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Modeling participant flows as a basis for decision support in human service programs

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ABSTRACT

In the human services, participants flow into, through and out of programs. The complete set of flows, if described accurately and measured precisely, is valuable for understanding a program both qualitatively and quantitatively. The complexity of these flows, however, is an obstacle to program assessment and to the development of decision support tools.

Drawing on the traditions of the information systems field, we present a methodology for defining and graphically modeling participant flows. The methodology, Status-Transition-Cycle (STC) mapping, suggests a common approach for information systems design, program planning, knowledge transfer and statistical reporting. In this paper, we focus on how STC mapping can aid the design and implementation of decision support capabilities for a human services program, and we provide a case example of its use.

Keywords

human services, decision support, data models, systems analysis and design, flow diagrams

INTRODUCTION

Human service programs are organizations that provide direct non-monetary services to clients. Human service programs are typically funded by government bodies, or are reimbursed by third-party payers. Rarely do clients pay for services directly. Although there is a financial aspect to program efficiency, program effectiveness is often measured by non-financial outcomes, and these outcomes have been difficult to measure and assess (Kettner, Moroney and Martin, 1999). In turn, difficulties in assessment and evaluation impede the development of data-driven or quantitative model-driven decision support systems that will help managers of human service programs. Some of the difficulties are because of ill-defined semantic conventions in understanding how human service programs run.

Semantic Conventions

A semantic convention is a commonly accepted way of modeling a particular kind of situation. Semantic conventions determine how enterprises organize their data (Hay, 1996). For this reason, a strong semantic convention can play a key role in rationalizing a whole field of endeavor. A familiar example is the commercial order, which contains the parties, date, and details of a transaction, and which has been recorded consistently for millennia. This semantic convention organizes data in a way that allows buyers and sellers to interact with each other smoothly throughout the world and across different commercial environments.

Human service programs accept participants and eventually discharge them. Participants, in other words, flow through programs. The entry and exit of participants is recognized as a common structural element of programs (Rutman and Mowbray, 1983; Lohmann and Lohmann, 2002). It is, however, a semantic convention of very limited power. It means that human service programs generally consider that a participant has a date of admission and a date of discharge, and reflect this in their data management. This semantic convention, however, focuses so narrowly on entry and exit points that it does not adequately reflect the real complexity of a program's structure and its participants' trajectories. In real life, participants flow into a program's screening process and out again without receiving services (ineligibility); they flow out of the program and into it again (repeating); and in a broader sense, they flow from one state of receiving services to another (progress and setbacks). The complete set of participant flows, if described accurately and measured precisely, is valuable for

understanding any program both qualitatively and quantitatively; that understanding is a necessary ingredient for the development of decision support systems for human service programs.

Drawing on the graphical modeling traditions of the information systems field, we present a methodology, Status-Transition-Cycle (STC) mapping, for modeling participant flows. STC mapping applies broadly to the human service sector, and its structure offers a new semantic convention that can be useful for program planning, knowledge transfer, statistical analysis and information systems design. Its use in systems analysis and data modeling has been addressed elsewhere (Coursen and Ferns, in press). Here we focus on its contribution to decision support design.

The methodology is based on three patterns. First, a program has a set of categories that organizes the universe of its actual and potential participants. In STC mapping, each category is a "status." Second, when involved with the program, individual participants undergo "transitions" from one status to another in meaningful and structured ways that reflect the program's clinical and business rules. Third, certain transitions mark the beginning or the end of a participant's present involvement with the program. A complete instance of a particular participant's involvement can therefore be represented as a sequence of transitions through statuses from entry to exit. In this methodology, such a complete sequence is a "cycle." In many programs, the same participant may have multiple cycles.

These patterns are implicit in the work of designing and evaluating programs, but they have not previously been formalized. The Status-Transition-Cycle mapping presented in this paper models them in a rigorous and unambiguous way.

ANTECEDENTS IN INFORMATION SYSTEMS METHODOLOGIES

Many graphical modeling methodologies represent changes in the state of objects or flows among processes, and have informed our development of STC mapping:

- Finite state diagrams and their descendents. Finite automata, proposed by Alan Turing (1936), represent a machine that has a series of states that change based on input received. They can be represented graphically by a "finite state diagram" in which a state is a circle and input is an arrowed line. Later, Harel (1987) developed a more flexible notation called a "statechart" to address similar situations. A descendent, the "state transition diagram," is included in Unified Modeling Language (UML) (Booch, Rumbaugh and Jacobson, 1999).
- Flowcharts. Flowcharts represent a decision-making process by depicting a decision point and the actions that result from the decision. Diamonds, rectangles and arrowed lines represent decisions, actions and the links between them (Bright, 1959). Flowcharts model a wide range of decision-settings, from computer algorithms to emergency room protocols to criminal justice sentencing guidelines.
- Data flow diagrams (DFDs). Data flow diagrams describe how data move between processes in a system, and how processes alter, manipulate, or display the data (Gane and Sarson, 1979). An arrowed line is a data flow that represents a specific grouping of data, while a circle represents a process that changes the data through various acquisition or manipulation processes.

At a superficial visual level, these modeling tools are similar. All have initiation points, containers that represent an activity or state, and flows between containers. The meaning of a container and flow is different in each, however, and each is suited to a different use. Finite state diagrams and their successors represent deterministic problems with predictable inputs. Flowcharts specify the rules of micro-level decision-making within specific, narrow routines. DFDs describe the relationships between an organization's business processes.

Although different in meaning and purpose, all are generalist tools that employ abstract constructs. Status-Transition-Cycle mapping is, by contrast, specifically designed for modeling the flows of participants through human service programs. It is based on a set of commonalities specific to human service programs, and formalizes them as modeling conventions. This has the effect of imposing a discipline on thinking about and planning programs. This application of the STC mapping discipline should precede the use of the other analysis and design methodologies, for it will be difficult to apply the latter to an unrationalized system.

METHODOLOGICAL COMPONENTS

The six symbols shown in Figure 1 embody the fundamental concepts of STC mapping. Three of the symbols—a shaded cloud, an unshaded rectangle and a shaded one—represent categories of people. The shaded cloud stands for the whole universe of potential participants who have never been screened. An unshaded rectangle represents an "internal" status, a particular category of present or potential participants who are currently involved in some way with the program. A shaded rectangle is an "external" status, a category that is not currently involved with the program. The other three symbols represent

transitions, movements that people may make between the categories. An arrow crossed by a circle is a transition that begins a potential participant's involvement (cycle) with the program, and an arrow crossed by a bar ends a cycle. A plain arrow represents a transition within a cycle. Transitional arrows of any kind may be marked with numbers representing the various reasons why the transition might occur; if so, the numbered reasons are listed in a legend.

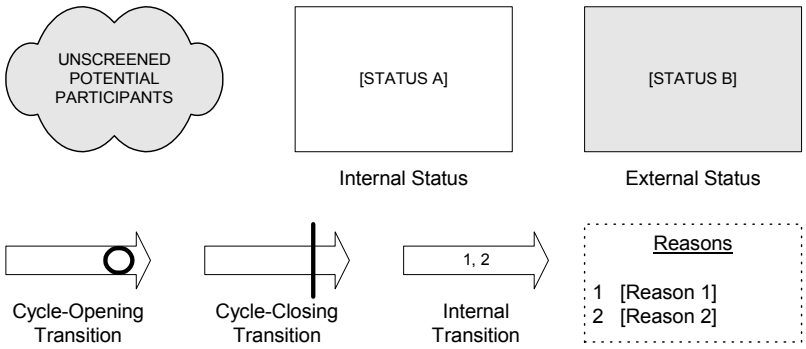

Figure 1: Status-Transition-Cycle Symbols

The STC map in Figure 2 models a "minimalist" job-counseling program. It shows that every potential participant goes through an intake assessment, and may be found ineligible based on any of three reasons: failing a means test, having a job, or living outside the program's geographic catchment area. An eligible participant goes on to receive counseling. The case is then closed, either because the participant completed the program or left without completing it. Anyone who has been found ineligible, or whose case has been closed, may return to the program later, passing through the same intake assessment.

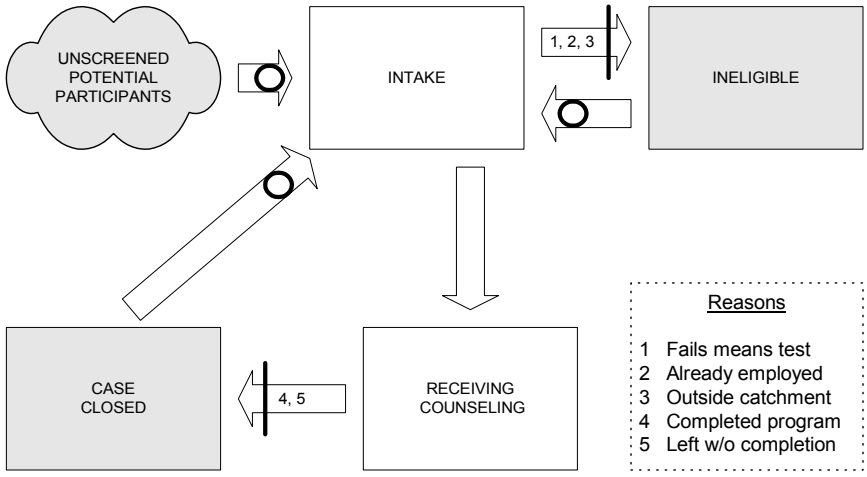

Figure 2: Job Counseling Program

A key point in this example is that INTAKE is an internal status. This challenges the convention that a participant is "in" a program only after being accepted to receive services. The INTAKE status is internal because the person has entered a recordable relationship with the program. This reflects the cyclical aspect of STC mapping. For those potential participants who are eligible, intake assessment is the beginning of their cycle of receiving program services. Those found ineligible, though, also go through a cycle of entry and exit, though it is only an intake cycle and does not include services. The importance of this point will become clear when we examine the methodology's implications for decision support.

Statuses

Visually, a status resembles a process on a traditional flowchart—both are represented by rectangles and both use arrows to indicate paths of flow. Their meanings differ fundamentally, however. A status is not a performed action, but a category of participants. Sometimes a status—such as INTAKE in the Job Counseling Program—corresponds to a single process. But often, participants in a particular status will go through many different processes. For example, the status RECEIVING COUNSELING might include resume writing, coaching sessions on interview skills, and a workshop on Internet job searches; the STC map does not attempt to represent these. Other statuses—such as INELIGIBLE and CASE CLOSED—contain participants who are not going through any processes at all.

In order to coherently organize the universe of participants, the set of statuses must meet certain requirements. The statuses must be:

- semantically well-defined, so that program staff understand and agree on their meanings;
- programmatically significant, so that they serve as the basis for analyzing performance and adjusting policies;
- clearly understood as either internal or external to the program; and
- both jointly exhaustive and mutually exclusive, so that the STC map completely covers all potential, present and past participants, and each participant is in exactly one status at any given moment.

Transitions and Cycles

A participant's trajectory entails transitions from one status to another. If programmatically significant statuses have been established, a transition will mark some important shift in the participant's relationship to the program.

Within any program's set of statuses, only some transitions will be permitted. For example, in the job-counseling program, a direct transition from CASE CLOSED back to RECEIVING COUNSELING is prohibited because the program requires that intake procedures be followed again. The set of permitted transitions, then, expresses clinical and business rules about how participants flow into, through, and out of the program.

The set of transitions must also follow certain rules.

- There must exist at least one transition from UNSCREENED POTENTIAL PARTICIPANTS to some internal status, but there cannot be any transition back into UNSCREENED POTENTIAL PARTICIPANTS;
- Every internal status must have at least one transition into it and at least one out of it, because participants do not stay involved in the program forever;
- Every external status must have at least one transition into it from an internal status, so that the map shows how participants exit the program;
- There may not be any transition into an external status from the UNSCREENED POTENTIAL PARTICIPANTS or from another external status. A change in the participant's status with the program can only occur when a transition is flowing through the program;
- Every permissible transition must be represented on the map, as the map is both descriptive and prescriptive.

Once the statuses and transitions have been mapped, it is simple to mark the transitional arrows with a circle or bar to indicate the opening or closing of a cycle. Any transition from an external status to any internal one constitutes the opening of a new cycle, while a transition from an internal status to an external one closes a cycle. Marking cycle boundaries in this way may seem redundant, but it emphasizes the boundary to the reader's eye.

IMPLICATIONS OF STC MAPPING

The basis of STC mapping is that generic patterns exist for the overall class of service programs, and these patterns can serve to develop a more formal model of any particular program. In many professions, practitioners perceive common patterns that they can use to formalize their work. Over time, the most popular and successful of these formalisms evolve into standards. The combination of formalizing and then standardizing the knowledge base will rationalize a field. Such a rationalization has many practical functions: agreement on professional standards, knowledge transfer to and training of practitioners, a common professional language, better record-keeping and reporting practices, systems analysis and data modeling leading to more effective information systems, decision support, and data sharing among systems. Here we will focus on the usefulness of

STC mapping in planning decision support systems. Decision support systems have been divided into broad categories of model-driven (Keen and Scott Morton, 1978) and data-driven DSS (Dhar and Stein, 1997), and STC mapping can be useful to both approaches.

Human Service Agencies and Model-Driven DSS

There are several impediments to DSS development for human service agencies. One obstacle is non-standardization of measures of effectiveness (Kettner et al, 1999). Unlike business sectors, where success measures such as profit, loss, and revenue growth are standardized and accepted across industries, quantitative outputs are not sufficient measures when part of an agency's mission is to produce qualitative change for its participants. The lack of clear success factors results in weak frameworks for measuring "good" decisions; those weak frameworks pose difficulties in developing model-driven DSS that use quantitative analysis and an *a priori* approach. In the human services, model-driven DSS are most prevalent in areas where there is a narrowly defined clinical problem, such as suicide assessment (Ferns, 1995), or where the decision structure has been largely imposed by the legal system, as in youth offender sentencing (Ferns, Dologite, Mockler and Pfeffer, 1996; Savaya, Monnickendam and Waysman, 2000).

In service areas where individuals may have a long-term involvement and may present a more complex set of problems, such as child welfare or drug treatment, success measures are more varied and often relative (i.e., the client is "better off" than she was before). Managers of such programs need tools to help them develop some modeling structure for decision support, and STC mapping is one such tool.

The early formulation of ill-structured problems is a necessary step in the DSS evolutionary process (Arnott, 1998). Using STC mapping to define statuses ensures that program planners and staff understand and agree on how to categorize the universe of participants. Mapping the transitions does the same for the clinical and business rules of how a participant's relationship within the program may change over time. An STC map can delineate a program's criteria for admission, major service milestones, ways of dealing with events in participants' lives, criteria for successful and unsuccessful completion, and conditions of reentry. This more "rationalized" model can thereby provide the basis of a decision support model. Used in this fashion, STC mapping provides a tool to activate cognitive triggers through interactions between parties involved in the DSS development (Arnott, 1998; Sprague and Carlson, 1982).

Human Service Agencies and Data-Driven DSS

The Client-tracking Data Model and the Data Warehouse

STC mapping supports the development of data-driven DSS through more robust client-tracking data, and through those data's dimensional organization in a data warehouse. The root of a database design is its data model, which represents a group of entities, their attributes and how the entities are related to each other. Data modeling theorists have created handbooks of the data model patterns commonly found in commerce, accounting, manufacturing, insurance, telecommunications, and many other industries (Hay, 1996; Silverston, 2001a, 2001b). Common data models for human service programs, however, are less well developed.

A database is only as good as its underlying data model, and a principal dimension of data model quality is conceptual completeness; it must adequately reflect the scope of the domain that it claims to represent (Reingruber and Gregory, 1994). In human service programs, the simple semantic convention that a participant is accepted and discharged often leads to a data model—and therefore a database—that does not capture the complexity of participant flows in real life. A database design may treat every passage through a program as a separate case record unlinked to the same participant's previous and subsequent passages, or fail to capture or link data on ineligible applications; if so, it will make it difficult to analyze larger patterns, both in the lives of participants and in the program's efforts to reach targeted populations. A database design may not accurately track how participants flow from one state of receiving services to another; such a design will make it harder to spot patterns that could illuminate reasons for success and failure. For example, Wulczyn, Hislop and Goerge (2000) analyzed trajectories across states' child welfare systems. Their research was based on "spells" in substitute care, a concept equivalent to cycles in STC mapping. Among the problems with administrative data that they found were unevenness in the ways that entry and exit reasons were recorded, and the overwriting of data from previous spells.

All of these issues are explicitly addressed by STC mapping (Coursen and Ferns, in press). Each of the methodology's three major components—statuses, transitions and cycles—translates to an entity within a data model. An information system based on such a data model will accurately capture how participants flow through the program. It will capture each of a participant's transitions, when it occurred and why. The system will capture the participant's complete history of one or many program cycles, with each cycle containing its specific sequence of multiple transitions.

Data-driven DSS often utilize data warehouses, as opposed to online transaction processing systems, for *a posteriori* analysis and decision-making (Power, 2003). The use of dimensional modeling, as opposed to entity-relationship modeling, is a central design tenet of data warehousing (Kimball, Thornthwaite, Reeves and Ross, 1998). However, in using STC mapping to construct the client-tracking data model of the human service agency, the database designer also ensures that both cycles and trajectories will be available as dimension tables in the data warehouse design.

Quantitative Analysis for Macro Level Decision Support

A common way of measuring a program's output is through the volume of its caseload, whether as a whole or at specific points of its service delivery process (Poister, 2003). Because STC mapping is a standardized way of modeling a program's participant flows, it suggests a number of formats for standardized quantitative reports. The census of current and former participants and those in the intake process corresponds to the list of all statuses, with the current count in each. Statistics on intakes, completions, other discharges, and important milestones achieved are represented by a list of the program's significant transitions, with the count of participants who went through each. Formats for descriptive statistics on how long participants stay in different statuses, or on the program's cyclical aspect, could also be developed.

Most programs already try to compile statistics of this sort, but STC mapping improves the process in several ways. First, the methodology points toward standardized formats. Second, the STC map directly links the statistics to a schematic qualitative description of the program. Third, the concept of cycles helps communicate the difference between statistics on individuals and statistics on their (potentially multiple) passages through the program. Fourth, the STC map guides the program to collect and organize its data in an unusually comprehensive and flexible way: the program will be able to deliver statistics on any participant flow—or any trajectory pattern—that the map represents. Analyses of these have great potential value.

A simple example from the job counseling program would be to look at STC trajectories that end in INELIGIBLE. It may show that far more applicants are being deemed ineligible than eligible. This may indicate either too stringent entry criteria, or operational problems at the intake process that need correcting. Further analysis may show that many individuals deemed ineligible are outside of the program's catchment area, but are clustered in a nearby neighborhood. This may suggest an opportunity for expanding the program's services to other areas.

A more complex example would be to consider the repeaters of the program, those who have the trajectory pattern CASE CLOSED → INTAKE → RECEIVING COUNSELING → CASE CLOSED. A DSS using neural networks to analyze these participants' characteristics could arrive at heuristics for identifying the groups of participants most likely to repeat; this in turn could help managers develop strategies that would help them succeed (Schoech, Quinn and Rycraft, 2000).

Matching Patterns to Support Decisions on Individual Cases

At the level of individual cases, service providers routinely face decisions of daunting complexity. Among the most important supports for such decision-making is the capacity to recall information from similar cases, and to analyze and synthesize that information in the aggregate (Schoech and Schkade, 1980). By organizing participant data into trajectory patterns, STC mapping facilitates comparison of similar cases. As mentioned above, a DSS to support individual case decisions could include heuristics based on group patterns. In addition, it could offer the user in-depth information—including decisions made and resulting outcomes—from a set of the cases having the most similar trajectories. Trajectory patterns could include not only the sequence of statuses but the length of time in statuses and the reasons for transition. With the inclusion of those variables, participant trajectories can become a standardized and precise way of matching similar cases.

CASE EXAMPLE: LA CASITA

La Casita, located in downtown Manhattan, is a drug treatment program run by a larger nonprofit organization, which we will refer to as "Downtown Community Services" (not the organization's real name) or "DCS." The mission of DCS is to provide, among other services, substance abuse treatment and prevention to the population of the greater New York area. Programs run by DCS include outpatient detoxification clinics using methadone, outpatient methadone maintenance programs, and methadone-to-abstinence residential programs. DCS also carries out research and clinical trials.

La Casita is a long-term (12 to 18 months) residential program for people on methadone maintenance. The initial part of the treatment is a gradual detoxification from methadone in a restricted environment, followed by a series of decreasingly restrictive structures. Besides drug treatment, case managers provide a range of services to the clients: psychiatric evaluation, mental health counseling, family and vocation counseling, primary health care, and more.

An analysis of La Casita's participant flows produces the STC map in Figure 3.

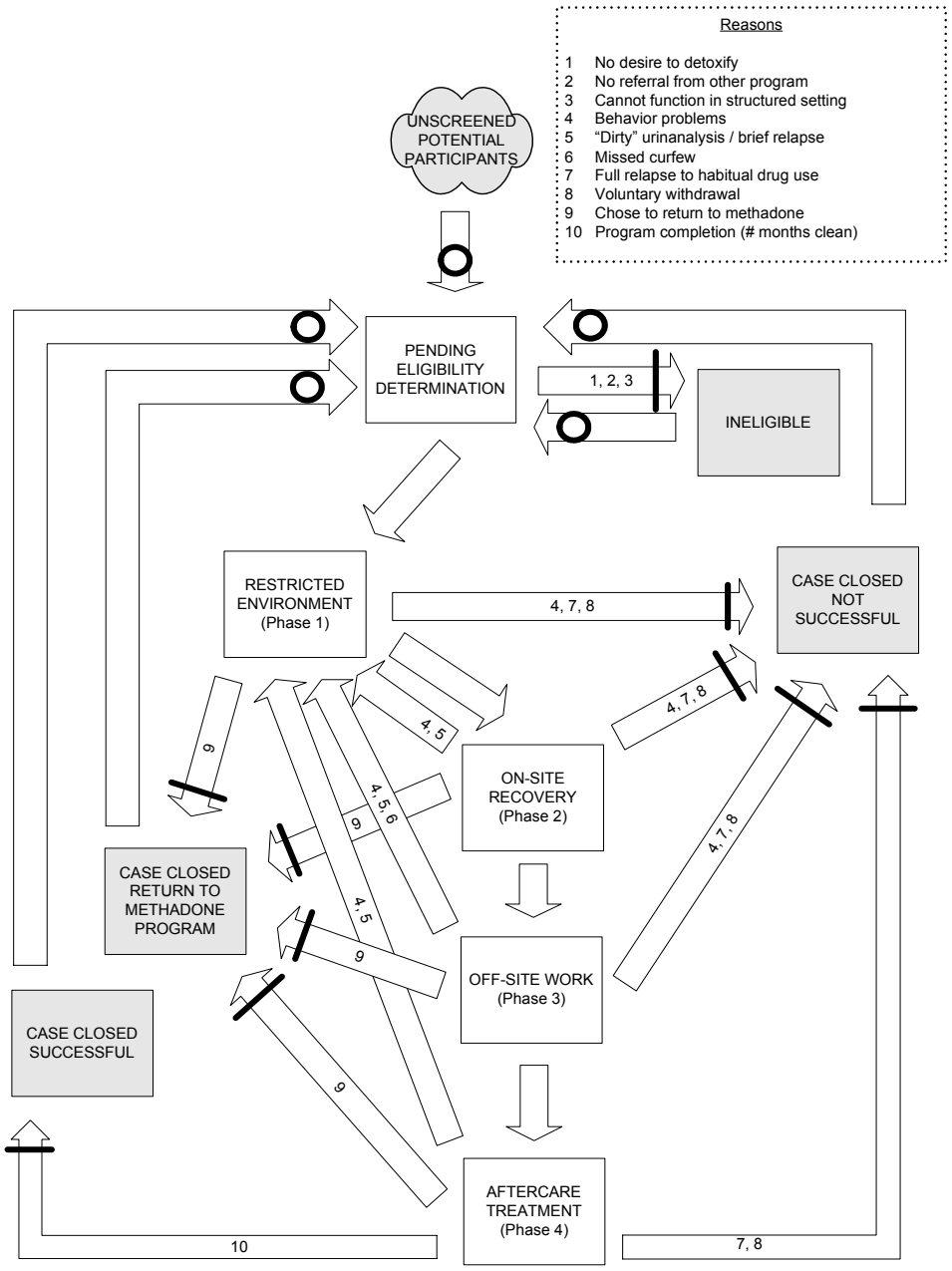

Figure 3: STC Map of La Casita

As the map shows, clients flow in, through and out of La Casita in complex ways. Some of the most salient points about the program's set of flows are:

- In PENDING ELIGIBILITY DETERMINATION, staff assesses potential participants to make sure that they meet three criteria: they have been referred by another program, such as an outpatient methadone maintenance program or a counseling service; they want to detoxify; and they can function within a highly structured environment.
- Participants in the program receive services of different kinds according to their current status. RESTRICTED ENVIRONMENT (Phase 1) corresponds roughly to the first three-to-six months in the program. During this period, the client is weaned from methadone to abstinence, and lives and works on-site in a structured environment with daily meetings and frequent drug tests. In ON-SITE RECOVERY (Phase 2), the client enjoys increased privileges such as

family visits, less monitoring, and increased and higher-level responsibilities in running the program. The client still lives and works onsite. OFF-SITE WORK (Phase 3) provides the participant the opportunity to work off-site, while living at the program. Participants observe curfews, which are strictly enforced. The client still participates in intensive activities such as group support meetings. In the last phase, AFTERCARE TREATMENT (Phase 4), the participant lives and works off-site, while participating in La Casita's Aftercare Program to meet in a group to sustain the benefits achieved and maintain contact with resources.

- There are three statuses of former participants. Participants who return to habitually using controlled substances other than methadone or who drop out of the program are in CASE CLOSED NOT SUCCESSFUL. Those who complete the program are in CASE CLOSED SUCCESSFUL. The third group is participants who decide they are not yet prepared for abstinence, and they return to a legally sanctioned methadone program; their status is CASE CLOSED—RETURN TO METHADONE PROGRAM.
- There is an "ideal" trajectory from PENDING ELIGIBILITY DETERMINATION to RESTRICTED ENVIRONMENT to ON-SITE RECOVERY to OFF-SITE WORK to AFTERCARE TREATMENT to CASE CLOSED SUCCESSFUL.
- Setbacks and difficulties in participants' lives make for many possible trajectories. A participant might ask for a move back from OFF-SITE WORK to RESTRICTED ENVIRONMENT, and some participants might be moved back because of brief relapses—as opposed to a return to habitual drug use—or missed curfews.
- Some initially ineligible people are referred again, and the program accepts former participants for readmission. There are therefore transitions back from all of the external statuses to PENDING ELIGIBILITY DETERMINATION, and these allow participants to begin new cycles.

The program's information system will, if informed by the STC map, track all these flows. This will serve as the basis for designing tools that deliver analyses of participant flows to support decision-making.

CONCLUSION

Status-Transition-Cycle mapping provides a methodology for uniformly analyzing and describing human service programs, and for developing both models and data designs to support decision-making. Using STC mapping, developers can represent a program's participant flows precisely as a prelude to building model or data-driven decision support tools.

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