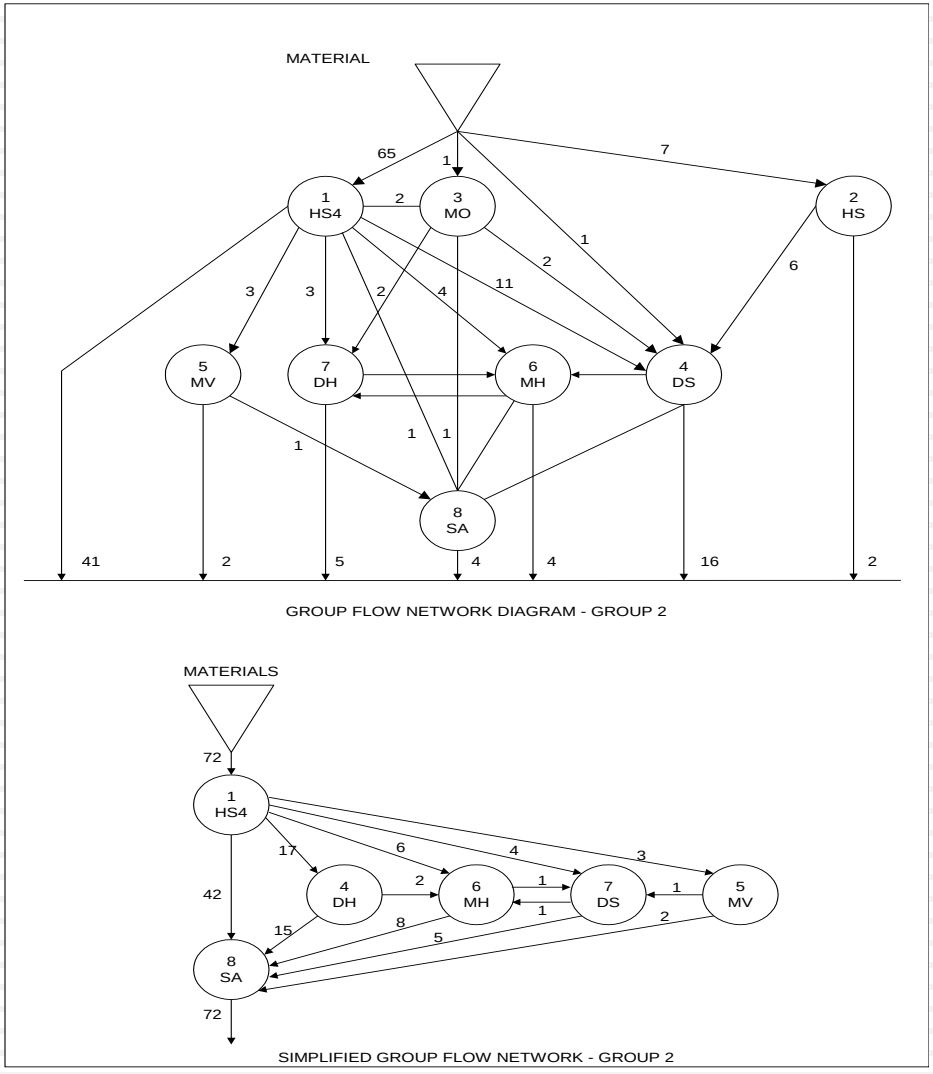
COMPONENT - MACHINE CHART. INITIAL RECORD. FORGE.

PART/PRODUCT

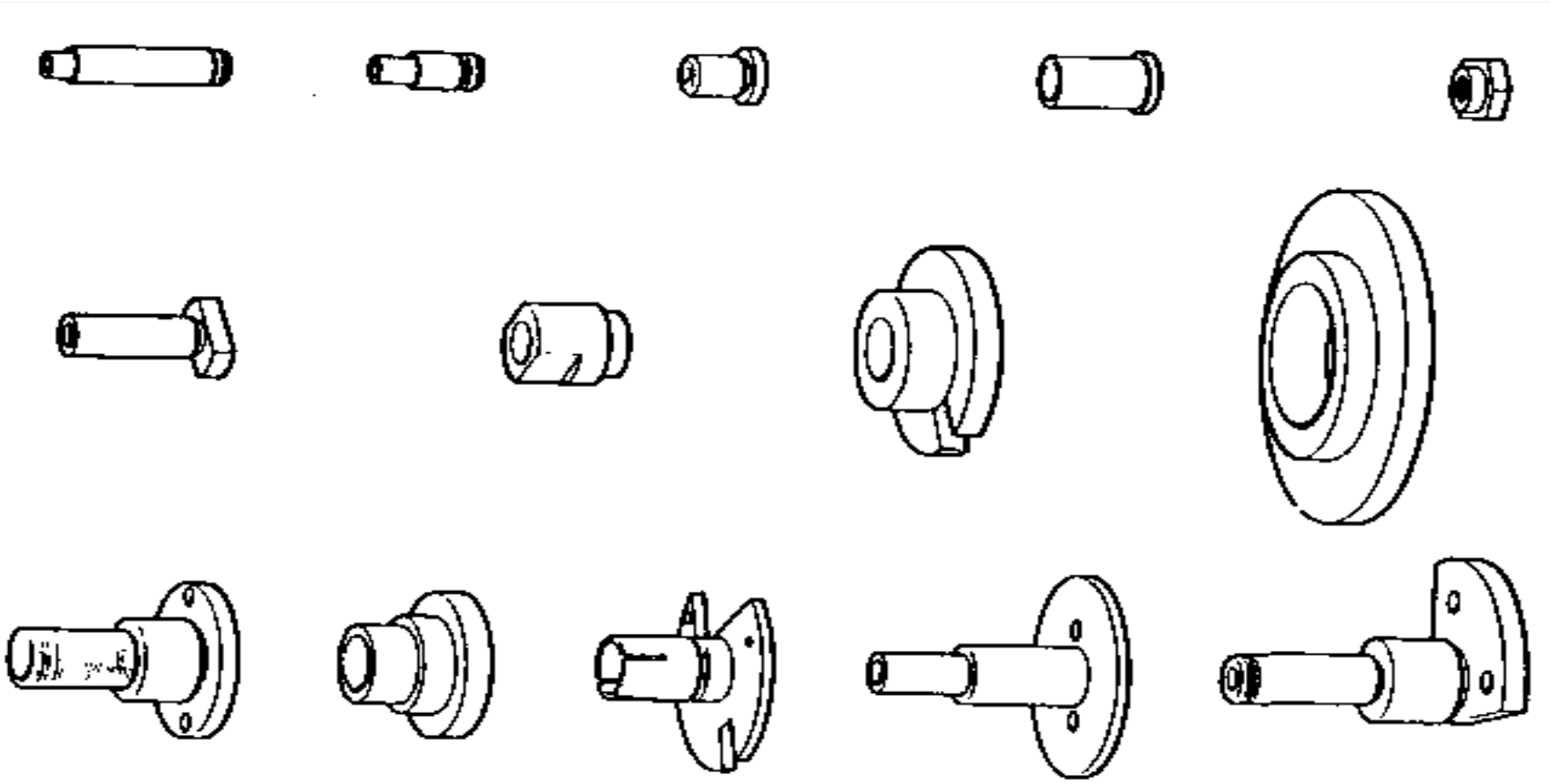
MACHINE/WORKSTATION	L48267B	K34596	M48265D	E33494	K44276C	L48388M	E7392	K34098A	K45199	K43590	M61592	M48195C	M44276D	E34267	E12204	E18694	E41795	E48596	M48386H	K48251A	L48388	M45691D	M45691B	M44276E	K47697	E47782	E46364	E12288	E33295	E48586	M47693F
PG	X	X	X	X	X	X																									
DM 3/1	X	X	X	X																											
DXY 3/1	X	X																													
RP							X																								
	FAMILY - 1																														
P&G								X	X	X	X	X	X	X	X	X	X	X	X			ONE "EXCEPTION"							(X)		
DMT 3/2								X	X	X				X		X					X										
DM 3/2								X	X	X	X		X		X																
DXY 3/2								X	X	X	X									X	X										
W&P								X	X	X		X								X											
WG3															X																
													FAMILY - 2																		
PGG																						X	X						X		
PGB																						X	X	X	X	X			X		
PGR																											X	X			
DMT 3/3																									X	X	X			X	
DM 3/3																								X	X				X		
P&GR																															X
																									FAMILY -3						

COMPONENT - MACHINE CHART. AFTER FINDING FAMILIES AND GROUPS

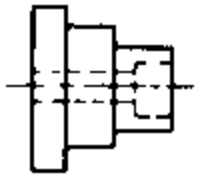
Line Analysis



Tooling and Workplace Layout Analysis

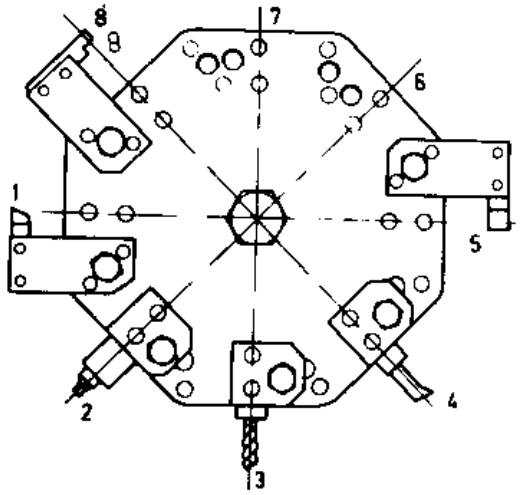


Tooling and Workplace Layout Analysis (contd.)



Turret Pos.	Tool Description
1	Face and Rgt. Turn (use as stop)
2	Center
3	Drill
4	Boring
5	Finish Turn
6	Free
7	Free
8	Part Off

Notes – Additional tools should be placed
in a free position where possible
thus preserving the basic settings



What work did they do in this Project?

- PFA was used to ***simplify*** patient flows between different units of a new, acute care hospital planned for 2011
  - Increases in patient flow volumes between 2007-2011 was factored into the analyses
- The current hospital is functionally organized
- Patient flows for five main care-lines – Cardiology, Traumatology, Neurology, Surgery and Non-Surgical Treatment – were analyzed
  - Results from patient flow analysis for only one care-line – Neurology – are reported in the paper ☹
  - Only one of the four phases of PFA – Factory Flow Analysis – was utilized for this project ☹
  - Only 7 (of 20) important PRN's used ("80-20 Pareto Law")

What work did they do in this Project? (contd.)

- Several departments – Emergency, Radiology, Laboratory, Intensive Care, Operating Theater Units and Maintenance – were asked to give feedback on the patient route codes (PRN)
- Analyses for remaining four main care-lines not reported in the paper
  - FFA was done for each of these four care-lines
  - From-To Charts for the five FFA's were summed up to produce the entire hospital's primary patient flow network
- Primary flows for five care-lines and entire hospital used to design the final layout

WHAT THEY DID

Key Decisions for Future Hospital's Facility Layout

- Final layout based on 80-20 Pareto Law --- The primary patient flow network was created from ***only*** 7 (of 20) PRN's --- Should the ***remaining*** 13 PRN's have been ignored?
- Emergency (P) department got its own Radiology (R) resources
- Stroke Unit (D), Ultrasound Examination (U) and Radiology (R) departments were merged --- CT Imaging/MRI placed adjacent to Stroke Unit
- New hospital's facility layout designed using From-To Charts --- Quantitative estimates of expected traffic volumes were used to plan the proximities between various units

Process Codes for Neurology (Table 1 in Karvonen et al)

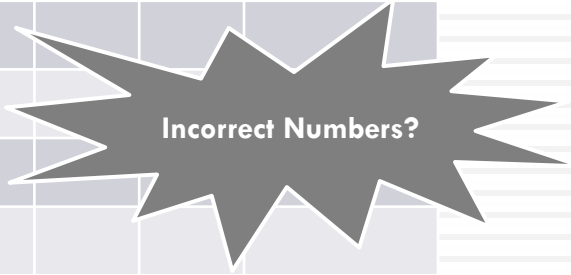
Code for the Processing Unit	Process
D	Stroke Unit
E	Intensified Monitoring
I	Invasive Cardiology
K	Home
M	Intensive Care Unit
N	Cardiac Care Unit
P	Emergency
Q	Neurology Ward
R	Radiology
T	Monitoring
U	Ultrasound Examination

Process Route Code (PRN) Frequency Chart for Neurology Patient Flows in 2011 (Table 2 in Karvonen et al)

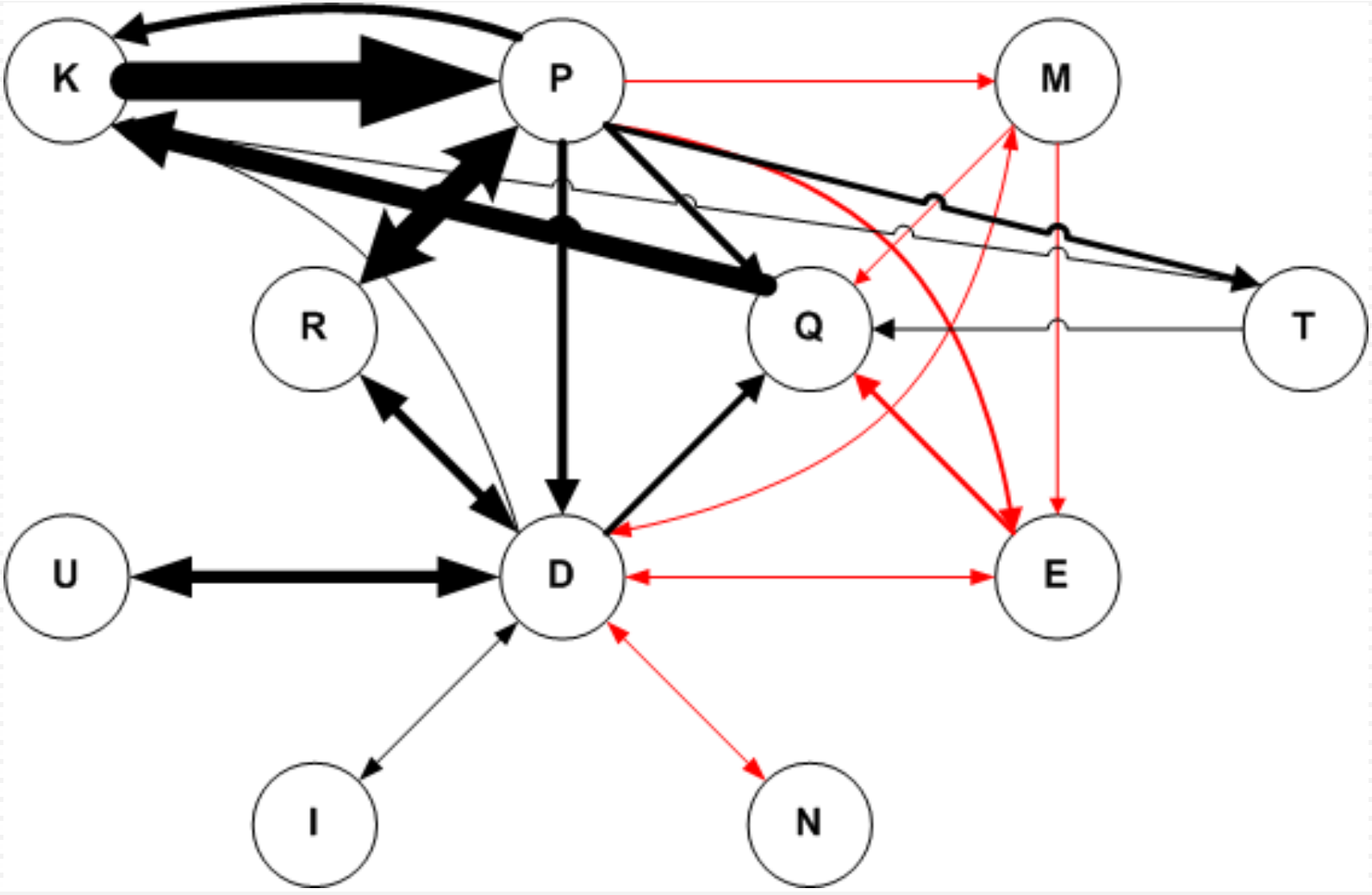
	Process Route Number (PRN)	Number of Patients
1	KPRPQK	1200
2	KPK	1000
3	KPRPEQK	700
4	KPRPDRDUDQK	517
5	KPRPK	500
6	KPRPTQK	500
7	KPRPDRDUDQK	333
8	KPRPDRDUDUDQK	258
9	KPTK	500
10	KPRPDRDUDUDK	167
11	KPRPMEQK	80
12	KPRPDRDUDIDQK	67
13	KPRPDRDUDUDIDQK	33
14	KPRPDRDYDNDQK	33
15	KPRPDRDUDEDQK	33
16	KPRPMQK	20
17	KPRPDRDUDUDNDQK	17
18	KPRPDRDUDUDEDQK	17
19	KPRPDRDUDMDQK	17
20	KPRPDRDUDUDMDQK	8
	Total Number of Patients	**6000**

From-To Chart for Neurology Patient Flows in 2011 (Table 3 in Karvonen et al)

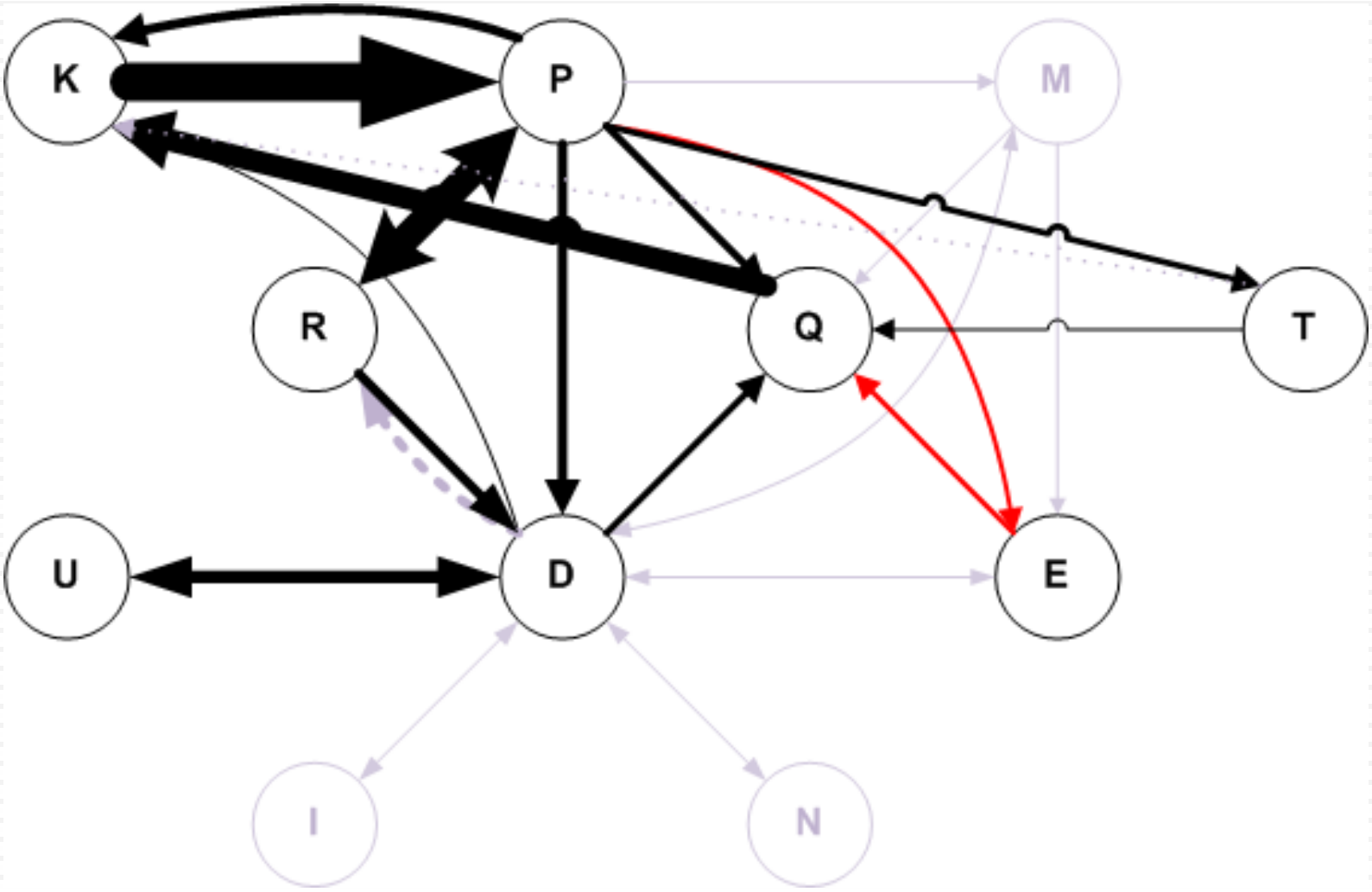
		TO										
		D	E	I	M	N	P	Q	R	T	U	Home (K)
FROM	D		50	100	25	50		1000	1500		2000	500
	E	50						780				
	I	100										
	M	25	80					20				
	N	50										
	P	1500	700		100			1200	4500	1000		1500
	Q											3500
	R	1500					4500					
	T							500				500
	U	2000										
	Home (K)						6000					



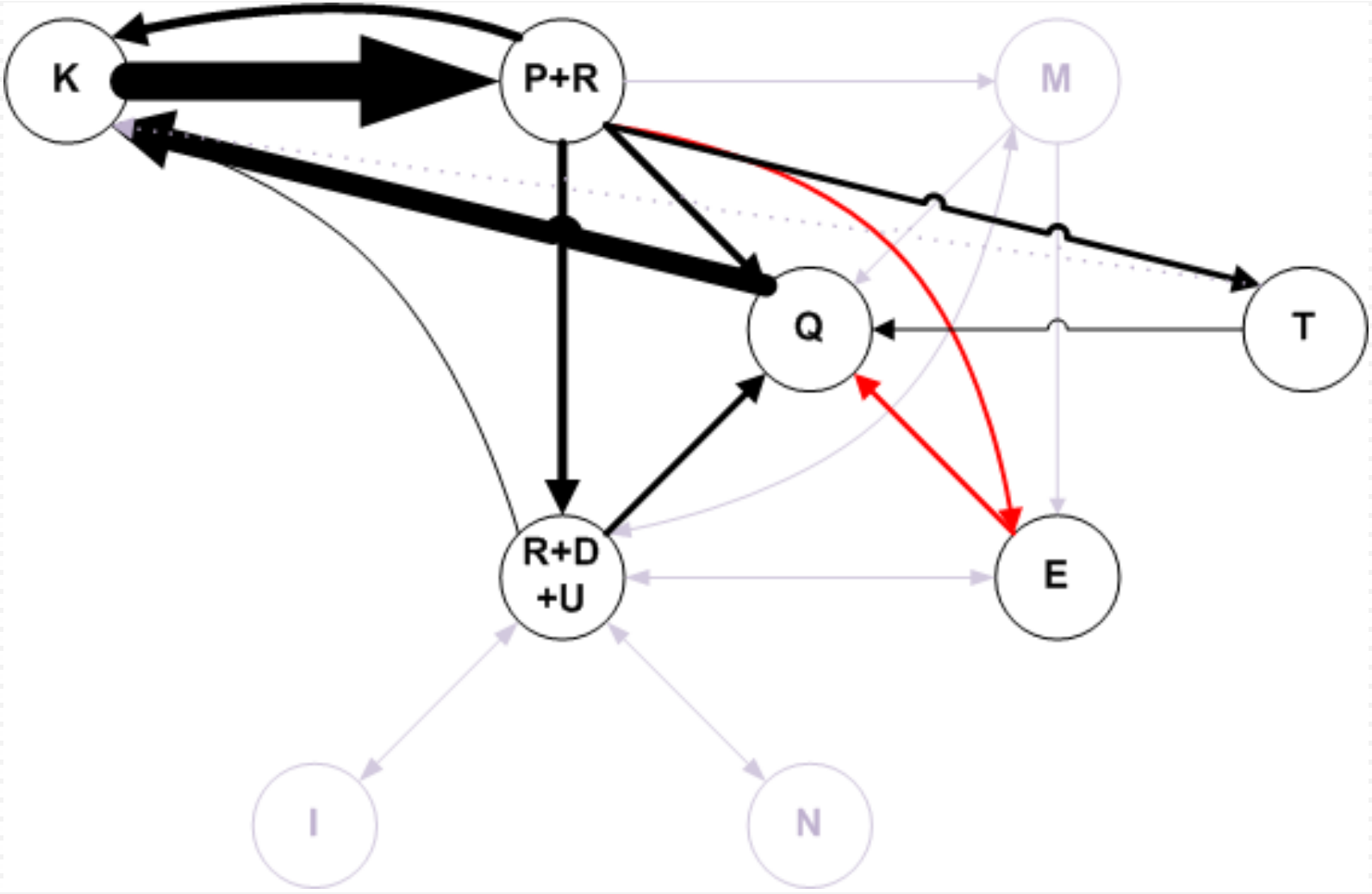
Neurology's Patient Flow Network in 2011, based on Functional Organization (Figure 1 in Karvonen et al)



Primary Patient Flow for Neurology in 2011, based on Functional Organization (Figure 2a in Karvonen et al)



Streamlined Primary Patient Flow for Neurology in 2011 (Figure 2b in Karvonen et al)



Benefits Claimed for ***only*** Acute Neurological Patients

- Unnecessary and potentially risky transfers reduced
- Direct cost savings
  - Fewer personnel needed for patient transfers between Ultrasound, CT or MRI
- Improved teamwork due to proximity of needed resources and personnel for end-to-end care
- Indirect cost savings
  - Reduced delays and errors due to transfers
  - Nurses spend more time in Stroke Unit and less on transporting patients
  - Elimination of referrals between units
  - Reduced usage (and repair/maintenance) of elevators and other transport equipment

Short List of "Game-Changing" Ideas

- "Evidence Based Design" – Facility layout was designed based on numerical estimates of predicted traffic volumes
- A well-established quantitative method for facility layout (Production Flow Analysis) was used
- Some functional departments ("process villages") were merged
- Some functional departments were de-centralized and duplicated in several *other* departments
- Data-driven criteria were identified for cross-training employees in "clusters" of complementary skills often required for patient care
- Similar to the position of a "Value Stream Manager", a "Patient Flow Manager" who will manage entire patient flow (including intermediate support activities) for a "family of patients" ought to be considered ex. the James Comprehensive Breast Care Center

WHAT WE DID

What We Did: Revised Process Codes for Neurology

Process Unit Code	Process
K-ARR	Arrive from Home
D	Stroke Unit
E	Intensified Monitoring
I	Invasive Cardiology
M	Intensive Care Unit
N	Cardiac Care Unit
P	Emergency
Q	Neurology Ward
R	Radiology
T	Monitoring
U	Ultrasound Examination
K-DEP	Depart to Home

Keep patient arrivals from their homes (K-ARR) separate from patient departure to their homes (K-DEP)

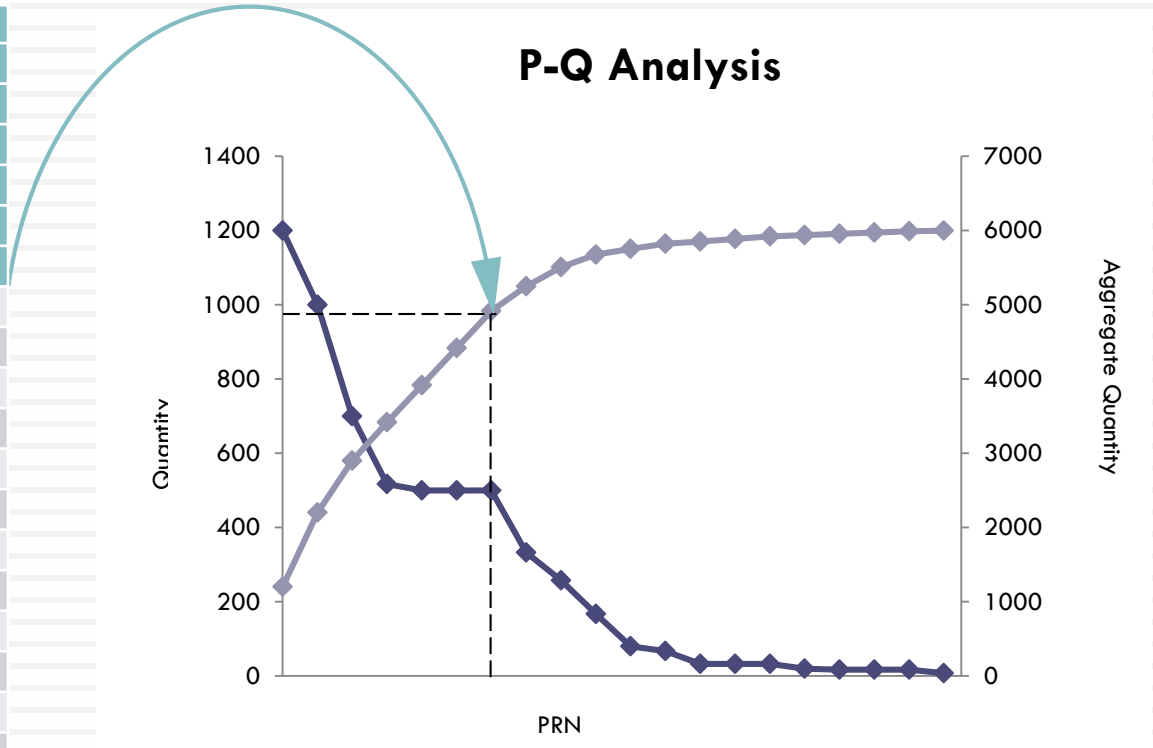
What We Did: P-Q Analysis

	PRN	QTY.
1	K-ARR->P->R->P->Q->K-DEP	1200
10	K-ARR->P->R->P->D->R->D->U->D->U->D->K-DEP	167
11	K-ARR->P->R->P->M->E->Q->K-DEP	80
12	K-ARR->P->R->P->D->R->D->U->D->I->D->Q->K-DEP	67
13	K-ARR->P->R->P->D->R->D->U->D->U->D->I->D->Q->K-DEP	33
14	K-ARR->P->R->P->D->R->D->Y->D->N->D->Q->K-DEP	33
15	K-ARR->P->R->P->D->R->D->U->D->E->D->Q->K-DEP	33
16	K-ARR->P->R->P->M->Q->K-DEP	20
17	K-ARR->P->R->P->D->R->D->U->D->U->D->N->D->Q->K-DEP	17
18	K-ARR->P->R->P->D->R->D->U->D->U->D->E->D->Q->K-DEP	17
19	K-ARR->P->R->P->D->R->D->U->D->M->D->Q->K-DEP	17
2	K-ARR->P->K-DEP	1000
20	K-ARR->P->R->P->D->R->D->U->D->U->D->M->D->Q->K-DEP	8
3	K-ARR->P->R->P->E->Q->K-DEP	700
4	K-ARR->P->R->P->D->R->D->U->D->Q->K-DEP	517
5	K-ARR->P->R->P->K-DEP	500
6	K-ARR->P->R->P->T->Q->K-DEP	500
7	K-ARR->P->R->P->D->R->D->U->D->Q->K-DEP	333
8	K-ARR->P->R->P->D->R->D->U->D->U->D->Q->K-DEP	258
9	K-ARR->P->T->K-DEP	500

	QTY.	AGG. QTY.	AGG. QTY. %	
1	1200	1200	20.0	High Volume PRN's
2	1000	2200	36.7	
3	700	2900	48.3	
4	517	3417	57.0	
5	500	3917	65.3	
6	500	4417	73.6	
9	500	4917	82.0	
7	333	5250	87.5	Low Volume PRN's
8	258	5508	91.8	
10	167	5675	94.6	
11	80	5755	95.9	
12	67	5822	97.0	
13	33	5855	97.6	
14	33	5888	98.1	
15	33	5921	98.7	
16	20	5941	99.0	
17	17	5958	99.3	
18	17	5975	99.6	
19	17	5992	99.9	
20	8	6000	100.0	

What We Did: P-Q Analysis (contd.)

PRN	QTY.	AGG. QTY.	AGG. QTY. %
1	1200	1200	20.0
2	1000	2200	36.7
3	700	2900	48.3
4	517	3417	57.0
5	500	3917	65.3
6	500	4417	73.6
9	500	4917	82.0
7	333	5250	87.5
8	258	5508	91.8
10	167	5675	94.6
11	80	5755	95.9
12	67	5822	97.0
13	33	5855	97.6
14	33	5888	98.1
15	33	5921	98.7
16	20	5941	99.0
17	17	5958	99.3
18	17	5975	99.6
19	17	5992	99.9
20	8	6000	100.0



In the Pareto sample of 7 PRN's, except for PRN #4, the remaining PRN's represent simple patient flow routes. Therefore, in order to treat patients whose routes correspond to the other 13 PRN's (which are more complex patient pathways), the same hospital layout will need to "flex" and operate as a quick-response jobshop to treat those patients ***equally*** efficiently and effectively. A Process Layout is simply not capable of being efficient and effective for both segments of the patient population arriving for treatment to Neurology!

What We Did: PR Analysis I/II

Problem?

ICU shared by 2 families of patient routes

Parts	Work Centers											
	E	K-ARR	P	K-DEP	R	Q	D	U	M	N	I	T
10		1	1	1	1		1	1				
12		1	1	1	1	1	1	1			1	
13		1	1	1	1	1	1	1			1	
14		1	1	1	1	1	1	1		1		
17		1	1	1	1	1	1	1		1		
19		1	1	1	1	1	1	1	1			
20		1	1	1	1	1	1	1	1			
4		1	1	1	1	1	1	1				
7		1	1	1	1	1	1	1				
8		1	1	1	1	1	1	1				
15	1	1	1	1	1	1	1	1				
18	1	1	1	1	1	1	1	1				
16		1	1	1	1	1			1			
11	1	1	1	1	1	1			1			
3	1	1	1	1	1	1						
1		1	1	1	1	1						
6		1	1	1	1	1						1
5		1	1	1	1							
2		1	1	1								
9		1	1	1								1

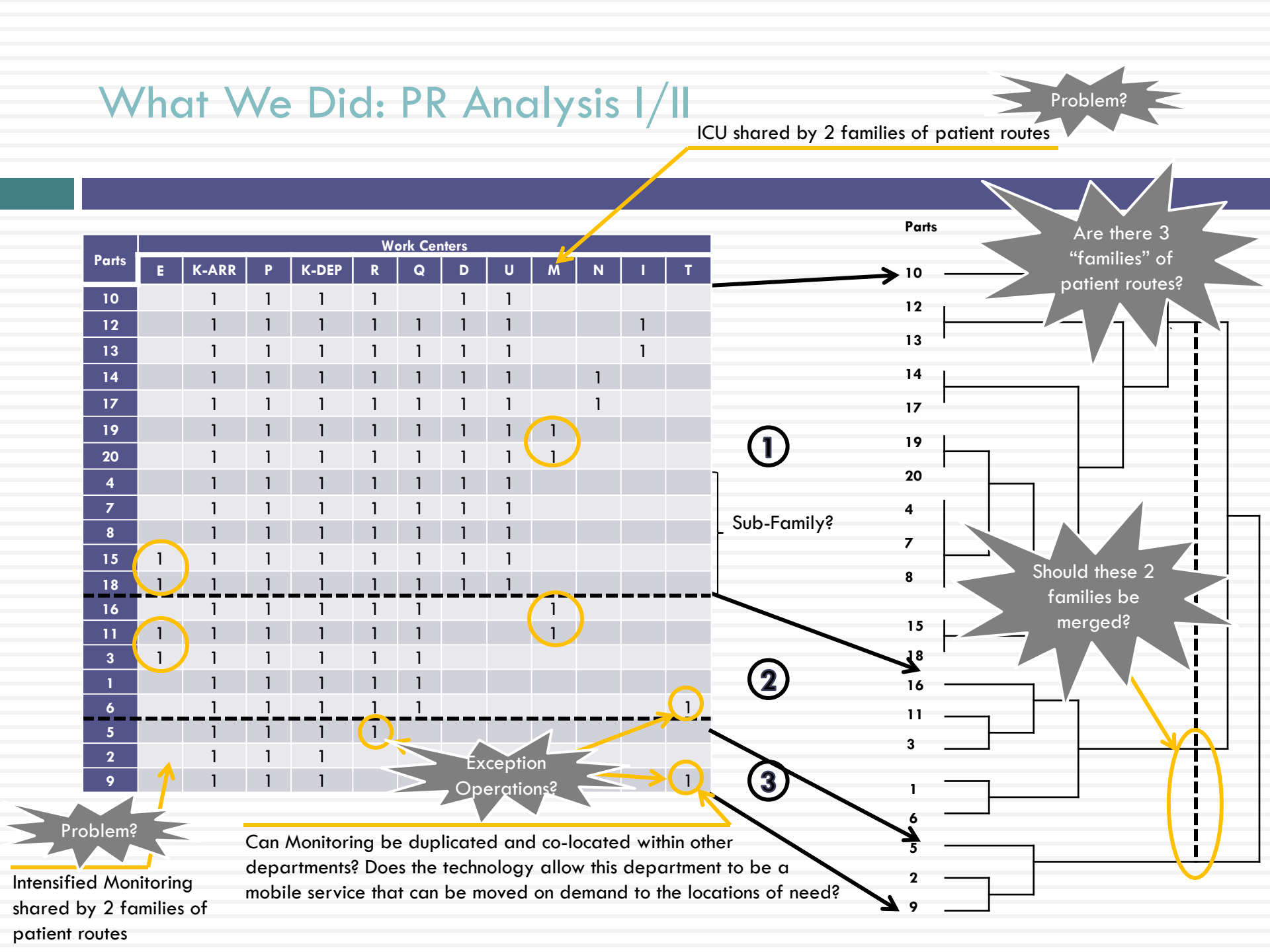
Sub-Family?

Exception Operations?

Problem?

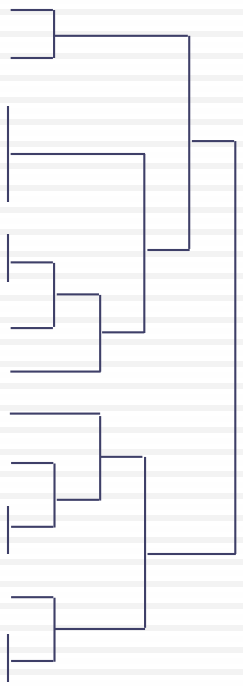
Intensified Monitoring shared by 2 families of patient routes

Can Monitoring be duplicated and co-located within other departments? Does the technology allow this department to be a mobile service that can be moved on demand to the locations of need?



What We Did: PR Analysis III

LENGTH	FREQUENCY	% QTY.	% REV.	SUBSTRING
2	2	16.67	10.00	P->T
2	2	25.00	10.00	P->K-DEP
5	2	1.67	10.00	K-ARR->P->R->P->M
4	18	75.00	90.00	K-ARR->P->R->P
2	20	100.00	100.00	K-ARR->P
11	2	14.17	10.00	K-ARR->P->R->P->D->R->D->U->D->Q->K-DEP
9	12	25.00	60.00	K-ARR->P->R->P->D->R->D->U->D
2	12	25.00	60.00	U->D
11	6	8.33	30.00	K-ARR->P->R->P->D->R->D->U->D->U->D
4	2	1.67	10.00	I->D->Q->K-DEP
4	2	0.83	10.00	N->D->Q->K-DEP
3	11	22.22	55.00	D->Q->K-DEP
4	2	0.42	10.00	M->D->Q->K-DEP
4	2	0.83	10.00	E->D->Q->K-DEP
2	16	63.88	80.00	Q->K-DEP
3	2	13.00	10.00	E->Q->K-DEP



What We Did: PR Analysis IV

(See PR Type I also) Is the Neurology Ward a monument? Else, since it is shared by 2 families of patient routes, could there be priority conflicts between patient clusters?

Problem?

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
10	K-ARR	P	R	P	D	R	D	U	D	U	D															Q	K-DEP
12	K-ARR	P	R	P	D	R	D			U	D	I	D													Q	K-DEP
13	K-ARR	P	R	P	D	R	D	U	D	U	D							I	D							Q	K-DEP
17	K-ARR	P	R	P	D	R	D	U	D	U	D									N	D					Q	K-DEP
18	K-ARR	P	R	P	D	R	D	U	D	U	D													E	D	Q	K-DEP
20	K-ARR	P	R	P	D	R	D	U	D	U	D											M	D			Q	K-DEP
8	K-ARR	P	R	P	D	R	D	U	D	U	D															Q	K-DEP
19	K-ARR	P	R	P	D	R	D			U	D											M	D			Q	K-DEP
15	K-ARR	P	R	P	D	R	D			U	D					E	D									Q	K-DEP
14	K-ARR	P	R	P	D	R	D			U	D			N	D											Q	K-DEP
4	K-ARR	P	R	P	D	R	D			U	D															Q	K-DEP
7	K-ARR	P	R	P	D	R	D			U	D															Q	K-DEP
16	K-ARR	P				R															P	M				Q	K-DEP
11	K-ARR	P				R															P	M		E		Q	K-DEP
3	K-ARR	P				R															P			E		Q	K-DEP
1	K-ARR	P				R															P					Q	K-DEP
6	K-ARR	P				R															P				T	Q	K-DEP
5	K-ARR	P				R															P						K-DEP
9	K-ARR	P																							T		K-DEP
2	K-ARR	P																									K-DEP

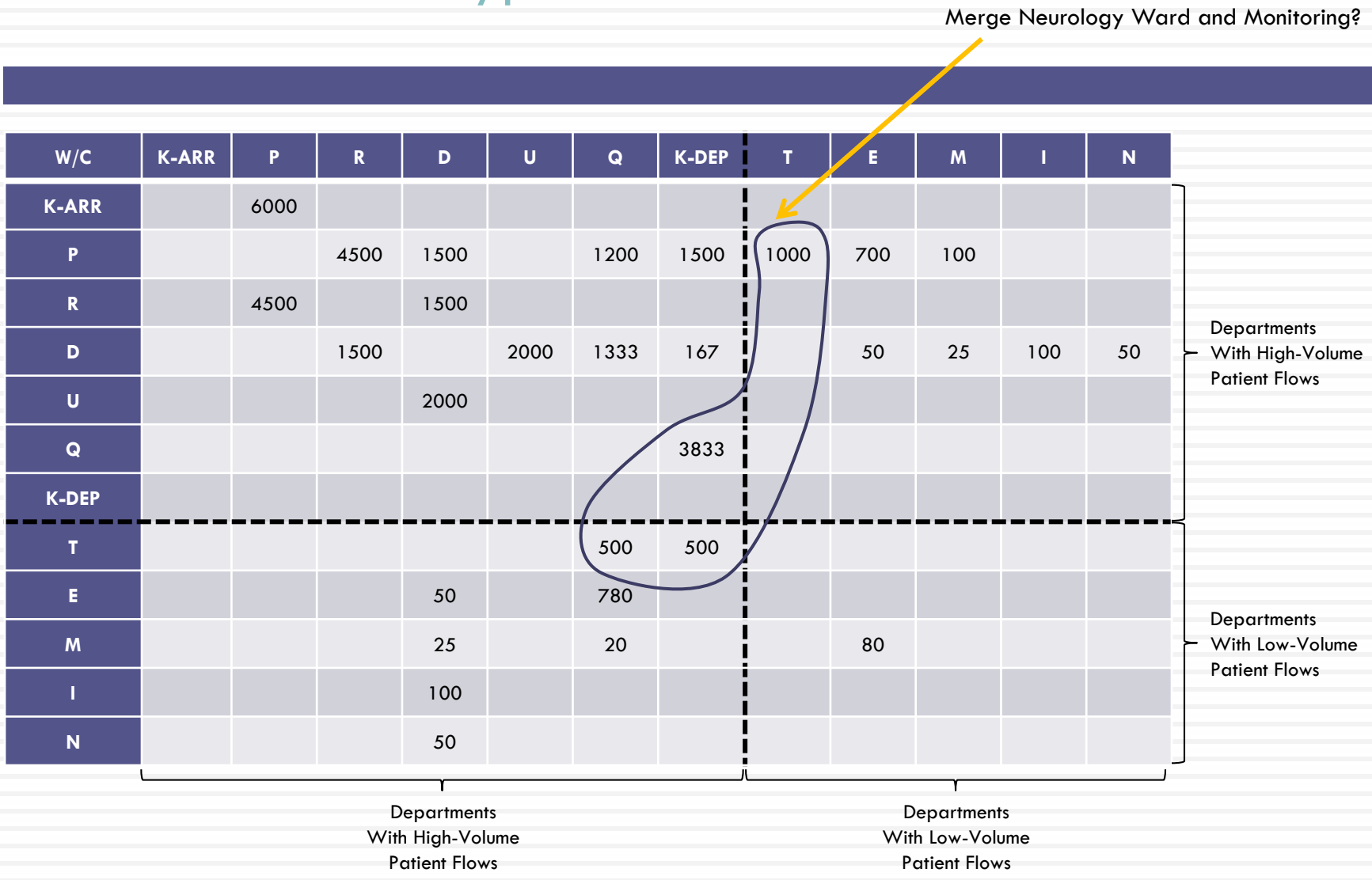
1 → Easier case of "pull scheduling" D → Q

2 → M, E, P, T → Q

3 → Much harder to "pull" schedule due to multiple supplying departments

(See the rows and columns for the Stroke Unit D in the Q-Type From-To Chart also) This department is unique to the Patient Family #1. But, the traffic from same departments to/form this department are high, whereas the traffic from/to the remaining departments is low. This "mixing" of patient flows will surely lead to setup-related problems.

What We Did: Q-Type From-To Chart

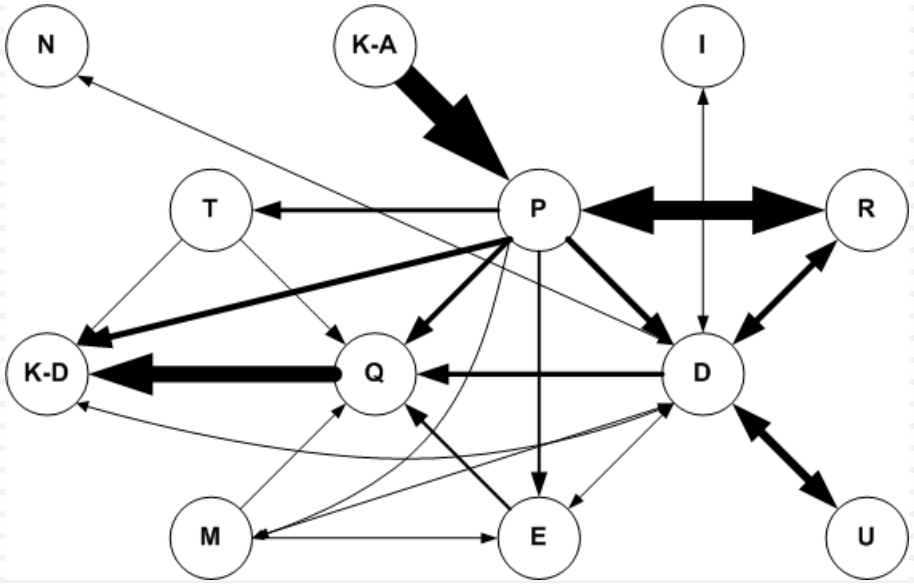


W/C	K-ARR	P	R	D	U	Q	K-DEP	T	E	M	I	N
K-ARR		6000										
P			4500	1500		1200	1500	1000	700	100		
R		4500		1500								
D			1500		2000	1333	167		50	25	100	50
U				2000								
Q							3833					
K-DEP												
T						500	500					
E				50		780						
M				25		20			80			
I				100								
N				50								

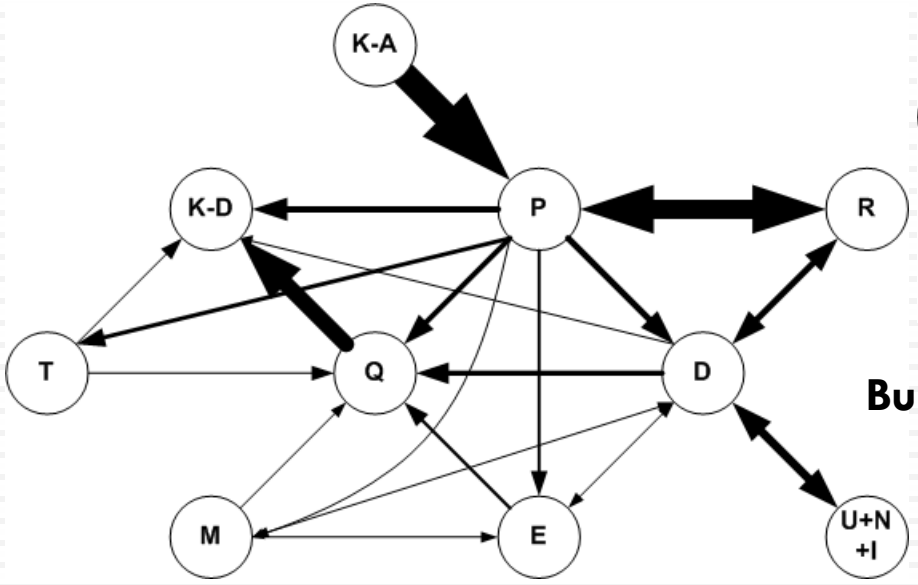
What We Did: Block Layout using STORM

	Col 1	Col 2	Col 3
Row 1	N	K-ARR	I
Row 2	T	P	R
Row 3	K-DEP	Q	D
Row 4	M	E	U

STORM Output

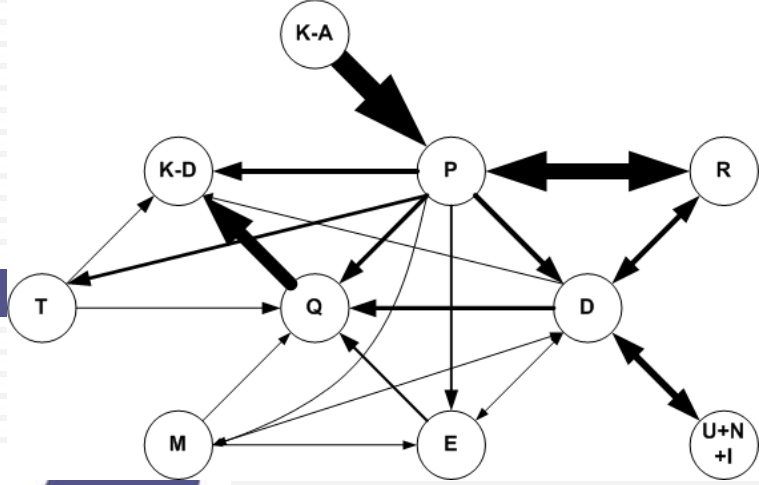


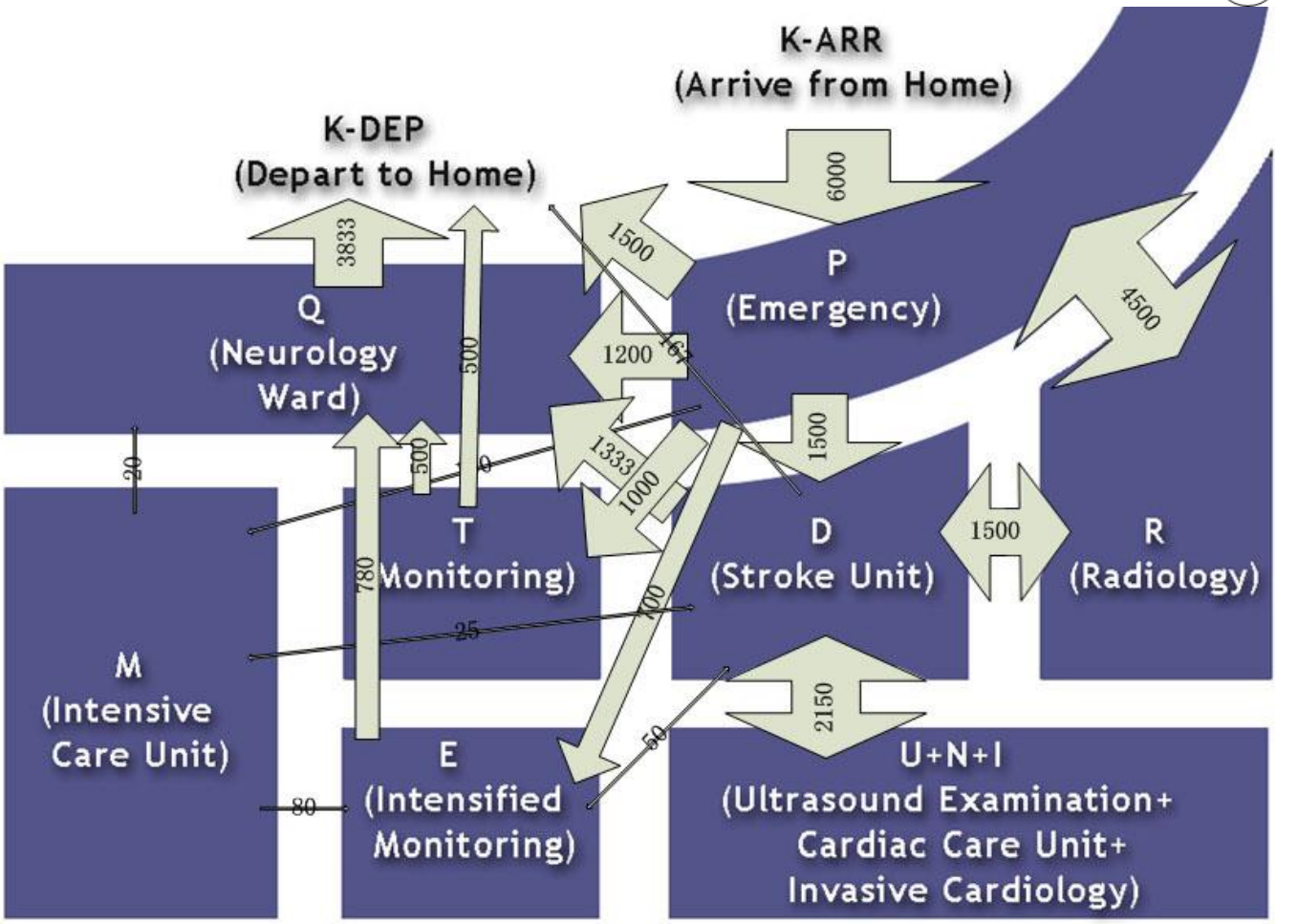
Bubble Diagram for Layout using STORM Output



Revised Bubble Diagram with "Real-World" Considerations

Layout Design





Conclusions

- The successful application of PFAST to design a new hospital suggests that some parts of a hospital operate like job shops and others operate like assembly lines.
- The possibility exists to determine the different patient care pathways (or routings) that a hospital is capable of supporting, and measuring the efficiency and quality of the healthcare services provided for each pathway.
- The use of manual methods, such as Spaghetti Diagrams, for hospital layout design should be complemented by a comprehensive computer-aided analysis of patient flows using Production Flow Analysis.

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