

## Conceptual Model: Service Networks = Queueing Networks

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- People, waiting for service: teller, repairman, ATM
- Telephone-calls, to be answered: busy, music, info.
- Forms, to be sent, processed, printed; for a partner
- Projects, to be developed, approved, implemented
- Justice, to be made: pre-trial, hearing, retrial
- Ships, for a pilot, berth, unloading crew
- Patients, for an ambulance, emergency room, operation
- Cars, in rush hour, for parking
- Checks, waiting to be processed, cashed
- Queues      Scarce Resources, Synchronization Gaps  
Costly, but here to stay
  - Face-to-face Nets (Chat) (min.)
  - Tele-to-tele Nets (Telephone) (sec.)
  - Administrative Nets (Letter-to-Letter) (days)
  - Fax, e.mail (hours)
  - Face-to-ATM, Tele-to-IVR
  - Mixed Networks (Contact Centers)

From Robert **Kaplan** (Accounting) and Michael **Porter** (Strategy),  
HBR, September 2011

**Question** (Title): “**How to Solve the Cost Crisis in Health Care**”

**Answer:** Does not require medical science breakthroughs or new governmental regulation. It simply requires a new way (**TDABC** = Time-Driven Activity-Based Costing) to accurately measure costs and compare them to outcomes.

**Indeed, accurately measuring costs and outcomes is the single most powerful lever we have today for transforming the economics of healthcare.**

**A TDABC budgeting process starts by predicting the volume and types of patients the provider expects.**

**The new approach engages physicians, clinical teams, administrative staff and financial professionals in creating **process maps** and **estimating the resource costs** involved in treating patients over their care cycle.**

Introduction:

Goal of Health care delivery system: Improve the **value** delivered to patients.

Value = measured in terms of **outcome** achieved per dollar expended (**cost**).

**Medical outcome:** has enjoyed growing attention.

**Cost** to deliver outcomes: received much less attention - the **FOCUS** here.

Opportunities to Improve Value:

- **Eliminate** unnecessary **process variations** and processes that don't add value.
- **Improve resource capacity utilization.**
- Deliver the right processes at the right location.
- Match clinical skills to the process.
- **Speed up cycle time.**
- **Optimize** over the full cycle of care.

### The Challenge of Health Care Costing:

- Health care today is a **highly customized job shop**
- Any accurate costing system must, at a fundamental level, account for the **total costs of all the resources used** by a patient as she or he traverses the system. That means **tracking the sequence of and duration of clinical and administrative processes used by individual patients – something the most hospital information systems today are unable to do.** (In the future: RFID etc.)
- With **good estimates of the typical path an individual patient takes** for a medical condition, providers can use the **Time-Driven Activity-Base Costing** (TDABC) to assign costs accurately and relatively easily to each process step along the path.
- Requires that **providers estimate only two parameters at each process step: the cost of each resource used in the process and the quantity of time the patient spends with each resource.**

### The Cost Measurement Process:

- Select the medical condition
- Define the care delivery value chain (CDVC), which charts the principal activities involved in a patient's care for a medical condition along with their location.
- **Develop process maps** of each activity in patient care delivery.
- **Obtain time estimates** for each process.
- Estimate the cost of supplying patient care resources.
- Estimate the capacity of each resource and calculate the capacity cost rate.
- Calculate the total cost of patient care.

**Reinventing Reimbursement:** Abandon the current complex fee-for-service payment schedule. Instead, payors should introduce value-based reimbursement, such as bundled payment, that covers the full care cycle and included care for complications and comorbidities (=several diseases).

From “**Managing Business Process Flows**”, by

Anupindi, Chopra, Deshmukh, Van Mieghem, Zemel (Kellogg, Northwestern)

- Job-shops typically display jumbled work flows with large amounts of storage and substantial waiting between activities.
- Thus, it is more practical to represent a jobshop with a **Network of Resources**, instead of **Network of Activities**.

On **Financial Measures**: Though the ultimate judge of process performance, financial measures are inherently lagging, aggregate, and more results oriented than action oriented. They also are reported infrequently.

The operations manager, however, needs **Operational Measures** – more detailed and more frequent measures that can be controlled and that ultimately have an impact on financial measures.

Ideally, companies want operational measures to be leading indicators of financial performance. The three types of financial measures (absolute performance, performance relative to asset utilization, cash-flow) would then mirror operational measures and provide daily support to process management.

**Uncharted Territory**: Information Technology (e.g. RFID), Statistics, Operations Research/Management plus Professionals (Physicians, Marketing,...) can jointly “close the gap” between financial and operational measures.

### Research Questions:

- Operational Models at the “**right**” **level of resolution** (individual transaction)
- **Imputed** / **Surrogate** for Costs (Profits) or Quality, inferred from the more easily observable operational measures.
  - o Tardiness costs via newsvendor
  - o Clinical quality via return-to-hospitalization
  - o Waiting costs from Constraint Satisfaction (e.g. 20-80 rule in call centers)
  - o Waiting/Abandonment costs? (There is literature on the “Cost of Waiting”)

# PATIENT FLOW IN HOSPITALS: A DATA-BASED QUEUEING-SCIENCE PERSPECTIVE

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Patient flow in hospitals can be naturally modeled as a queueing network, where patients are the customers, and medical staff, beds and equipment are the servers. But are there special features of such a network that sets it apart from prevalent models of queueing networks? To address this question, we use Exploratory Data Analysis (EDA) to study detailed patient flow data from a large Israeli hospital.

EDA reveals interesting and significant phenomena, which are not readily explained by available queueing models, and which raise questions such as: What queueing model best describes the distribution of the number of patients in the Emergency Department (ED); and how do such models accommodate existing throughput degradation during peak congestion? What time resolutions and operational regimes are relevant for modeling patient length of stay in the Internal Wards (IWs)? While routing patients from the ED to the IWs, how to control delays in concert with fair workload allocation among the wards? Which leads one to ask how to measure this workload: Is it proportional to bed occupancy levels? How is it related to patient turnover rates?

Our research addresses such questions and explores their operational and scientific significance. Moreover, the above questions mostly address medical units unilaterally, but EDA underscores the need for and benefit from a comparative-integrative view: for example, comparing IWs to the Maternity and Oncology wards, or relating ED bottlenecks to IW physician protocols. All this gives rise to additional questions that offer opportunities for further research, in Queueing Theory, its applications and beyond.

90 X 90 Matrix, Sub-Ward Resolution

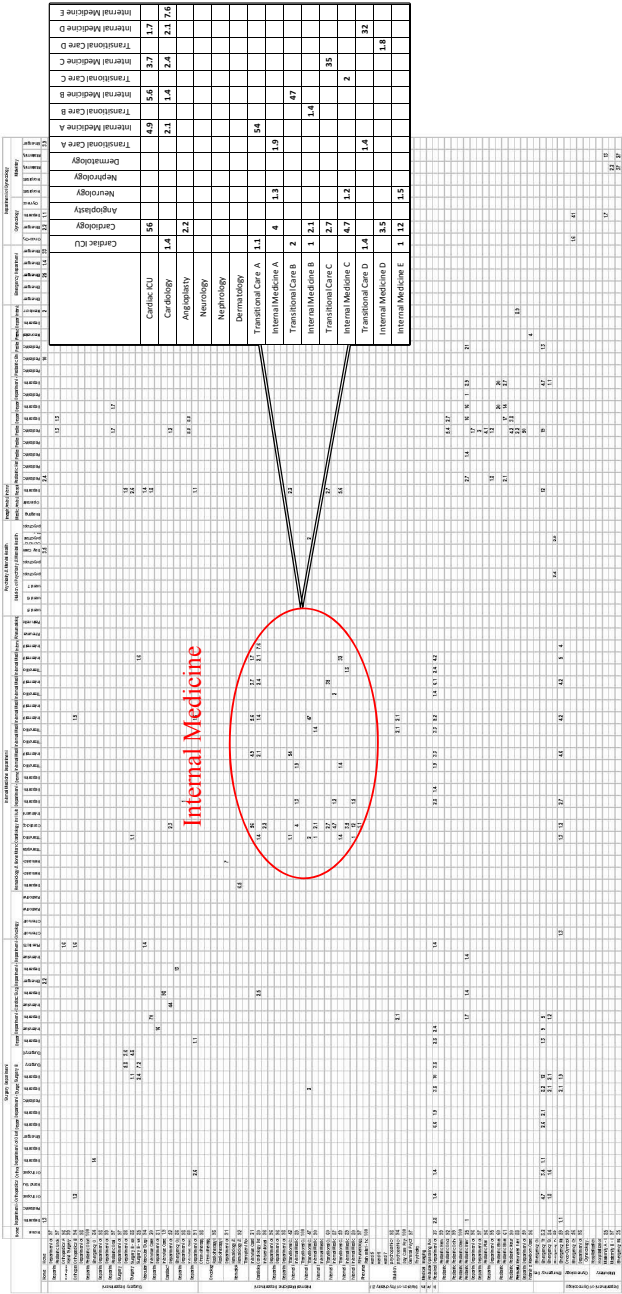


FIG 2. Transition probabilities between hospital wards, at the resolution of sub-wards. For example, during the period over which the matrix was calculated (January 4th, 2005 to June 31st, 2005), 47% of the patients in the Transitional Care Unit of IW A were transferred to IW A itself. plausibly after their condition improved enough for the transfer.

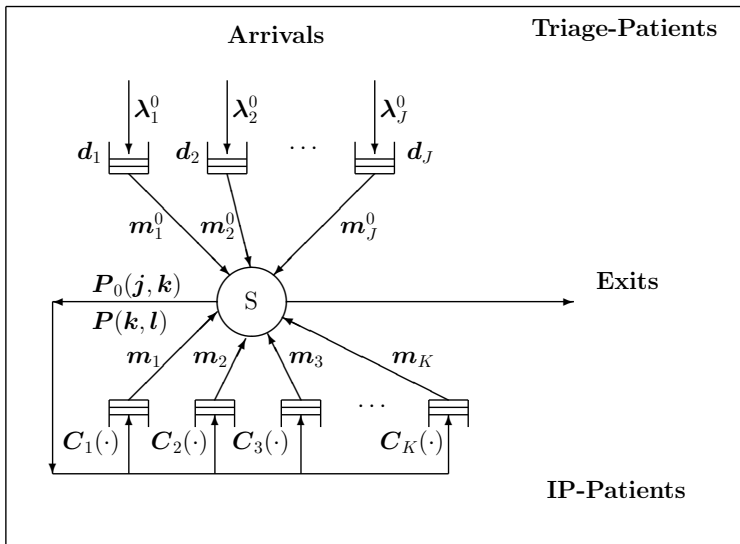


FIG 15. An ED modeled as a multiclass **queueing network** with feedback and priorities

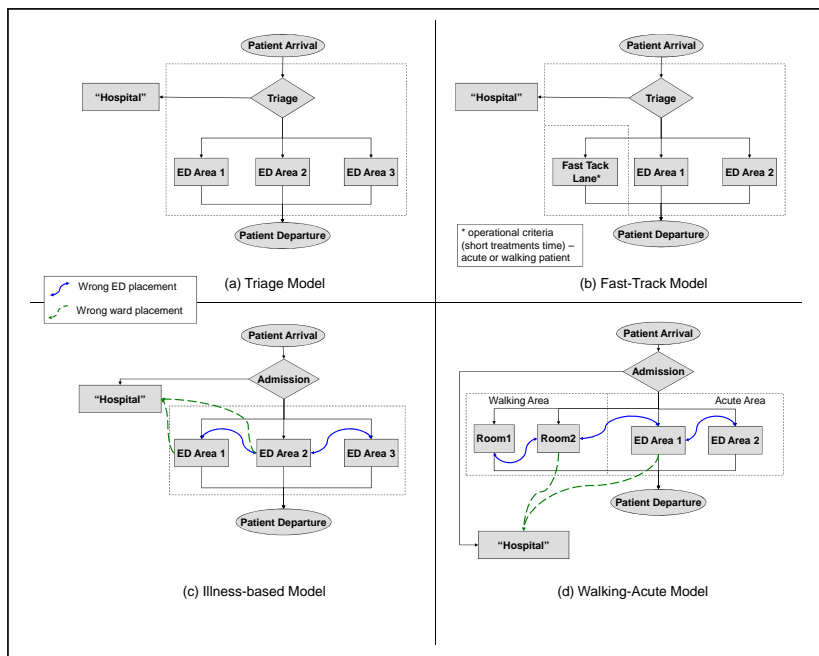


FIG 16. **Emergency Department design** of prevalent operational models

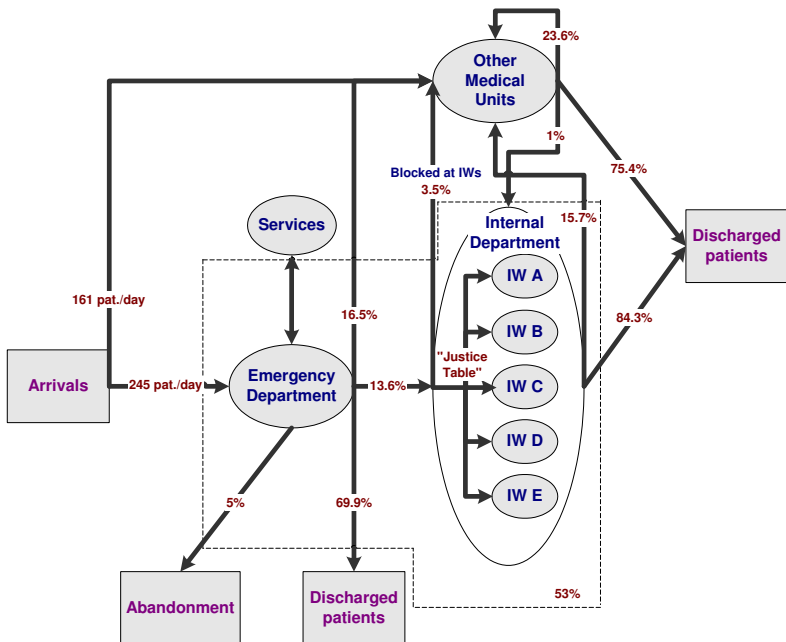


FIG 1. The **ED+IW** system as a queueing network



# **DataMOCCA**

## **DATA MOdel for Call Center Analysis**

### **Volume 5.1**

### **Skills-Based- Routing in US Bank**

Mr Pablo Liberman  
Dr Valery Trofimov  
Professor Avishai Mandelbaum

Created: February 2008

## **Skills Groups Definitions**

### **Grouping**

Several factors influence the characterization of an agent's skills-set. Here we explain, via examples, the factors that we have been using.

When there are several types of calls served by an agent, one must decide if these types characterize a skill or, alternatively, they are random assignments due perhaps to random circumstances. (For example, an unforeseen increase in load that enforces unqualified agents to serve calls beyond their skill-set.)

Our grouping decisions are based on the different services types which the agents take, the percentage of the agent calls from each service type, the percentage of the service type calls that flows to each agent group, the agent skills characteristics over the different months and the number of agent with the same skills characteristics.

### **Grouping Examples, the May 2001 Case**

On May 2001, 1851 agents worked in the call center within 17 different skills-groups.

The largest group in May 2001 is Group 1, consisting of 575 agents. This group consists of all the agents that take mainly Retail service. In Table 2 we see that this group serves 36.26% of the Retail calls, and a very small percentage of others services. This small percentage is negligible because the number of calls is small and the number of agents is large, so it does not influence agents performance. (In Table 1 we see that this fraction is 0.01% of the agents calls). Still, the question arises whether these call types should affect the characterization of these agents' skills-set. To this end, we observe that, in later months, none of such call-types were served by these agents. Hence, we deduce that the service-types in question are not elements of these agents-skills-set.

There are 252 agents who serve mainly Retail group that form Group 2. The difference between this group and Group 1 is that the Group 2 agents take a small number of Premier, Business and Telesales calls, but in these cases we identify predictable patterns of those calls routing (in most of them, we see a small number of these service types calls to each agent on each month of the successive months).

The smallest group is Group 38, which is formed by only one agent. This one agent is very important because he or she serves 15.24% of the Subanco calls, and there are no others agents in the call center with the same skills characteristic.

### **Main Service**

Our Main Service decision is based on only two important parameters: the percentage of the agent calls from each service type and the percentage of the service type calls in each agent group.

### **Examples of Main Services, the May 2001 Case**

Group 12 is grouping 58 agents, who take 7.24% of the Retail calls; these 7.24% of the Retail calls represent 93.44% of those agents work, therefore the main service of this group is Retail service.

Group 31 is grouping 43 agents; 84.15% of their calls are Business calls and 15.62% are Platinum calls but, on the other hand, this group takes 39.5% of the Business calls and 95.51% of the Platinum calls. This is the reason that the main service of this group is Platinum calls.

**Table 1** (Groups work description): group code, total number of agents, main service, total number of calls and the percentage of the agent calls from each service type.

Group Code	Total # Agents	Main Services	Retail	Premier	Business	Platinum	Customer Loans	Online Banking	EBO	Telesales	Subanco	Summit	Total # Calls
1	575	Retail (1)	99.97	0.01	0	0	0.01	0	0	0	0	0	254075
2	252	Retail (1)	97.38	0.3	1.67	0	0	0.06	0	0.59	0	0	205875
4	17	Retail (1)	69.06	19.62	5.79	0	0	0	0	5.53	0	0	6387
6	94	Retail (1)	98.62	0.25	0.9	0	0	0.01	0	0	0.22	0	86529
9	44	Retail (1)	96.53	0.19	0	0.15	0.01	3.12	0	0	0	0	36369
10	78	EBO (7)	66.99	0.35	0.62	0	0	0	31.93	0.11	0	0	55452
12	58	Retail (1)	93.99	0.17	1.26	0	0	0	0	4.58	0	0	53943
15	43	Retail (1)	98.73	0.14	0.12	0	0	0.01	0	0	1	0	24996
19	89	Premier (2)	0.68	99.29	0	0.03	0	0	0	0	0	0	40681
29	64	Business (3)	0.58	0	98.89	0.47	0	0.02	0	0.02	0.02	0	37705
31	43	Platinum (4)	0.23	0	84.15	15.62	0	0	0	0	0	0	33493
33	83	Customer Loans (5)	7.35	0	0	0	92.65	0	0	0	0	0	67803
34	6	Subanco (9)	0.02	0	0	0	68.67	0	0	0	31.31	0	5273
35	178	Online Banking (6)	8.67	0.23	0	0	0	91.1	0	0	0	0	35404
36	129	Telesales (8)	0	0	0	0	0	0	0	100	0	0	74765
38	1	Subanco (9)	0	0	38.15	0	0	0.16	0	0	61.69	0	616
45	97	Summit (14)	0	0	0	0	0	0	0	0	0	100	111948

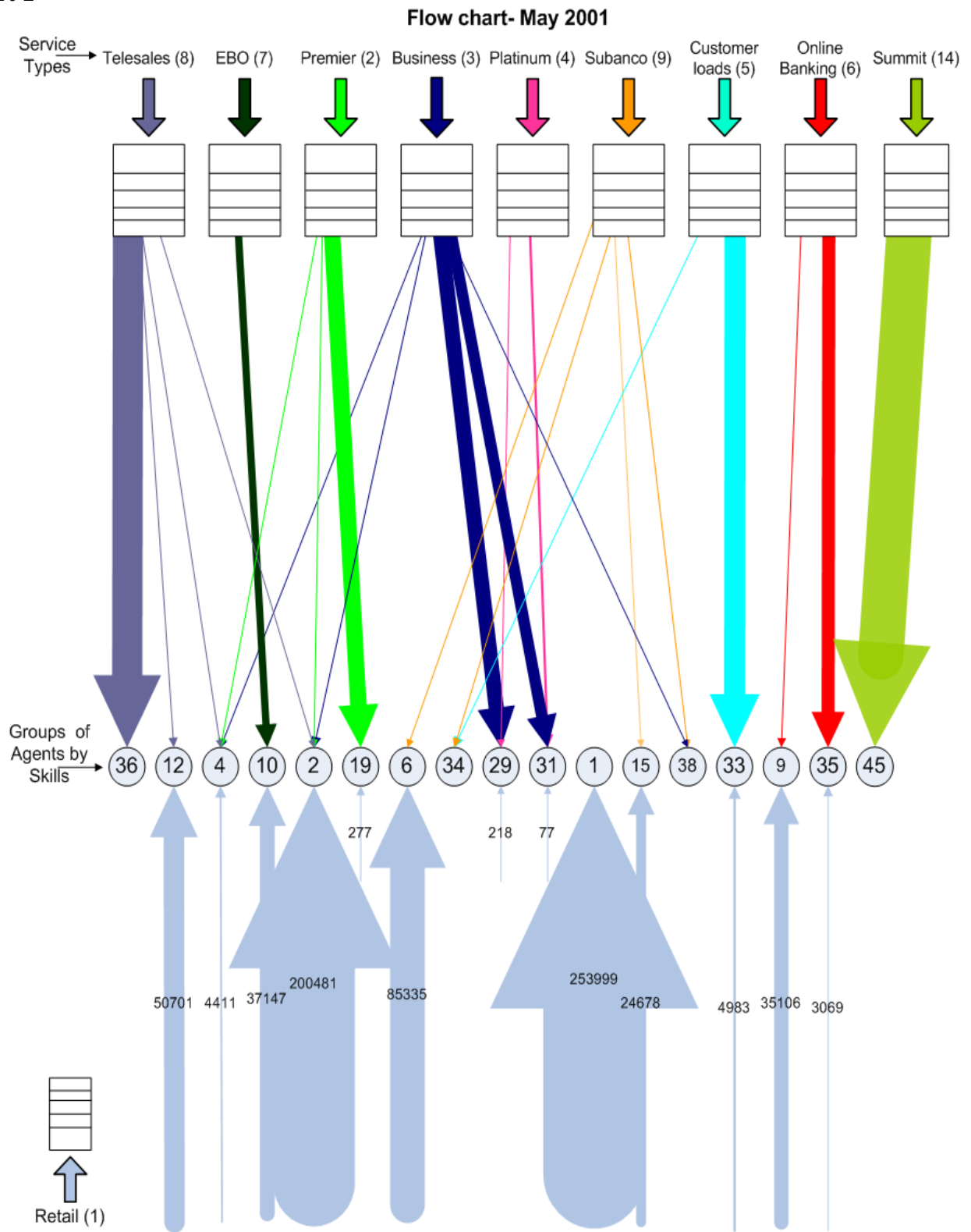
Note: Each row sums up 100%.

**Table 2** (Calls flow description): main service, group code, total number of agents, the percentage of the service type calls that flows to each agent group, and the number of calls arriving from each service.

Main services	Group Code	Total # Agents	Retail	Premier	Business	Platinum	Customer Loads	Online Banking	EBO	Telesales	Subanco	Summit
Retail (1)	1	575	36.26	0.07	0.01	0.02	0.03	0.01	0	0	0.16	0
Retail (1)	2	252	28.62	1.43	4.81	0	0.01	0.38	0.01	1.55	0.32	0
Retail (1)	4	17	0.63	2.92	0.52	0	0	0	0	0.45	0	0
Retail (1)	6	94	12.18	0.5	1.09	0	0	0.02	0	0	7.78	0
Retail (1)	9	44	5.01	0.16	0	0.99	0	3.39	0	0	0	0
EBO (7)	10	78	5.3	0.45	0.48	0.04	0	0	99.99	0.08	0	0
Retail (1)	12	58	7.24	0.21	0.96	0	0	0	0	3.13	0	0
Retail (1)	15	43	3.52	0.08	0.04	0	0	0.01	0	0	9.98	0
Premier (2)	19	89	0.04	93.99	0	0.22	0	0	0	0	0	0
Business (3)	29	64	0.03	0	52.26	3.23	0	0.02	0	0.01	0.28	0
Platinum (4)	31	43	0.01	0	39.5	95.51	0	0	0	0	0	0
Customer Loans (5)	33	83	0.71	0	0	0	94.51	0	0	0	0	0
Subanco (9)	34	6	0	0	0	0	5.45	0	0	0	66.2	0
Online Banking (6)	35	178	0.44	0.19	0	0	0	96.18	0	0	0.04	0
Telesales (8)	36	129	0	0	0	0	0	0	0	94.79	0	0
Subanco (9)	38	1	0	0	0.33	0	0	0	0	0	15.24	0
Summit (14)	45	97	0	0	0	0	0	0	0	0	0	100
Total # Calls			700703	43282	72149	35068	71742	36810	55458	78874	7965	111948

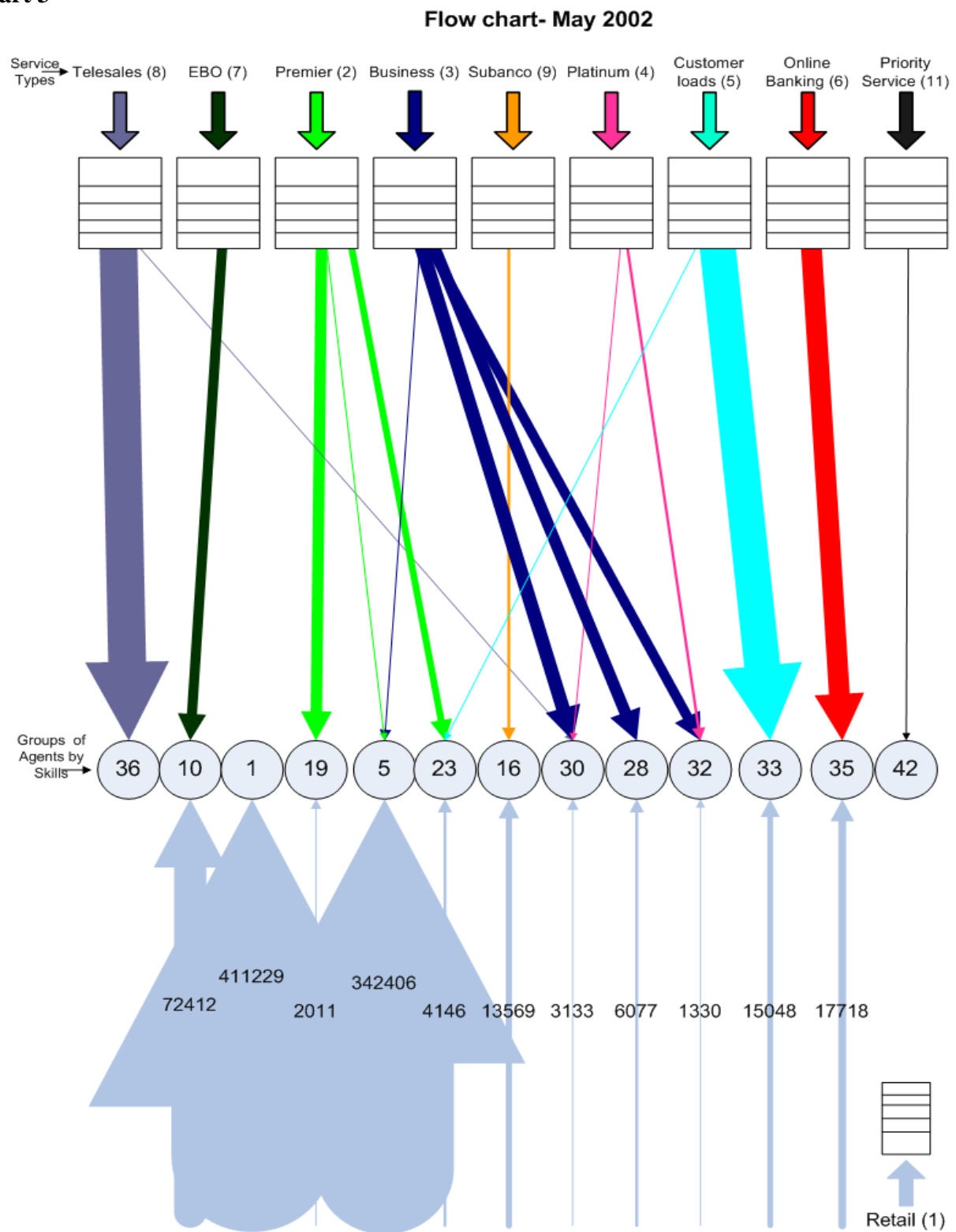
Note: Each column sums up 100%.

Chart 1



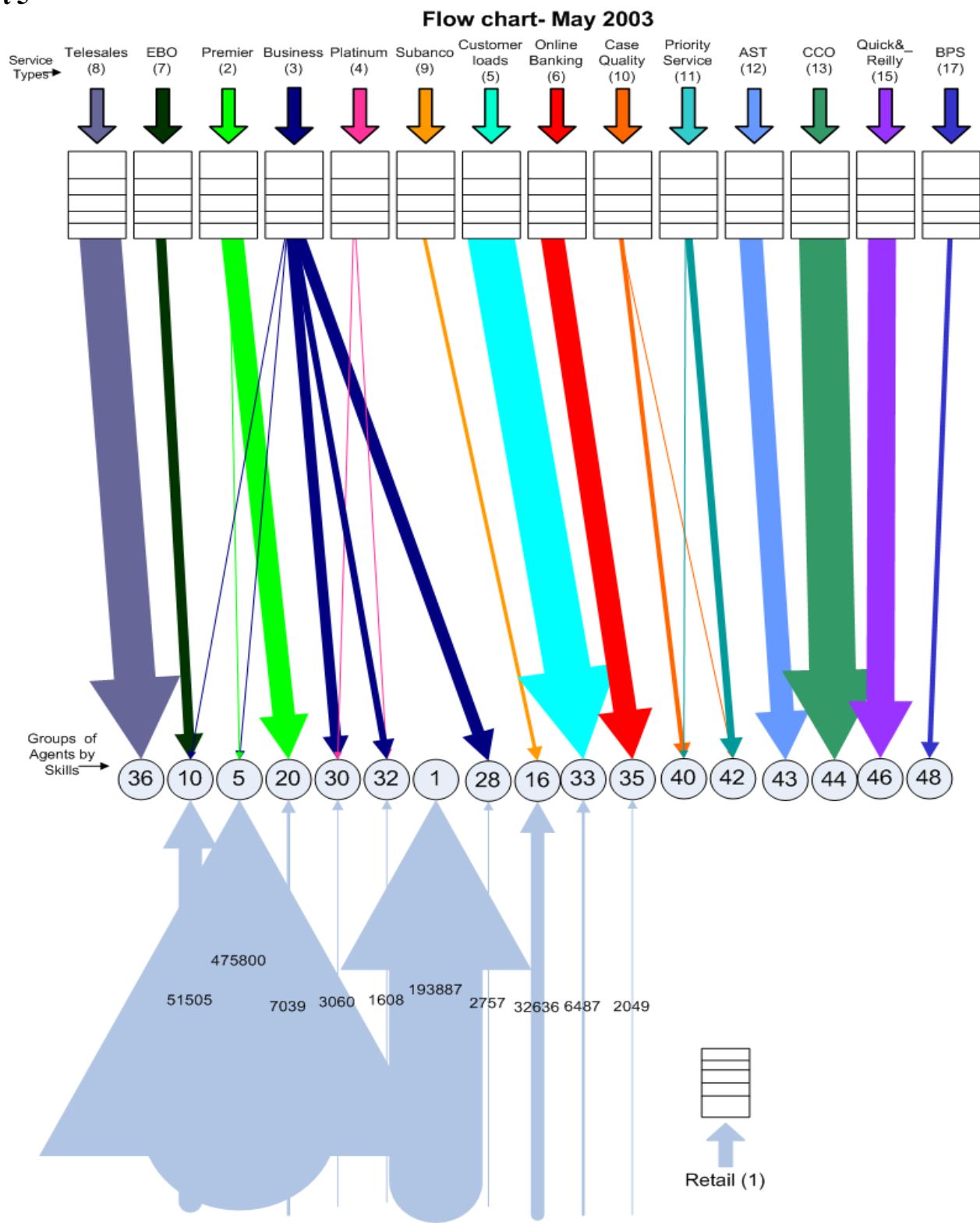
**Note:** The width of the arrows is proportional to the number of calls for all the arrows that represent more than 5000 calls. The width of all the arrows that represent less than 5000 calls is equal.

**Chart 3**



**Note:** The width of the arrows is proportional to the number of calls for all the arrows that represent more than 5000 calls. The width of all the arrows that represent less than 5000 calls is equal.

Chart 5



**Note:** The width of the arrows is proportional to the number of calls for all the arrows that represent more than 5000 calls. The width of all the arrows that represent less than 5000 calls is equal.

## Recitation 4, Part 1: Processing Networks. An Emergency Department Example

The tutorial objective is to teach how to model a queueing network as a “Fork-Join network”.

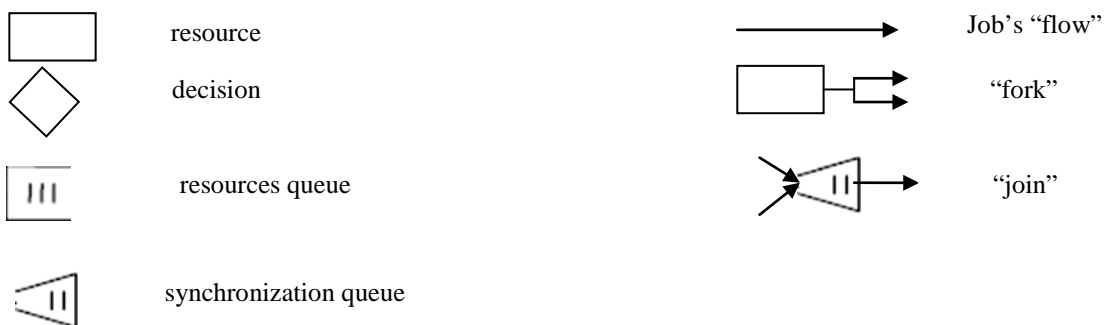
### Fork-Join Networks

A fork-join network consists of a group of service stations, which serve arriving customers simultaneously and sequentially according to pre-designed deterministic precedence constraints. More specially, one can think in terms of "jobs" arriving to the system over time, with each job consisting of various tasks that are to be executed according to some preceding constraints. The job is completed only after all its tasks have been completed. The distinguishing features of this model class are the so-called "fork" and "join" constructs. A "fork" occurs whenever several tasks are being processed simultaneously. In the network model, this is represented by a "splitting" of a task into multiple tasks, which are then sent simultaneously to their respective servers. A "join" node, on the other hand, corresponds to a task that may not be initiated until several prerequisite tasks have been completed. Components are joined only if they correspond to the same job; thus a join is always preceded by a fork. If the last stage of an operation consists of multiple tasks, then these tasks regroup (join) into a single task before departing the system.

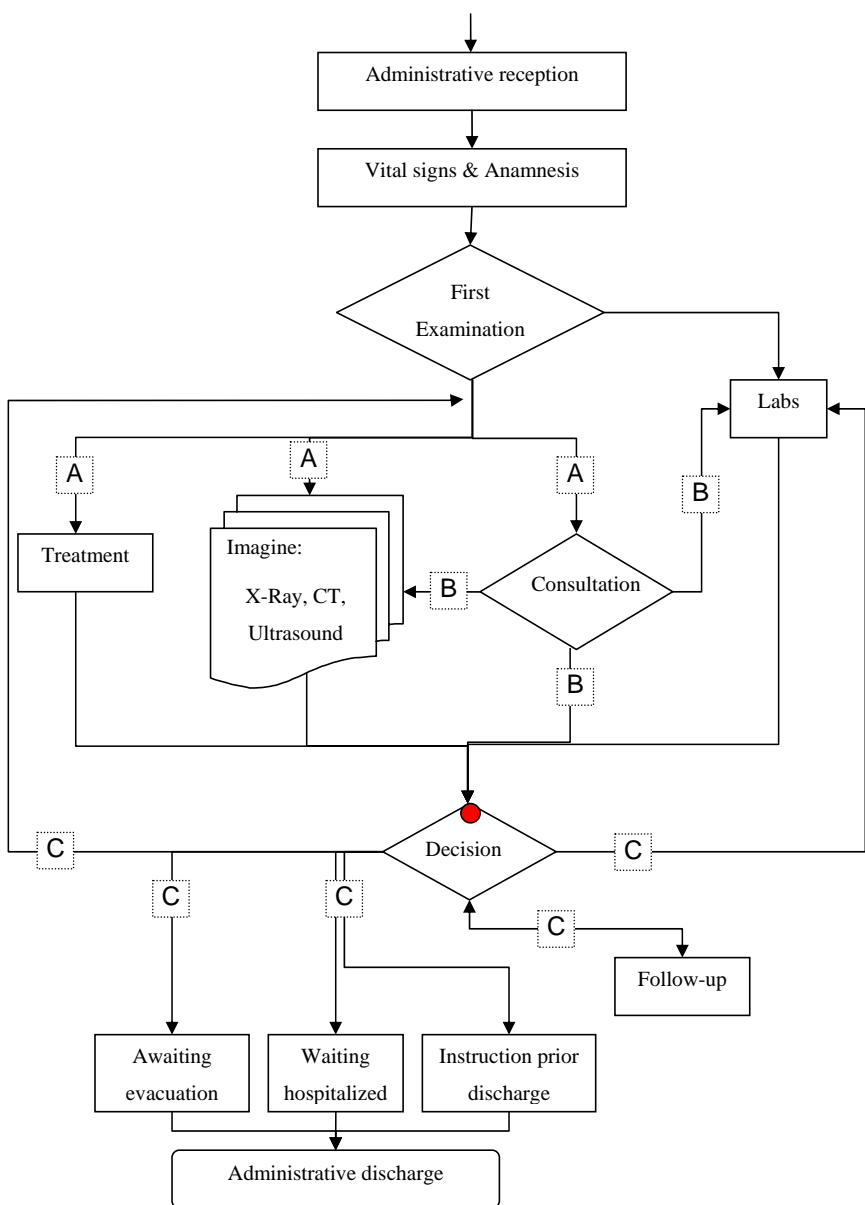
### Modeling

We model our “fork-join network” using 4 specific flow-charts: activities, resources, activities plus resources, and information. To draw these 4 flow charts one must list all resources of the network and all activities as well, and then write which activity is using which resource. Next, one draws the flow charts, using the following “language”:

### Flow-Chart Legend



Often times, reality is too complex to capture with the above “language”. Then one must be creative, hence introduce, ad hoc, the notation that will tell one’s specific story. (As an example, see page 2 where the “red-dot” is such a special notation)

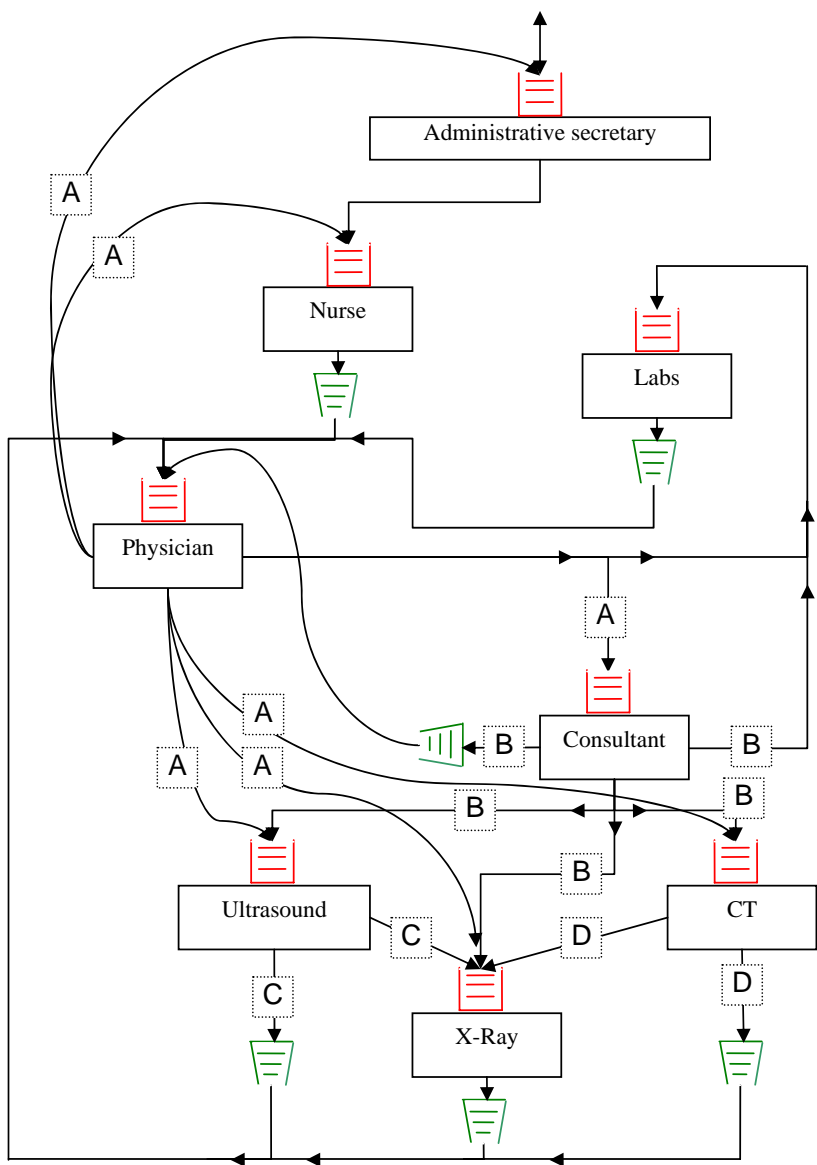


Alternative Operation - C

Ending point of alternative operation - ●

Figure 67: Activities flow chart in the ED





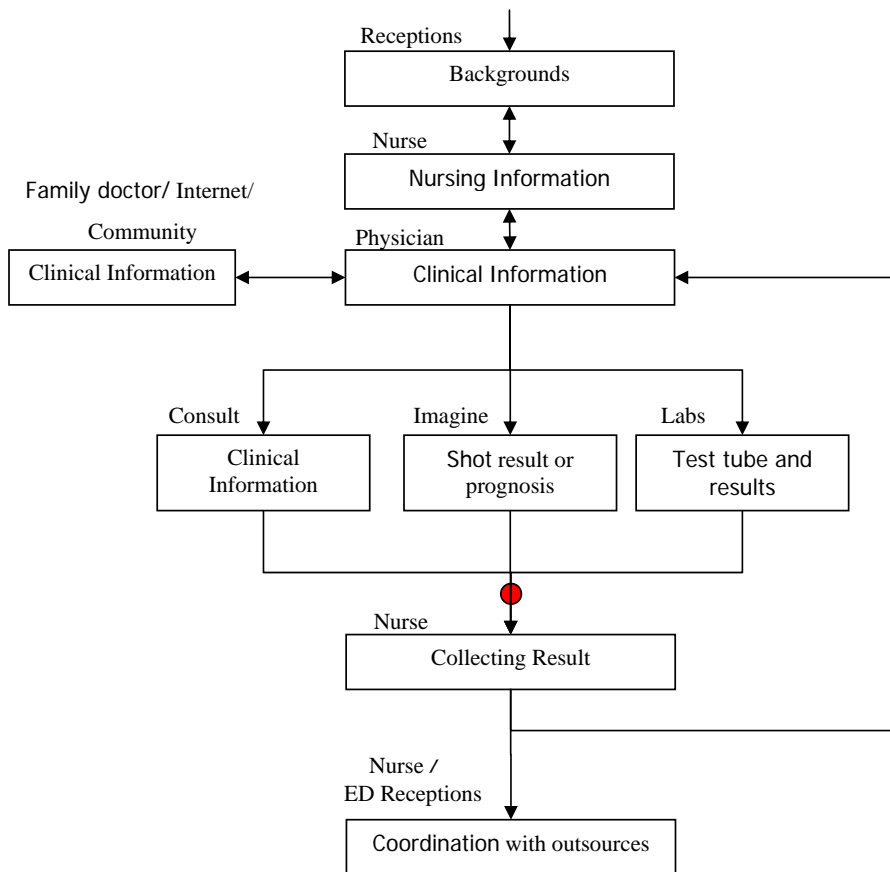
Alternative Operation - [A]

Recourse Queue - [Red Queue Icon] Synchronization Queue - [Green Queue Icon]

Ending point of alternative operation - [Red Circle]

Figure 66: Resources flow chart in the ED



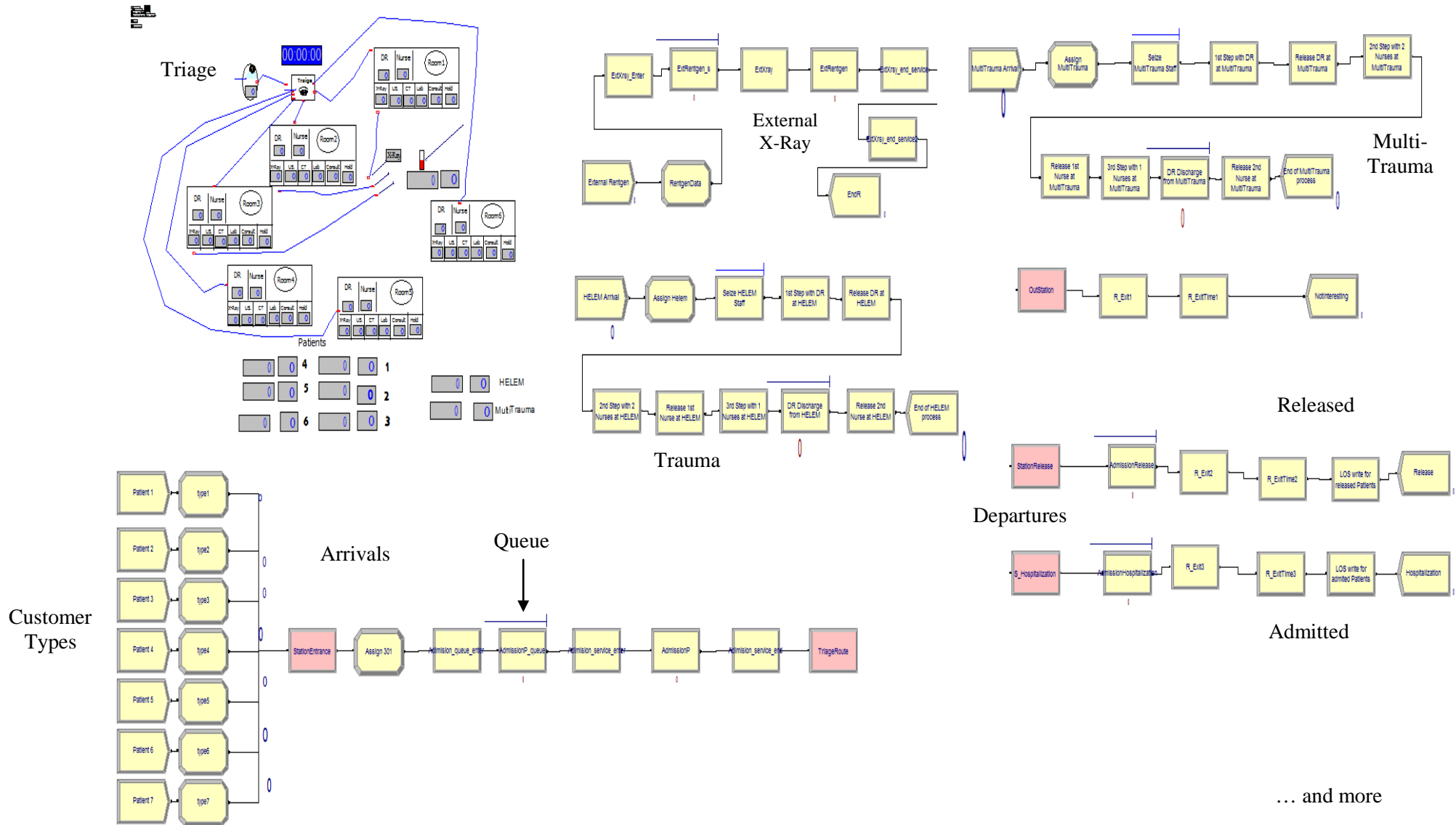


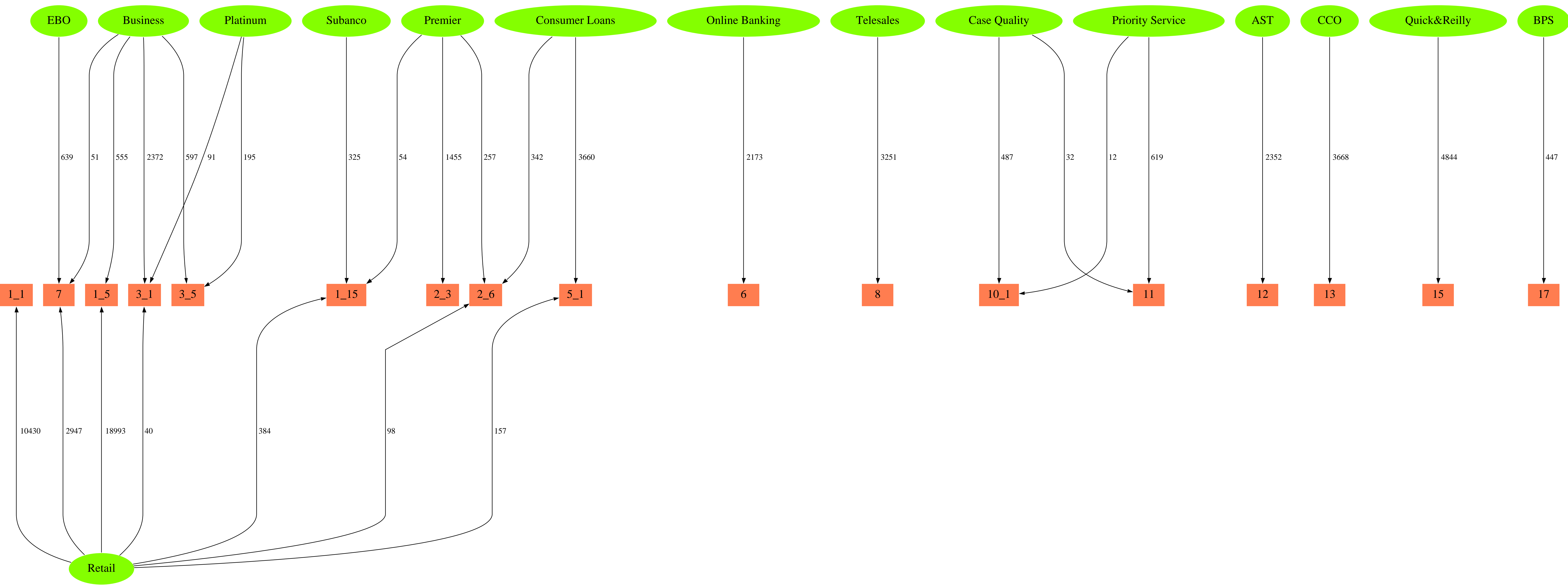
Ending point of alternative operation - ●

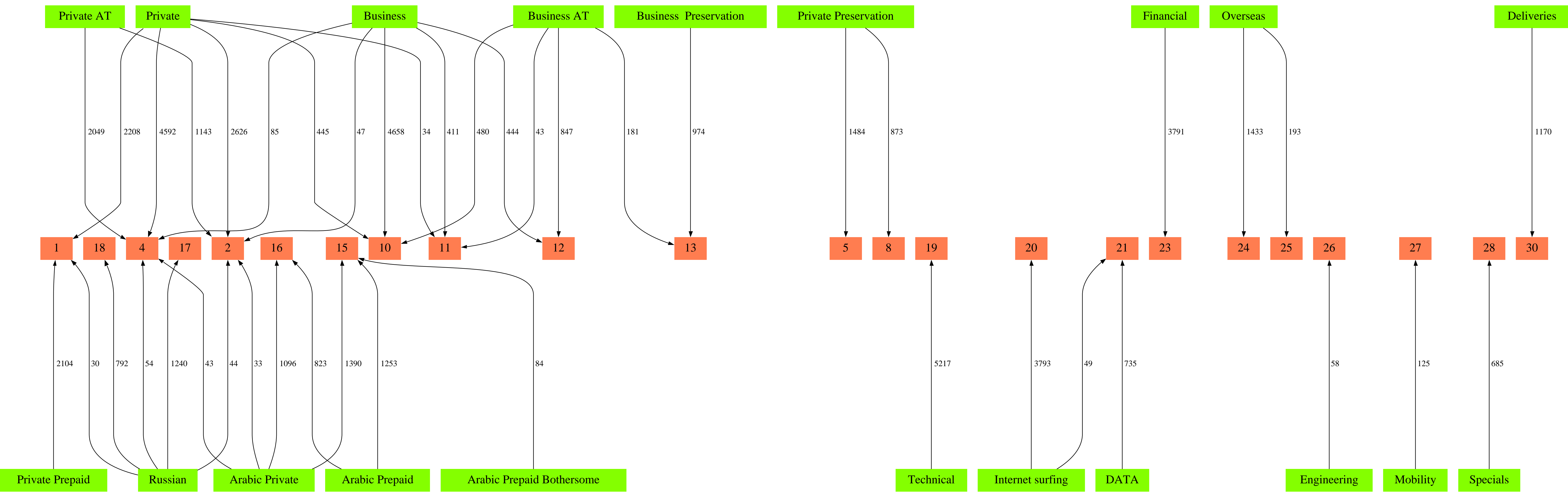
Figure 68: Information flow chart in the ED

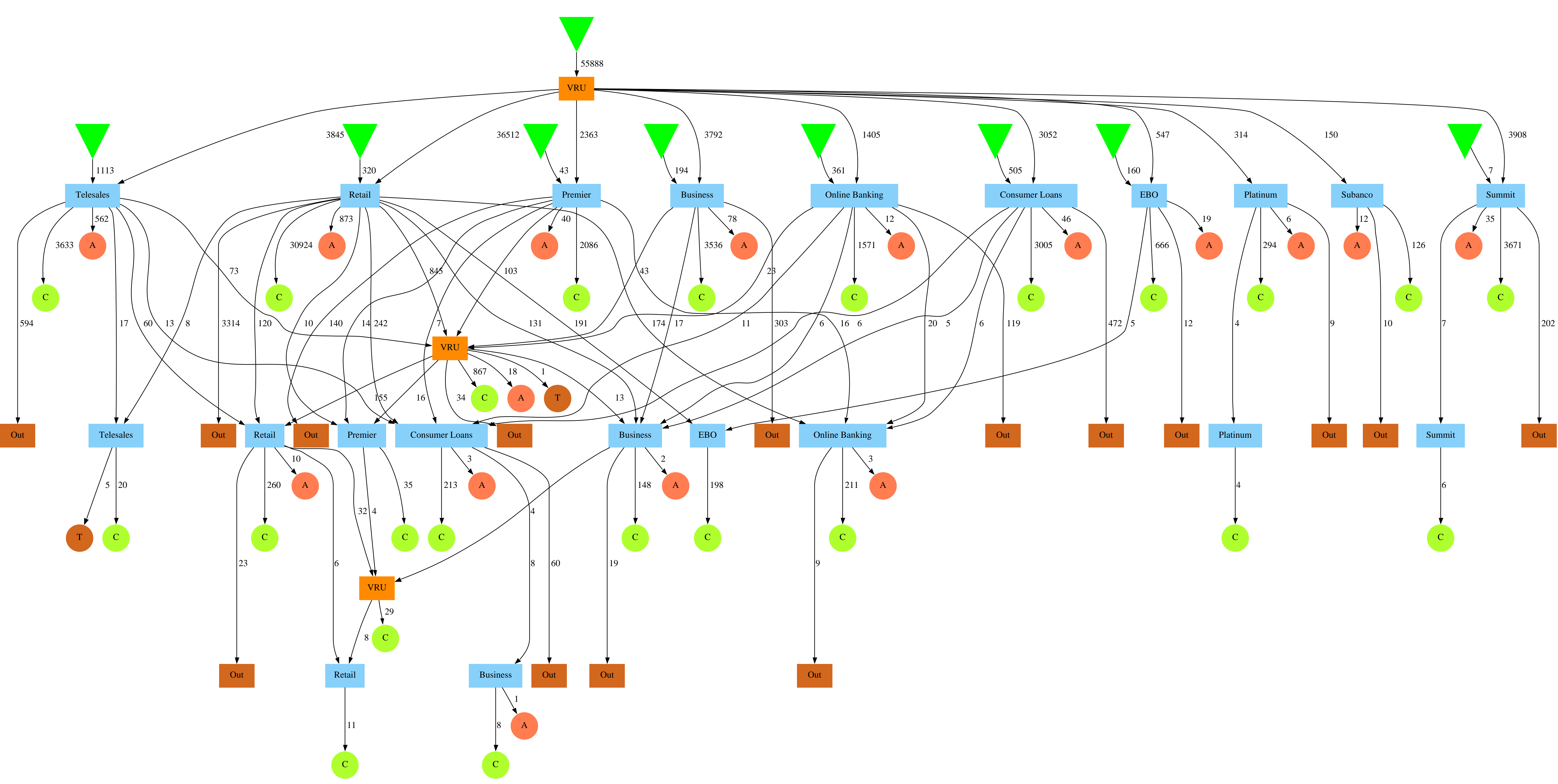
## Part 3: Applications and Results

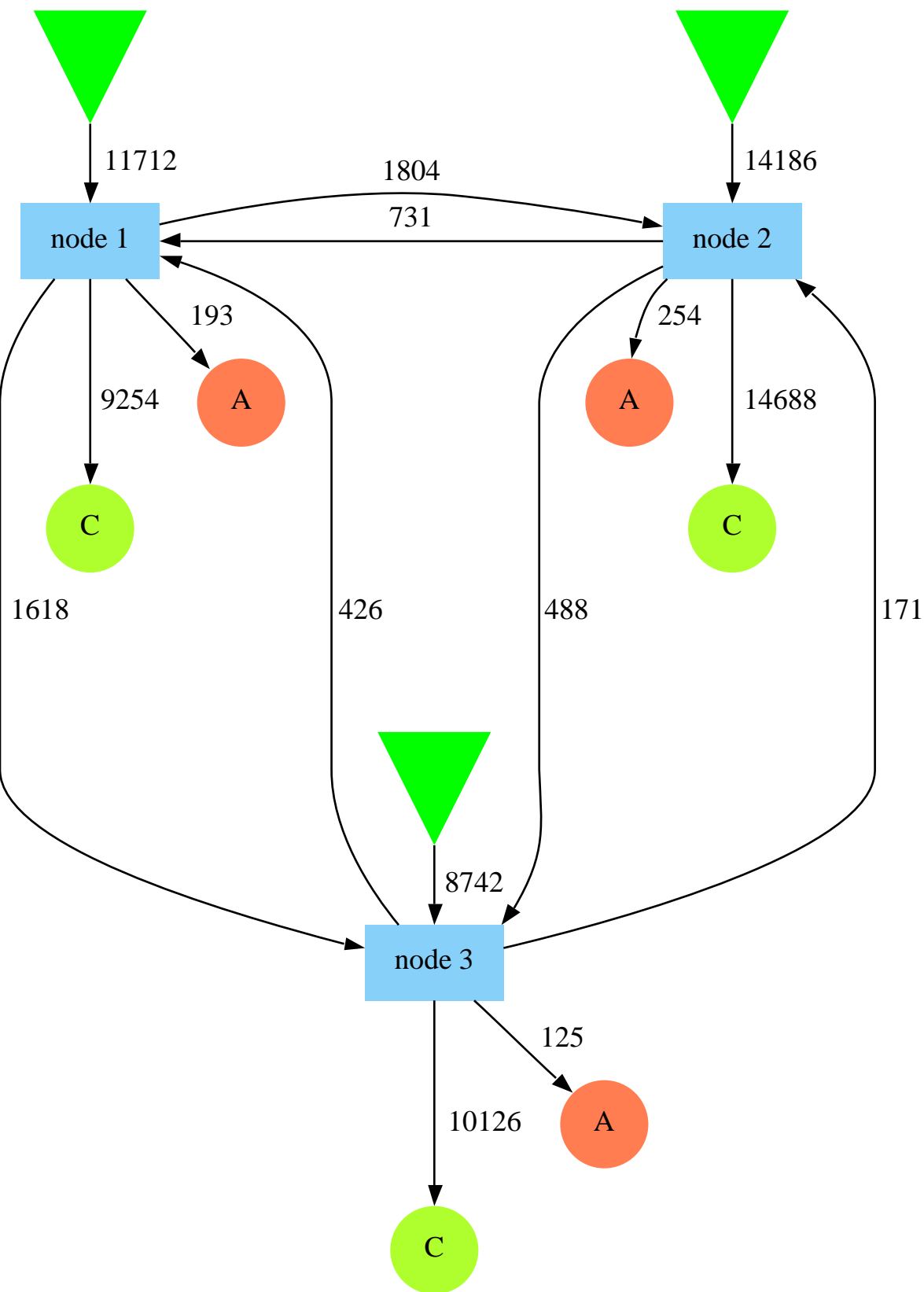
The data is taken from an ED simulator written in Arena12.



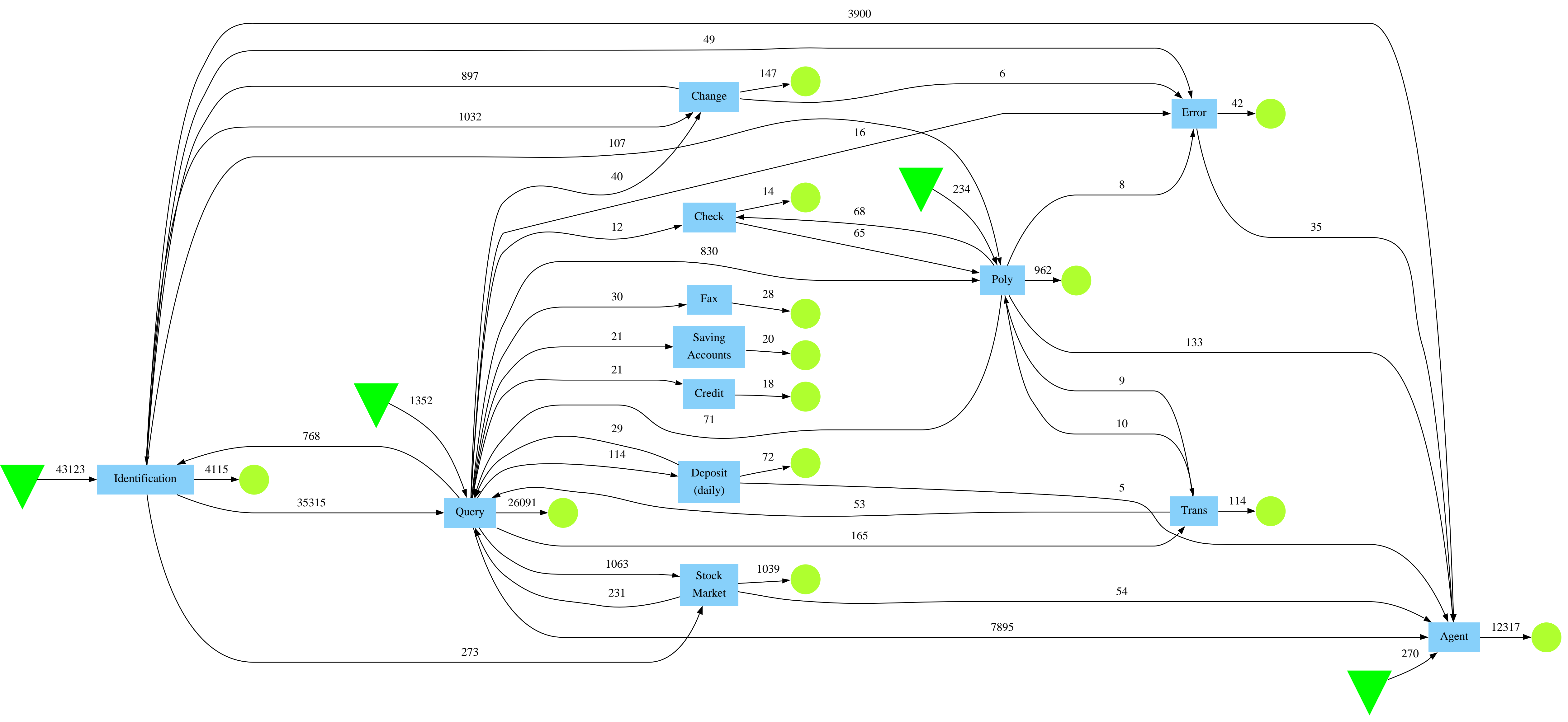




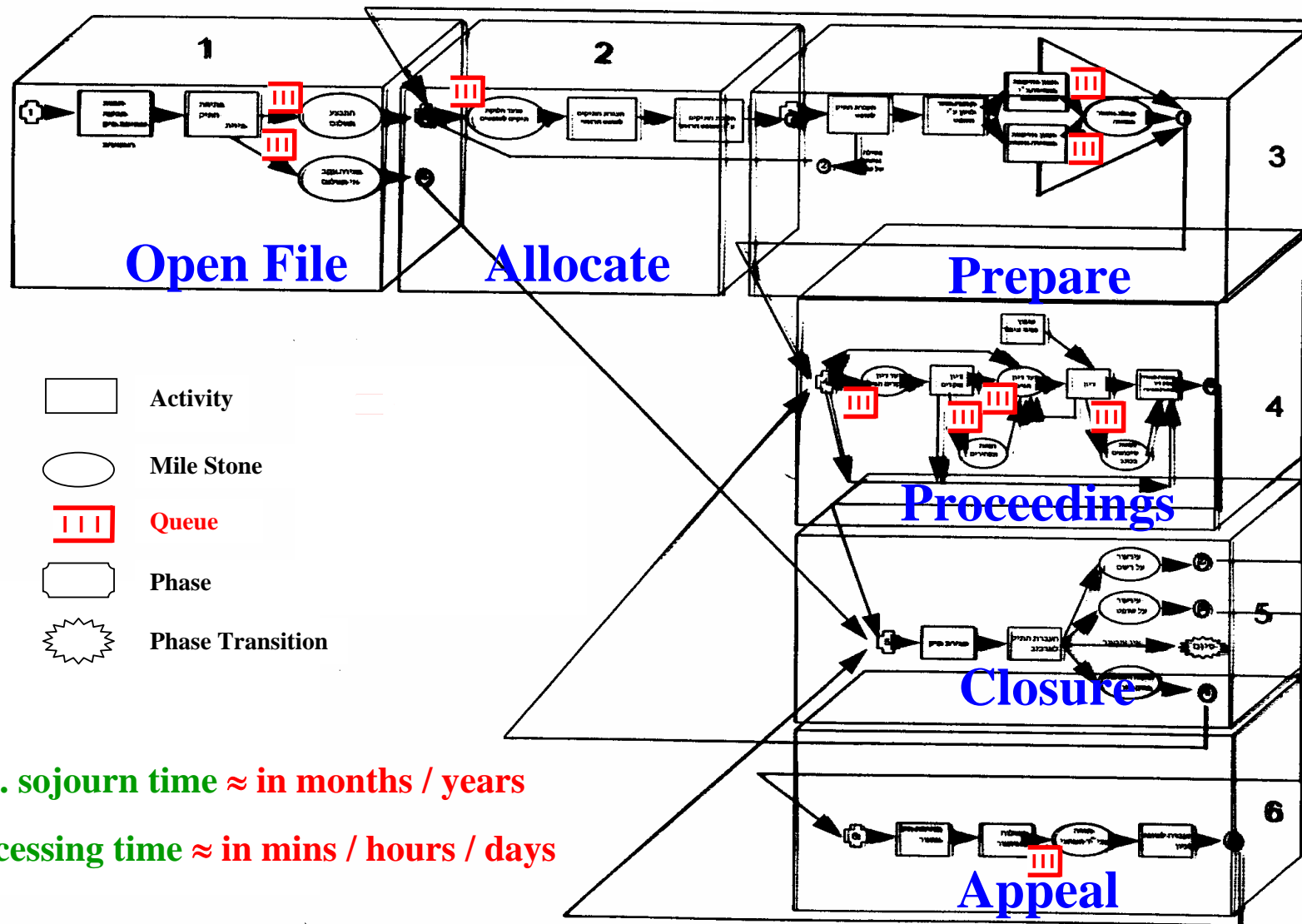








# Conceptual Model: The Justice Network, or The Production of Justice



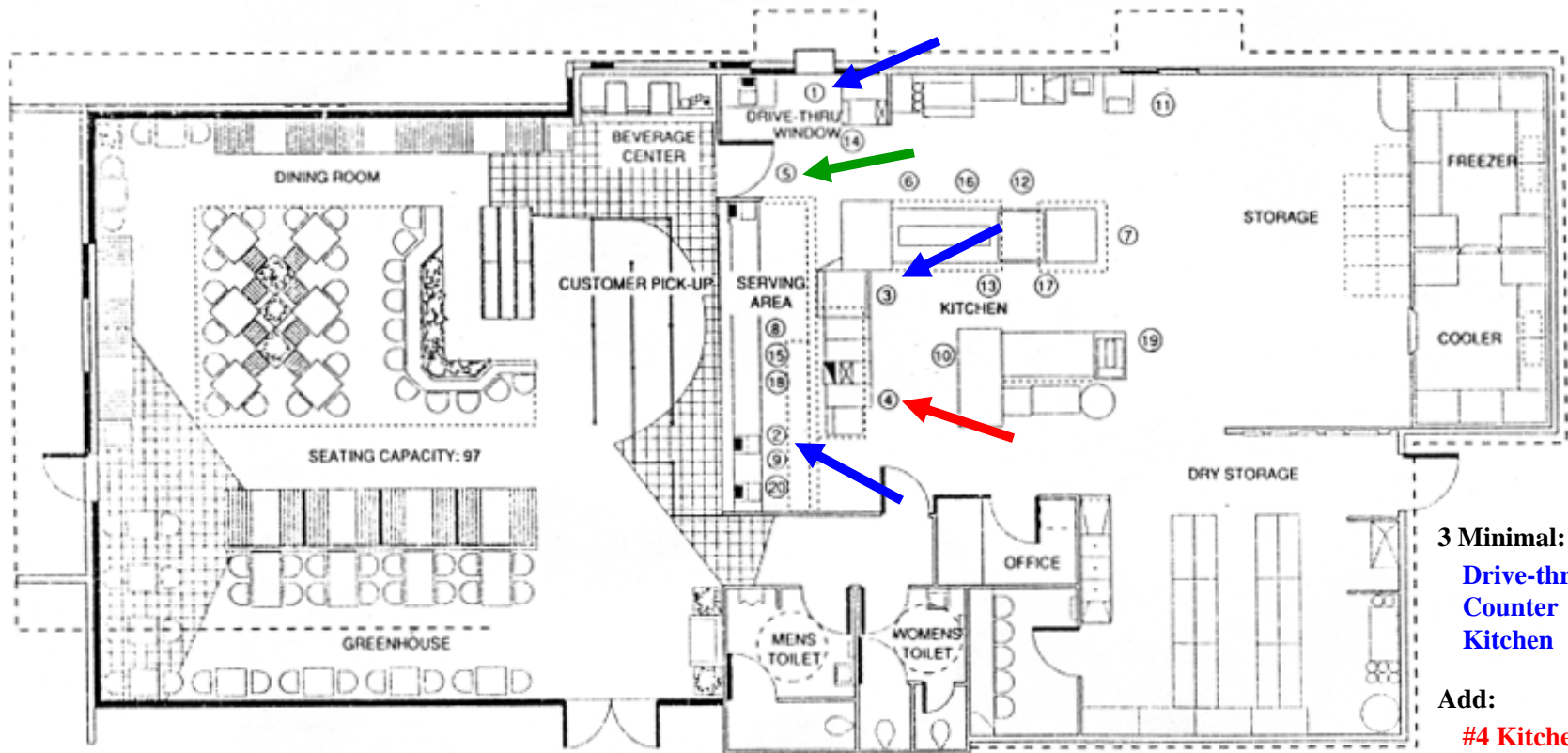
Avg. sojourn time  $\approx$  in months / years

Processing time  $\approx$  in mins / hours / days

# Conceptual Model: Burger King Bottlenecks

**Bottleneck Analysis:** Short – Run Approximations  
Time – State Dependent Q-Net

TOUR F / A WORKER-PACED LINE FLOW PROCESS AND A SERVICE FACTORY 155



3 Minimal:  
Drive-thru  
Counter  
Kitchen

Add:  
#4 Kitchen  
#5 Help  
Drive -thru

FIGURE F1 Layout of the Noblesville Burger King. The circled numbers indicate the sequence of additions of workers to the kitchen as demand increases.