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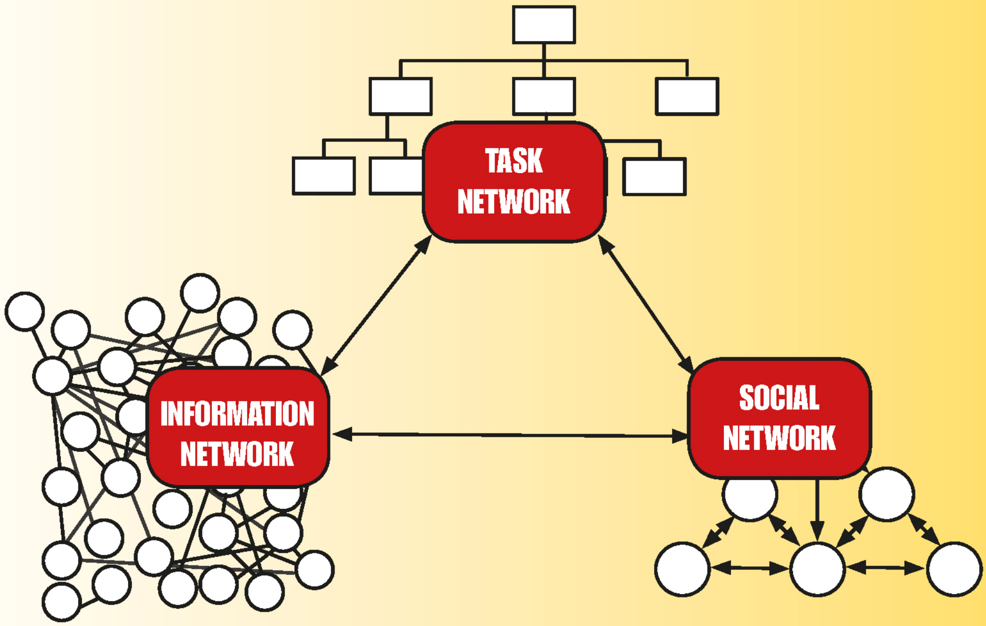
SYSTEMS THINKING IN PRACTICE

Applications of the Event Analysis of Systemic Teamwork Method



Neville A Stanton • Paul M Salmon
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Preface

This book has arisen from the desire to share our insights into the practical application of the Event Analysis of Systemic Teamwork (EAST) framework. Over the past decade, we have applied EAST in many domains and have been impressed by the insights that the products of the analysis afford. EAST offers a systemic and systematic approach to the analysis, design and evaluation of sociotechnical systems. As a formative method, we have used it to design new concepts of operations, new teams and new ways of working. As a summative method, we have used it to gain new insights into existing systems and current ways of working.

The EAST method was initially developed for a programme of research into command and control funded by the UK Ministry of Defence called the Human Factors Integration Defence Technology Centre. This research began in 2003 and ended in 2012.

The total funding was for £30 million over 10 years, and one of our projects was to provide Human Factors advice for new networked architectures for command and control. The idea was that potentially all military systems across all of the forces (from the infantry soldier to the moving platforms [on land, in the air and at sea] to the joint operations headquarters) could be connected like the World Wide Web is for civilian activities.

This kind of connectivity meant we had to look at command and control in a completely new way. Rather than develop completely new methods, we developed EAST by integrating existing methods, as is explained in this book. Prof Chris Baber and I decided to use network methods to investigate these command and control networks. This began with investigations into both civilian and military examples of command and control, some of which are presented in this book. The approach has developed into the EAST method as we know it today. Over the years, we have developed and refined the approach. What we particularly like about the network methods is that they are both scalable and systemic in nature. We can analyse the networks both qualitatively and quantitatively (using network statistics, as demonstrated in this book).

We imagine people will approach this book with different purposes. For those new to the EAST approach, we advise reading Chapter 1 and then finding a chapter with your domain of interest. For those familiar with EAST, go straight to the chapters that are of interest. For researchers and those keen on extending the EAST approach, the final section of chapters on developments and future directions will be of most interest. Each of the chapters is intended to be read as a stand-alone article, so there is some inevitable repetition on the overview of EAST (although different emphases and approaches to the method are taken). Experts in EAST can skip over those sections. For those who use EAST and find it useful in their work, we say, welcome to the tribe of happy EASTers. That EASTer tribe already comprises the authors in this book, and we are aware of other groups using EAST around the world. All of the chapters were led by one or more of the lead authors of the book with the exception of Chapters 9 and 10, which were both led by Victoria Banks. We are grateful for the contributions and insights from our co-authors and the progress that has been made with the method since its original conception.

The EAST development journey is not at the end yet. There have been recent developments that have extending the use of EAST. EAST, as a systems method, has fared well, as systems approaches are very much in favour in the Ergonomics and Human Factors world. We have had some successes linking EAST to other systems methods, such as Systems Theoretic Accident Model and Process |(STAMP) and Cognitive Work Analysis (CWA). We have also used EAST in formative ways to predict system network resilience. The journey does not end here, however, and we are sure that we and others will continue to develop and extend the approach and apply it to even more domains of application.

Neville A. Stanton
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University of Southampton

RECOMMENDED FURTHER READING ON EVENT ANALYSIS OF SYSTEMIC TEAMWORK

Salmon, P. M., Read, G. J. M., Goode, N., Grant, E., Dallat, C., Carden, T., Naweed, A., Walker, G. H. and Stanton, N. A. (2018). STAMP goes EAST: Integrating ergonomics methods for the analysis of railway level crossing safety management. *Safety Science*: doi.org/10.1016/j.ssci.2018.02.014.

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THERE ARE ALSO THESE BOOKS:

Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C. and Jenkins, D. (2005). *Human Factors Methods: A Practical Guide for Engineering and Design* (first edition). Ashgate: Aldershot.

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Professor Neville Stanton, PhD, DSc, is a chartered psychologist, chartered ergonomist and chartered engineer. He holds the Chair in Human Factors Engineering in the Faculty of Engineering and the Environment at the University of Southampton in the United Kingdom. He earned degrees in Psychology, Applied Psychology and Human Factors and has worked at the Universities of Aston, Brunel, Cornell and MIT. His research interests include modelling, predicting, analysing and evaluating human performance in systems as well as designing the interfaces and interaction between humans and technology. Professor Stanton has worked on the design of automobiles, aircraft, ships and control rooms over the past 30 years on a variety of automation projects. He has published 40 books and over 300 journal papers on Ergonomics and Human Factors. In 1998, he was awarded the Institution of Electrical Engineers Divisional Premium Award for research into System Safety. The Institute of Ergonomics and Human Factors awarded him the Otto Edholm Medal in 2001, the President's Medal in 2008 and the Sir Frederic Bartlett Medal in 2012 for his contributions to basic and applied ergonomics research. The Royal Aeronautical Society awarded him and his colleagues the Hodgson Prize and Bronze Medal in 2006 for research on design-induced, flight-deck error published in The Aeronautical Journal. The University of Southampton awarded him a Doctor of Science in 2014 for his sustained contribution to the development and validation of Human Factors methods.

Professor Paul Salmon holds a Chair in Human Factors and is creator and director of the Centre for Human Factors and Sociotechnical Systems at the University of the Sunshine Coast. He currently holds a prestigious Australian Research Council Future Fellowship and has almost 15 years' experience in applied Human Factors research in a number of areas, including defence, transportation safety, sports and outdoor recreation and disaster management. Professor Salmon currently leads major research programmes in the areas of road and rail safety, identity theft and cybersecurity and led outdoor recreation accidents. He has co-authored 14 books, over 180 peer-reviewed journal articles and numerous conference articles and book chapters. He has received various accolades for his contributions to research and practice, including the Australian Human Factors and Ergonomics Societies 2016 Cumming Memorial medal, the UK Ergonomics Society's Presidents Medal, the Royal Aeronautical Society's Hodgson Prize for best research and paper and the University of the Sunshine Coast's Vice Chancellor and President's Medal for Research Excellence. Professor Salmon's current research interests relate to extending Human Factors and Sociotechnical Systems theory and methods to support the optimisation of systems in many areas. Specific areas of focus include accident prediction and analysis, systems thinking in transportation safety, the development of systemic accident countermeasures, human factors in elite sports and cybersecurity.

Professor Guy Walker works within the Institute for Infrastructure and Environment at Heriot-Watt University in Edinburgh. He lectures on Human Factors and is the author/co-author of over 100 peer-reviewed journal articles and 13 books. He and his co-authors have been awarded the Institute for Ergonomics and Human Factors President's Medal for the practical application of Ergonomics theory and the Peter Vulcan Prize for best research paper by the 2013 Australasian Road Safety Research Conference. In 2011, he also won Heriot-Watt University's Graduate's Prize for inspirational teaching. Prof Walker earned a BSc Honours degree in Psychology from the University of Southampton and a PhD in Human Factors from Brunel University. His research interests are wide ranging, spanning driver behaviour and the role of feedback in vehicles, using Human Factors methods to analyse black-box data recordings and the application of sociotechnical systems theory to the design and evaluation of civil engineering systems through to safety, risk and reliability. His research has featured in the popular media, from national newspapers, TV and radio through to an appearance on the Discovery Channel.

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Section I

Overview of EAST

1 The Event Analysis of Systemic Teamwork (EAST) Method

With Nicholas J. Stevens

In this book, we describe a series of studies that apply the systems thinking approach using the Event Analysis of Systemic Teamwork (EAST) method. Systems thinking is a contemporary approach that has currency within the discipline of human factors. It aims to understand and improve safety and performance in complex sociotechnical systems. Human factors issues are increasingly being examined through the systems thinking lens (Karsh et al. 2014; Salmon et al. 2017; Walker et al. 2017). In line with this, since the turn of the century, a range of Human Factors methods have either been developed or have experienced a resurgence in popularity. These include systems analysis frameworks, such as Cognitive Work Analysis (CWA) (Vicente 1999) and EAST (Stanton et al. 2008); accident analysis methods, such as AcciMap (Svendung and Rasmussen 2002), the Systems Theoretic Accident Model and Processes (STAMP) (Leveson 2004), and the Functional Resonance Analysis Method (FRAM) (Hollnagel 2012); and systems design methods, such as the MacroErgonomic Analysis and Design method (MEAD) (Kleiner 2006) and the Cognitive Work Analysis Design Toolkit (Read et al. 2016).

The aim of this book is to demonstrate how one of these methods, EAST, can be used to provide in-depth analyses of performance and safety in complex sociotechnical systems (STS). The systems thinking approach involves taking the overall system as the unit of analysis, looking beyond individuals and considering the interactions between humans and between humans and artefacts within a system. This view also encompasses factors within the broader organisational, social or political system in which behaviour takes place. Taking this perspective, behaviours emerge not from the decisions or actions of individuals but from interactions between humans and artefacts across the wider system. At the most basic level when examining STS, the descriptive constructs of interest can be distilled down to simply

- *Why*: the goals of the system, sub-system[s] and actor[s]
- *Who*: the actors performing the activity, including humans and technologies
- *When*: when activities take place and which actors are associated with them
- *Where*: where activities and actors are physically located
- *How*: (how activities are performed and how actors communicate and collaborate to achieve goals).

To assist researchers and practitioners explore these constructs, EAST (Stanton et al. 2013) offers a comprehensive framework for the design, evaluation and analysis of complex sociotechnical systems. As well as offering a description of the activity performed within a particular system, the approach provides methods that can be used to develop an in-depth analysis of the constraints that shape agent activity within the system. Sociotechnical systems scenarios are often so complex and multi-faceted, and analysis requirements so diverse, that various methods need to be applied as one method in isolation cannot cater for the scenario and analysis requirements. Building on a long history and tradition of methods integration in human factors research and practice (Stanton et al. 2005), EAST (Stanton et al. 2008, 2013) provides an integrated suite of methods for analysing the performance of complex sociotechnical systems. The framework supports this by providing methods to describe, analyse and integrate three network-based representations of activity: task, social and information networks. An overview of the EAST method is provided in the remainder of this introductory chapter.

BACKGROUND AND APPLICATIONS

EAST (Stanton et al. 2008) provides a framework of methods that allows system performance to be comprehensively described and evaluated. Since its conception, the framework has been applied in many domains, including land and naval warfare (Stanton et al. 2006; Stanton 2014), aviation (Stewart et al. 2008), air traffic control (Walker et al. 2010), road transport (Salmon et al. 2014a) the emergency services (Houghton et al. 2008) and elite cycling (Salmon et al. 2017). Within this book, the application areas covered include

- aviation (Chapters 2, 12 and 13)
- command and control (Chapters 3 and 5)
- energy distribution (Chapter 4)
- rail transportation (Chapters 6 and 11)
- road transportation (Chapters 7, 9 and 10) and
- sport (Chapter 8)

Underpinning the approach is the notion that distributed teamwork can be meaningfully described via a ‘network of networks’ approach, shown in Figure 1.1. Specifically, three networks are considered: task, social and information networks. Task networks describe the goals and subsequent tasks being performed within the system. Social networks analyse the organisation of the system (i.e. communications structure) and the communications taking place between the actors working in the team. Finally, information networks describe the information and knowledge (situation awareness) that the different actors use and share during task performance.

Recent applications of the framework have also adopted a composite network analysis approach whereby the three networks are integrated to show the relationships between tasks, social interactions and information (Stanton 2014).

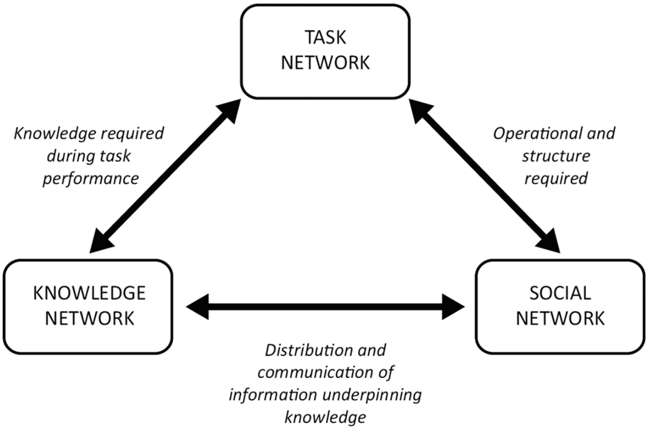

FIGURE 1.1 Network of networks approach.

DOMAIN OF APPLICATION

EAST is a generic approach that was developed originally for the analysis of teamwork in sociotechnical systems, but it has since been used to provide analyses at the micro (Salmon et al. 2014a), meso (Stanton 2014) and macro (Stanton and Harvey 2017) levels of sociotechnical systems. As such, it can be used in any domain in which social and technical elements are working together in pursuit of a common goal. The case study presented in this chapter, used to demonstrate EAST, is based on an application within the area of land use planning and in urban design (Stevens et al., 2018).

APPLICATION IN LAND USE PLANNING AND URBAN DESIGN (LUP & UD)

LUP & UD is most often a product of multi-disciplinary approaches to complex environments and sociotechnical systems (Stevens et al. 2018). Our projects and processes require different resources from a variety of participants over a range of time frames. Whilst we may not always define these approaches as teamwork, the EAST approach has the potential to offer critical insights into more effective and efficient cooperative processes and project performance.

PROCEDURE AND ADVICE

Step 1: Define Analysis Aims

First, the aims of the analysis should be clearly defined so that appropriate scenarios are used and relevant data are collected. In addition, not all components of the EAST framework may be required, so it is important to clearly define the aims at this point to ensure that the appropriate EAST methods are applied.

Step 2: Define the Task/System Under Analysis

Next, the task (or tasks) or scenario (or scenarios) under analysis should be clearly defined. This is dependent upon the aims of the analysis and may include a range of tasks or one task in particular. It is normally standard practice to develop a Hierarchical Task Analysis (HTA) (see Stanton 2006) for the task under analysis if sufficient data and subject matter expert (SME) access are available. This is useful later on in the analysis and is also enlightening, allowing the analyst to gain an understanding of the task before the observation and analysis begins.

Step 3: Data Collection

Once the aims of the analysis are clearly defined, the next step involves collecting targeted data about the system and its behaviour. The specific data collected are dependent on the analysis aims and the resources available; however, data collection for EAST typically involves observations, concurrent verbal protocols, structured or semi-structured interviews (e.g. the Critical Decision Method [CDM]; Klein et al., 1989), walkthrough analysis and documentation review (e.g. incident reports, standard operating procedures).

The observation step is often the most important part of the EAST procedure. Typically, a number of analysts are used to observe the system or scenario under analysis. All activities involved in the scenario under analysis should be recorded along an incident timeline, including a description of the activity undertaken, the agents involved, any communications made between agents and the technology involved. Additional notes should be made where required, including the purpose of the activity observed; any tools, documents or instructions used to support activity; the outcomes of activities; any errors made; and also any information that the agent involved feels is relevant. In addition, it is useful to video record the task and record verbal transcripts of all communications, if possible.

Once the task under analysis is complete, each 'key' agent (e.g. scenario commander, agents performing critical tasks) involved should be subjected to a CDM interview. This involves dividing the scenario into key incident phases and then interviewing the actor involved in each phase using a set of pre-defined CDM probes (e.g. O'Hare et al. 2000; see also Chapter 4 for more information on the CDM).

Step 4: Transcribe Data

Once all of the data are collected, it should be transcribed in order to make it compatible with the EAST analysis phase. An event transcript should then be constructed. This should describe the scenario over a timeline, including descriptions of activity, the actors involved, any communications made and the technology used. In order to ensure the validity of the data, the scenario transcript should be reviewed by one of the SMEs involved.

Step 5: Construct Task Network

The first analysis step involves constructing a task network. Prior to this, the initial HTA should be reviewed and refined based on the data collected during step 3.

The data transcription process allows the analyst to gain a deeper and more accurate understanding of the scenario under investigation. It also allows any discrepancies between the initial HTA scenario description and the actual activity observed to be resolved. Typically, activities in complex sociotechnical systems do not run entirely according to protocol, and certain tasks may have been performed during the scenario that were not described in the initial HTA description. The analyst should compare the scenario transcript to the initial HTA and add any changes as required.

Constructing the task network involves identifying high-level tasks and the relationships between them and creating a network to represent this. Some general rules around the construction of EAST networks are presented in Table 1.1.

TABLE 1.1

Analysis Rules Regarding the Relationships Between Nodes Within EAST Networks

Network	Nodes	Relationships	Examples
Task network	Represent high-level tasks that are required during the scenario under analysis. High-level tasks are typically extracted from the sub-ordinate goals level of the HTA	Represent instances where the conduct of one high-level grouping of tasks (i.e. task network node) influences, is undertaken in combination with or is dependent on another group of tasks	The nodes 'Identify legal constraints' and 'Identify site and zoning' are linked because the zoning cannot be established until the site has been legally identified
Social network	Represent human, technological, or organisational agents who undertake one or more of the tasks involved in the scenario under analysis (as identified in the HTA and task network)	Represent instances where agents within the social network interact with one another during the scenario under analysis	The nodes 'Urban planner' and 'community' are linked as the planner needs to communicate with and understand the local community if an informed analysis of the site is to be established
Information network	Represent grouped categories of information that is required by agents when undertaking scenario under analysis (as identified in the task and social network)	Represent instances where information influences other information or is used in combination with other information in the network during the scenario under analysis	The nodes 'views' and 'topography' are linked as the establishment of views requires appropriate topography

Step 6: Conduct Social Network Analysis

A Social Network Analysis (SNA) (Driskell and Mullen 2004) is used to analyse the relationships (e.g. communications, transactions) between the agents involved in the scenario under analysis. This involves first creating a social network matrix showing the relationships between agents followed by a social network diagram which provides a visual representation of the social network. Typically, the direction (i.e. from actor A to actor B) frequency, type and content of associations are recorded. It is normally useful to conduct a series of SNAs representing different phases of the task under analysis (using the task phases defined during the CDM part of the analysis).

Step 7: Construct Information Networks

The final step of the EAST analysis involves constructing information networks (see Chapter 7 for a full description) for each scenario phase identified during the CDM interviews. Following construction, information usage should be defined for each actor involved via shading of the information elements within the propositional networks.

Step 8: Construct Composite Networks

Composite networks are used to explore the relationships between tasks, agents and information (Stanton 2014). As such, composite networks are constructed by combining the different networks. For example, a *task by agents* network can be constructed by combining the task and social network to show which tasks are undertaken by which agents. This involves assigning a colour to the different agents within the social network and shading each node within the task network to show which agent performs that particular task. Useful composite networks to construct include

- Task by agents network (combined task and social network);
- Information by agents network (combined information and social network);
- Task and associated information network (combined task and information network);
- Information by agents and tasks network (combined task, social and information network).

Once the EAST networks are complete, it is pertinent to validate the outputs using appropriate SMEs and recordings of the scenario under analysis. Any problems identified should be corrected at this point.

Step 9: Analyse Networks

An important component of EAST analyses involved using network metrics to analyse the task, social and information networks. This enables analysis of the structure of the networks and identification of key nodes (e.g. tasks, agents, information) within the networks. Three popular network analysis metrics have previously been used to interrogate EAST networks:

1. *Network Density (overall network)*: Network density represents the level of interconnectivity of the network in terms of relations between nodes. Density is expressed as a value between 0 and 1, with 0 representing a network with no connections between nodes and 1 representing a network in which every node is connected to every other node (Walker et al. 2011). Higher density values are indicative of a well-connected network in which tasks, agents, information and controls are tightly coupled.
2. *Sociometric Status (individual nodes)*: Sociometric status provides a measure of how 'busy' a node is relative to the total number of nodes within the network under analysis (Houghton et al. 2006). In the present analysis, nodes with sociometric status values greater than the mean sociometric status value plus one standard deviation are taken to be the 'key' (i.e. most connected) nodes within each network. These nodes represent either key tasks, agents, pieces of information or controls. For example, in the case of the social network, the node with the highest sociometric status is the agent that is the most interrelated with other agents based on communication.
3. *Centrality (individual nodes)*: Centrality is used to examine the standing of a node within a network based on its geodesic distance from all other nodes in the network (Houghton et al. 2006). Central nodes represent those that are closer to the other nodes in the network as, for example, information passed from one to another node in the network would travel through less nodes. Houghton et al. (2006) point out that well-connected nodes can still achieve low centrality values as they may be on the periphery of the network. For example, in the case of the social network, nodes with higher centrality status values are those that are closest to all other agents in the network as they have direct rather than indirect links with them.

ADVANTAGES

- The analysis produced is extremely comprehensive and activities are analysed from various perspectives.
- The analysis is both qualitative (networks) and quantitative in nature (network analysis metrics).
- Composite networks enable analysts to explore the relationships between tasks, agents and information.
- The use of network analysis metrics enables analysts to identify key tasks, agents and information.
- The framework can be used both retrospectively and predictively to forecast system behaviour (e.g. Stanton and Harvey 2017).
- The framework approach allows methods to be chosen based on analysis requirements.

- EAST has been applied in a wide range of different domains for various purposes. The approach is generic and can be used to evaluate activities in any domain.
- Various Human Factor (HF) concepts can be examined, including distributed situation awareness, distributed cognition, decision making, teamwork and communications.
- It uses structured and valid HF methods and has a sound theoretical underpinning.

DISADVANTAGES

- When undertaken in full, the EAST framework is a very time-consuming approach.
- The use of various methods ensures that the framework incurs a high training time.
- In order to conduct an EAST analysis properly, a high level of access to the domain, task and SMEs is required.
- Some parts of the analysis can become overly time-consuming and laborious to complete.
- Some of the outputs can be large, unwieldy and difficult to present in reports, papers and presentations.
- Reliability and validity have not yet been formally tested.

RELATED METHODS

EAST uses HTA, social network analysis and information networks. Various methods can be used to collect the data required to construct task, social and information networks, including concurrent verbal protocol analysis, the CDM (Klein et al. 1986), observation, documentation review and content and thematic analysis.

APPROXIMATE TRAINING AND APPLICATION TIMES

Due to the number of different methods involved, the training time associated with the EAST framework is high. Similarly, application time is typically high, although this is dependent upon the task under analysis and the scope of the analysis.

RELIABILITY AND VALIDITY

Due the number of different methods involved, the reliability and validity of the EAST methods are difficulty to assess. Indeed, they have not yet been formally tested.

FLOWCHART

A flowchart showing the main phases of EAST is shown below, separated into the three phases of data collection, data analysis and representation methods (Figure 1.2).

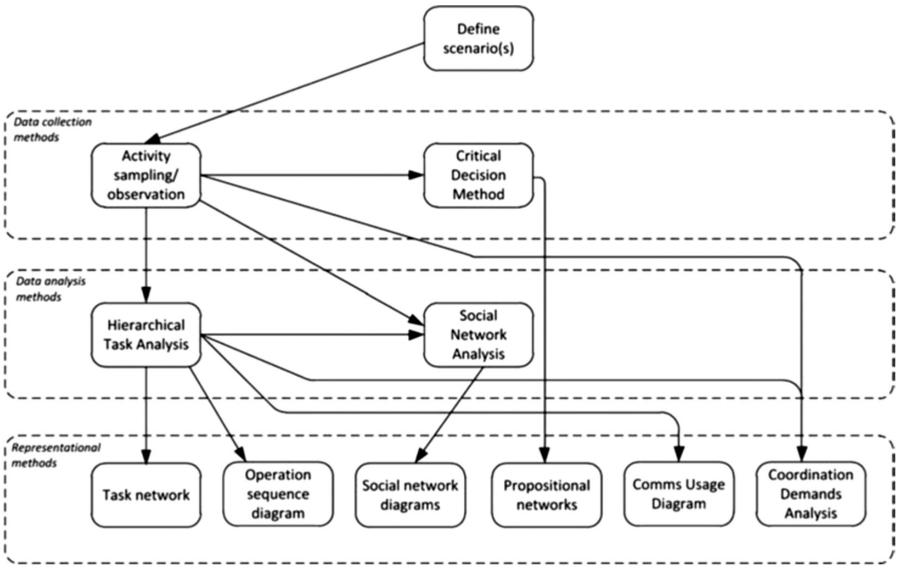

FIGURE 1.2 Flowchart showing phases and associated methods for EAST.

TOOLS NEEDED

Normally, video and audio recording devices are used to record the activities under analysis. A drawing software package such as Microsoft Visio is also typically used to reproduce the networks. The HTA tool or other task analysis tools can be used to support development of the task network. The AGNA social network analysis software tool is typically used to quantitatively analyse the networks, and the Leximaner thematic analysis tool can be used to construct information networks directly from verbal or communications transcripts (e.g. Salmon et al. 2014b).

EXAMPLE

In the following example, EAST was used to examine a generic land use and urban planning site analysis process (Stevens et al., 2018). Task, social and information networks were constructed to describe the key tasks, agents and information used during site analysis. Initially, a task network was constructed based on a HTA of a generic site analysis process.

As shown in Figure 1.3, 11 key interrelated tasks were identified. The task network is a dense one with many interdependencies between tasks, suggesting that the tasks required are tightly coupled. In particular, the tasks of analysing the neighbourhood and determining circulation patterns are the most connected within the task network, suggesting that they are central to the overall site analysis process.

A social network diagram was constructed based on identifying which agents are required to communicate with each other during the site analysis process (see