A Service-oriented Approach for Improving Quality of Health Care Transitions

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Outline

- Transition of Care
- Service System for Transition of Care
- The Mathematical Problem Formulation
- Example
- Conclusions and Future Work

Transition of Care

Transition of patients from a primary, expensive facility to a secondary, less expensive facility that provides medical support to ensure a successful recovery

Medical Problem

- Manage patients transitions between healthcare settings in a cost-effective way and at the same time improve their medical status
- The transferring party provides medical records and instructions to the receiving party
- The receiving party monitors predefined patient characteristics and evaluates the health status of the patient
- The communication and the coordination of services between the two health care providers are performed by an intermediary
  - provides electronic health record technologies to gather, share and exchange information.

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Our Approach

- We define a **service system** that describes the interconnections among
  - humans (doctors, patients, engineers),
  - organizations (hospitals, insurance companies, data management service companies) and
  - technology (cloud environments, data repositories, sensors, etc.
- ***Objective***: facilitate the transition of patients in a cost effective way and at the same time improve their medical status

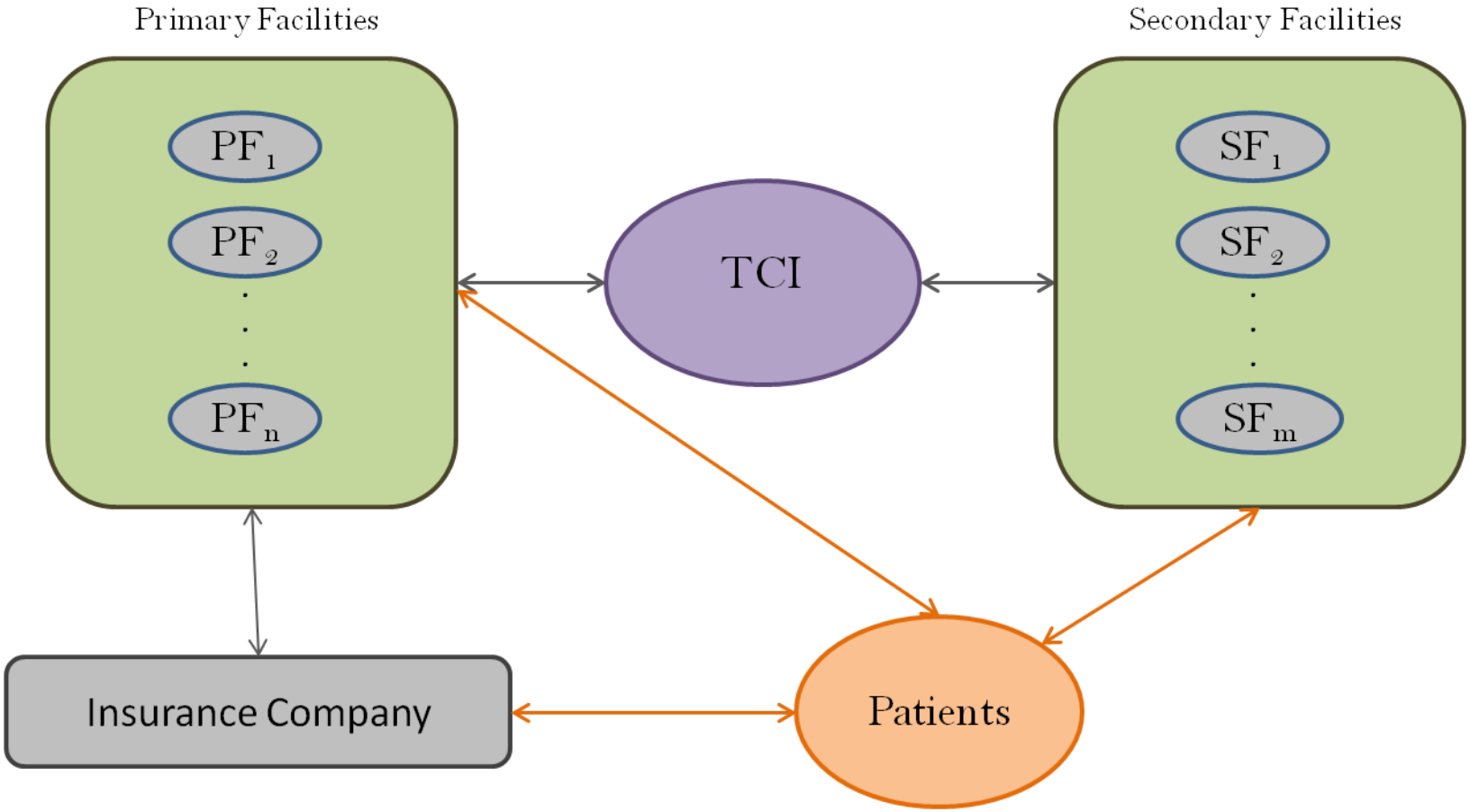
The Service System of Transition of Care

- The components of the proposed service system are
  - the entities that interact with each other and
  - the relationships that enable the flow of information, services and revenues among entities

The Service System of Transition of Care

- We define the following types of entities
  - A number of **primary facilities** (PF): they provide a healthcare service to patients
  - A number of **secondary facilities** (SF): they provide a healthcare service to patients
  - Transition of care **intermediary** (TCI):
    - handles the logistics of the patient transfer from PF to SF
    - matches PFs to SFs
    - there might be more than one competing TCIs
  - **Patients**: they use health services provided by PFs and SFs
  - **Insurance company**: covers hospitalization costs

The Service System of Transition of Care



The Service System of Transition of Care

- We use the following payment model to specify the flows of revenues over the relationships among the entities of the service system:
  - **Bundled payments model** (ACO):
    - The insurance company pays PF to insure a population of potential patients
    - The PF pays the SF and TCI, either on a per patient basis or as a bundled payment
    - There are cost limits on a per patient basis as well as per disease basis

Key Performance Indicators

- The performance of the service system is measured through a number of Key Performance Indicators (KPIs)
  - Cost of care per patient
  - Patient satisfaction
  - Readmission rate from SF back to PF that reflects the quality of service provided by SF
  - Market share each intermediary gains in a competitive environment

Factors that Affect KPIs

- Services provided by the various entities
  - High quality services reduce readmission rate
- Use of Infrastructure (EMR of the patient, sensors in the patient room, automation in transition process)
  - Decreases readmission rate → decreases costs (indirectly)
  - Increases cost (directly)
- Matching of PFs to SFs
  - Considering patient preferences increases patient satisfaction
  - Considering geographical constraints reduces costs

The Problem of Matching Pfs to SFs

- We analyze the proposed service system for solving the following problem
  - What is the **optimal matching** of PFs and SFs such that the overall cost is minimized provided that patients' preferences and economic constraints are satisfied?

The Problem of Matching Pfs to SFs

- The formulation of the service system and the interactions among the entities depend on the way the intermediaries match PFs to SFs
  - **Match PFs to SFs statically, on a per facility basis**: A PF may be matched to one or multiple SFs and an SF may be matched to one or multiple PFs
  - Match PFs to SFs dynamically, on a per patient basis
  - Match PFs to SFs on a per disease basis: SFs are specialized with patients of a common disease

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Matching Pfs to SFs

- The transition of care intermediary (TCI) aims at statically matching primary facilities (PFs) to secondary facilities (SFs) on a per facility basis
- **Objective**: choose the matching of each PF to a set of SFs so as to **minimize the total cost** of PFs

Properties of SFs

- Let $SCF = \{SF_1, \ldots, SF_J\}$ be the set of secondary facilities
  - RR_j: the readmission rate $(0 \leq RR_j \leq 1)$
  - $\bar{C}_j$: the cost per patient that SF_j charges $(\bar{C}_j > 0)$
  - PSI_j: the patient satisfaction index $(0 \leq PSI_j \leq 1)$

Properties of PFs

- Let $PCF = \{PF_1, \dots, PF_I\}$ be the set of primary facilities
  - GC_i: the geographical constraint (subset of the set $\{1, \dots, J\}$)
  - MCP_i: the maximum cost per patient ($MCP_i > 0$)
  - MRR_i: the maximum tolerable readmission rate ($0 \leq MRR_i \leq 1$)
  - $MPSI_i$: the minimum tolerable patient satisfaction index ($0 \leq MPSI_i \leq 1$)

The Objective Function

- Let M_i denote the set of SF_j that will receive patients from PF_i
- Let M denote the matching of all PFs to SFs

$$M = \{M_1, M_2, \dots, M_I\}$$

- **Total cost** for choice M:

$$C(M) = \sum_{i=1}^{I} C_i(M_i)$$

where $C_i(M_i) = \frac{1}{|M_i|} \sum_{j \in M_i} \bar{C}_j$

The Constraints

- The constraints to be satisfied are the following:
  - $M_i \in GC_i, \forall i \in \{1, \dots, I\}$
  - $RR_j \leq MRR_i, \ \forall j \in GC_i, \forall i \in \{1, \dots, I\}$
  - $PSI_j \geq MPSI_i, \ \ \forall j \in GC_i, \forall i \in \{1, \dots, I\}$
- The set of choices satisfying the constraints is denoted as $\mathcal{M}$

Cost Minimization

$$\min_{M \in \mathcal{M}} C(M) \text{ such that}$$

$$C_i(M_i) \leq MCP_i, \forall i \in \{1, \ldots, I\}$$

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Numerical example

- Properties of primary care facilities

PF_i	GC_i	MCP_i	MRR_i	$MPSI_i$
1	{1,2,3}	1100	0.8	0.8
2	{2}	1100	0.8	0.8
3	{1,2,3,4,5}	1000	0.7	0.6

Numerical example

- Properties of secondary care facilities

SF_j	$\overline{C}_j$	RR_j	PSI_j
1	1100	0.7	0.9
2	1000	0.8	0.8
3	1000	0.8	0.7
4	1000	0.7	0.8
5	900	0.6	0.8

Numerical Example

- Feasible choices with no constraints

$$|M|=(2^5-1)(2^5-1)(2^5-1)=29791$$

- Feasible choices with constraints

$$|\mathcal{M}|=(2^2-1)(2^2-1)=9$$

- The optimal solution

$PF_1 \rightarrow SF_2,\ PF_2 \rightarrow SF_2, PF_3 \rightarrow SF_5$

$M=\{\{2\},\{2\},\{5\}\}$ with total cost $C(M)=2900$

Future Work

- Model strategic interactions among healthcare facilities for improving the performance of the service system in terms of patient satisfaction or readmission rate