14. Human Factors Science and Safety Engineering. Can the STAMP Model Serve in Establishing a Common Language?

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Abstract. A symbiotic relationship between human factors and safety scientists is needed to ensure the provision of holistic solutions for problems emerging in modern socio-technical systems. System Theoretic Accident Model and Processes (STAMP) tackles both interactions and individual failures of human and technological elements of systems. Human factors topics and indicative models, tools and methods were reviewed against the approach of STAMP. The results showed that STAMP engulfs many human factors subjects, is more descriptive than human factors models and tools, provides analytical power, and might be further improved by including more aspects of human factors. STAMP can serve in minimizing the gap between human factors and safety engineering sciences, which can collectively offer inclusive solutions to the industry.

Keywords: human factors, safety, STAMP, STPA

Introduction

A quick search into academic and professional publications reveals that traditionally, human factors has been a field where psychologists have prevailed, and safety has been a discipline that engineers have dominated. However, this picture has started changing; engineers and other professional groups study, research and apply human factors, and psychologists have moved beyond experimental and theoretical studies on human decision making, behaviour etc. and become increasingly involved in safety management and safety at the work floor (e.g., Dekker, 2005; Hetherington, Flin, & Mearns, 2006; Karsh, Holden, Alper, & Or, 2005; Lioua, Tzengb, & Changa, 2007; Hoca, Youngb, & Blossevillec, 2009). Thus, we witness an era where human factors and safety engineers have started sharing common concerns and cooperate closer, a relation partially dictated by the complexity of our systems and the need to view the role of humans in this context (e.g., Carayon, 2009; Jenkins, Stanton, Salmon, &

Walker, 2009; Woods, Dekker, Cook, Johannesen, & Sarter, 2010). Although a synergetic relationship between those two domains is needed to ensure the provision of holistic solutions that reconcile academic research and professional experience, various models are still used within and between the human factors and safety disciplines. The plurality and diversity of models might serve science and academic debate but do not always support the establishment of a *lingua franca* between human factors and safety scientists and practitioners (e.g., Lowe, 2008; Larouzee & Guarnieri, 2015).

Albeit the progress made in embedding human factors in safety engineering, most of the safety, risk and reliability models and tools view human error as a "component" failure. Following decomposition of systems, as is suggested by methods like the prevalent Fault Tree Analysis, older and newer safety engineering publications suggest the assignment of probabilities to human error and an evaluation of system vulnerability in conjunction with the failure probabilities of technical components (e.g., Andrews & Moss, 2002; Smith, 2011; Pham, 2011; Roland & Moriarty, 1990). Such approaches neglect the high variability of human performance due to individual characteristics and effects of the social, physical, technological and organizational environments, although the aforementioned factors are sparingly mentioned in the safety engineering publications. Hence, although the human element rests in the centre of socio-technical systems and guarantees their sustainability and viability, humans are seen as components with defined specifications and human error becomes a local problem rather than a symptom of flawed designs (Leveson N. , 2011) and deeper systemic deficiencies (e.g., Dekker, 2002).

On the other hand, various concerns have been published around the validity and applicability of human factors research. Eysenck & Keane (2000) recognised the difficulty to generalise the findings of cognitive psychology research to real world situations due to the optimal experimental conditions where cognition is assessed and studies are performed in isolated environments. The aforementioned authors claimed that psychologists frequently ignore the effects of the social, technical and physical environment, the individual characteristics and the variable emotional states on the behaviour and performance of humans. The challenge to collect the right data in the light of numerous possible measures in the human factors area and the difficulty to report respective findings to non-human factors experts was underlined by Charlton (2002). Nevertheless, albeit a complete understanding of the applicability of human factors to the performance of tasks is missing from a safety engineering perspective, the paramount importance of human factors science and its potential to improve system safety and performance has been acknowledged (Sandom & Harvey, 2004).

Taking into account the challenges safety and human factors scientists and practitioners meet due to the complexity of modern socio-technical systems, and the need to minimize the distance between safety and human factors disciplines, this paper is a first attempt to show at a conceptual level the commonalities and differences between human factors science and a new paradigm in safety engineering, named STAMP (System Theoretic Accident Model and Processes). The current paper discusses how STAMP might foster a synergetic relationship between safety engineers and human factors scientists.

The STAMP model

STAMP is a model based on systems engineering and applied to socio-technical systems (Leveson N. , 2011). STAMP suggests that unwanted events occur mainly due to uncontrolled interactions of human, technological and external elements of systems and claims that a focus solely on reliability studies of individual system components does not suffice to ensure safety, security or other emergent system properties. The core concept of STAMP is the requirement to “close the loop”, in order to ensure that (human and computer) controllers receive feedback and become aware of how processes run, so they can make the required adjustments (i.e. control actions), and minimize the gap between the work-as-planned (i.e. control algorithm) and work-as-done (i.e. process/mental model) (Figure 1).

Training, work experience, time and productivity pressures, centralized and distributed decision making, individual unsafe actions, effects of the environment on human error, human-centred design, detection and perception, effects of automation, interdependencies, culture, leadership and management comprise some areas discussed as part of the STAMP theory (Leveson N. , 2011), thus indicating that STAMP, in principle, integrates various human factors topics.

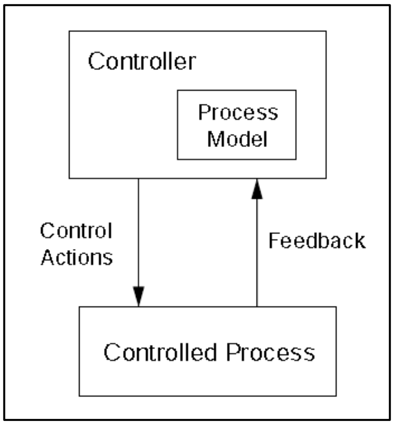


Figure 1. Basic Control Structure (quoted from Leveson, 2011)

STAMP is accompanied by the System Theoretic Process Analysis (STPA) method, which is a structured way to identify hazardous states and causal factors related to individual system components and their interactions (Leveson N. , 2011). Following the definition of accidents for the system under study, the derivation of high-level hazards and safety constraints, and the drawing of the control structure, the analyst with the support of an analytical method, first examines how the system can drift into uncontrolled states (i.e. Unsafe Control Actions - UCAs) and then explores why such states could emerge (i.e. Causal Factors). The key difference of STPA with other hazard identification methods is that the UCAs are linked to system states and temporal factors, therefore human error is examined in its context and is not viewed as a failure of the human component. The typical syntax of a UCA is “someone does (not) do something when the system is in a specific state”, indicating that the controller is not examined in isolation from the environment. Indeed, reliability of system components is still addressed in the level of causal factors and expert judgment is paramount in assessing why UCAs could happen. However, this is not the starting point of analysis; fully reliable systems can still be unsafe due to uncontrolled and unanticipated interactions of individual elements.

The examination of temporal factors and (co)existence of multiple system states and conditions are included in the glossary of STPA as a means to identify how control actions might prove hazardous. Both steps of “how” and “why” hazardous states emerge, lead to the generation of corresponding safety requirements and the engineering of risk controls. The final stage of the STPA is the development of scenarios, where the system is subject to various combinations of hazards and causal factors and is tested against those as a means to validate the results of the analysis and search for unidentified hazards, even the ones sourcing from the abundance and/or interlinks of risk controls.

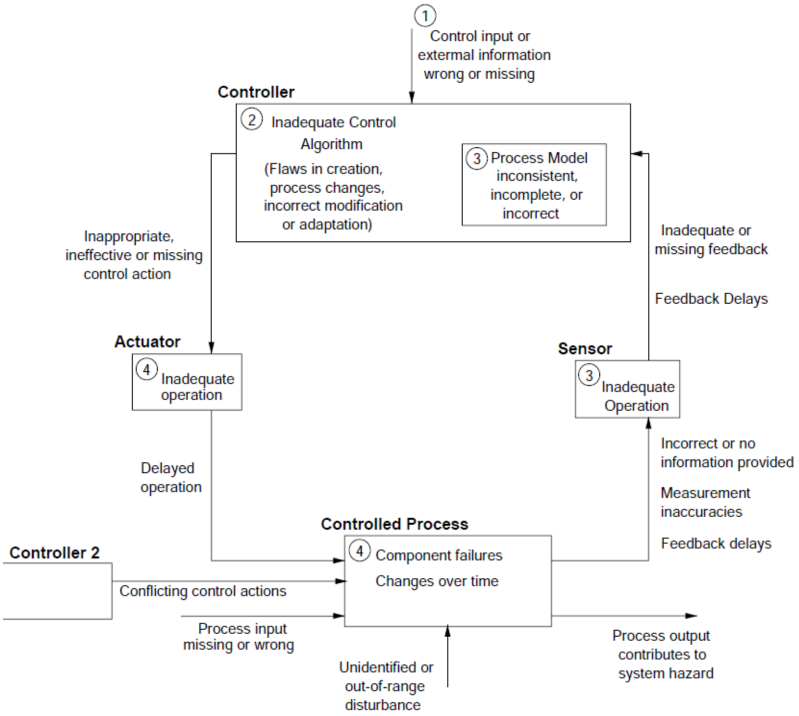


Figure 2. Control Flaws Leading to Hazards (quoted from Leveson, 2011)

Method

The current study had three objectives: (1) assessing the extent to which STAMP theory encompasses contemporary human factors topics, (2) showing how conceptually close the STAMP model and STPA method are with human factors ones, and (3) discussing how human factors science and safety engineering, through the lens of STAMP, can mutually benefit. In order to achieve the aforementioned objectives, a literature review of human factors related publications, partially specific to aviation, was performed. During the review the author listed the principal human factors topics discussed in the literature, and he considered: (a) three widely cited models suggested for the representation of human performance related processes [i.e. human information processing, (Wickens & Hollands, 1992); decision making, (Clarke, 1986); situation awareness, (Endsley, 1995)], (b) two representative task analysis methods [i.e. Task Decomposition (Kirwan & Ainsworth, 1992) and Tabular Task Analysis (Kirwan, 1994)] and (c) three human error categorizations [i.e. Systematic Human Error Reduction and Prediction Approach-SHEPRA (Embrey, 1986), Technique for the Retrospective and Predictive Analysis of Cognitive Errors--TRACEr (Shorrock & Kirwan, 2000) and Human Error Template-HET (Marshall, et al., 2003)].

The information collected from the literature references was compared against the principal STAMP/STPA reference (Leveson N. , 2011) in order to accomplish the study objectives 1 & 2. Since the work of Leveson (2011) is aimed to safety scientists and practitioners and not in human factors specialists, the researcher credited a reference to each human factors topic when the latter was mentioned as a contributing factor to unsafe events or a system variable that the analyst shall consider. The 3rd objective was achieved through a review of two process charting methods mentioned in human factors literature (i.e. Fault Tree Analysis and Event Tree Analysis) and a discussion of those in relation to the STAMP/STPA. Books were preferred over journal articles because the former sources are inclusive in terms of theories and research findings. The criteria for the selection of the books was the range of coverage of human factors subjects and their availability to the author. Table 1 presents the publications reviewed.

Table 1. Human Factors Literature Reviewed

Book Title and Reference (in alphabetical order of title)
Aviation Maintenance Technician Handbook, Chapter 14 (FAA, 2008)
Aviation Psychology and Human Factors (Martinussen & Hunter, 2010)
Cognitive Psychology: A Student's Handbook (Eysenck & Keane, 2000)
Handbook of Aviation Human Factors (Garland, Wise, & Hopkin, 2010)
Handbook of Human Factors Testing and Evaluation (Charlton & O'Brien, 2002)
Hierarchy of Needs by Abraham Maslow, a First Look at Communication Theory (Griffin, 1996)
Human Factors for Engineers (Sandom & Harvey, Human factors for engineers, 2004)
Human Factors in Aviation (Salas & Maurino, 2010)
Human Factors Methods: A Practical Guide for Engineering and Design (Stanton, Salmon, Walker, Baber, & Jenkins, 2005)
Human Performance on the Flight Deck (Harris, 2011)
Human Performance, Workload, and Situational Awareness Measures Handbook (Gawron, 2008)
Introduction to Human Factors and Ergonomics for Engineers (Lehto & Buck, 2008)
On The Design of Flight-Deck Procedures (Degani & Wiener, 1994)
Techniques of safety management (Peterson, 1971).
The handbook of human factors and ergonomics methods (Stanton, Hedge, Brookhuis, Salas, & Hendrick, 2004)

Results

The table in the Appendix presents the human factors related topics found in the literature reviewed, their connection with the components of Figures 1 & 2 as indicated in the theoretical foundations of STAMP/STPA in conjunction with the relevant human factors literature, and their reference in the work of Leveson (2011). It is clarified that even a single flaw on a STAMP/STPA component is expected to lead to cascade effects across the whole system; hence, column 2 of the table in the Appendix presents either the primary STAMP/STPA component that will be affected or multiple components that the specific human factor might influence at different or identical time points.

Although the categorization of human factors subjects is not always clear and is occasionally contradictory in the literature, the subjects included in the Appendix were grouped following a reconciliation of the literature reviewed. It is also noted that the topics reported in the Appendix might not be exhaustively inclusive. In addition, the human factors themes in the 1st column of the table in the Appendix might co-exist or be dependable to each other (e.g., health problems might affect the sensory system, knowledge is related to object recognition, fatigue affects the ability to concentrate).

Table 2 is based on the information of the Appendix and reports the frequencies and percentages of human factors topics referred in the literature reviewed and found in the STAMP/STPA theory. The acronyms used in the 2nd row of Table 2 are: CAL for Control Algorithm, CAC for Control Action(s), PM for Process Model, CINP for Control Input(s), PINP for Process Input(s), CON for other Controllers, and DIST for External Disturbances.

Table 2. Frequency and Distribution of Human Factors Topics in the STAMP/STPA theory.

Human Factors categories	Connection with STAMP components [number of factors in (Leveson N. , 2011) / number of factors in literature]							Total*	
	CAL	CAC	PM	CINP	PINP	CON	DIST	Ratio	%
Individual physiology factors	2/6	2/9	3/7	-	-	-	-	3/10	33%
Individual mental/cognitive factors	7/10	5/5	8/10	-	-	1/3	-	12/15	80%
Individual personality/emotion factors	3/7	-	-	-	-	1/3	-	3/8	38%
Effects on the individual	7/9	6/8	6/7	-	-	4/5	-	8/10	80%
Human-human interaction	-	-	-	-	-	5/7	-	5/7	71%
Physical working environment	0/4	0/7	0/5	-	-	-	1/1	1/8	13%
Technical/technological environment	1/1	3/4	4/5	-	-	-	-	6/7	86%
Organizational factors	10/12	-	2/2	2/2	2/4	7/9	-	14/16	88%
Task organization	-	8/12	-	-	-	-	-	8/12	67%
Work resources	1/1	-	-	-	4/4	-	-	5/5	100%
Total ratio	31/50	24/45	23/36	2/2	6/8	18/27	1/1	65/98	66%
%	62%	53%	64%	100%	75%	67%	100%		

* The column "Total" refers to discrete human factors topics and not the sum of each row since each topic in the Table is frequently connected with several STAMP/STPA components.

Table 3 presents a mapping of the components of STAMP/STPA with the elements included in the three human factors related models considered, as shown in Figures 3, 4 and 5.

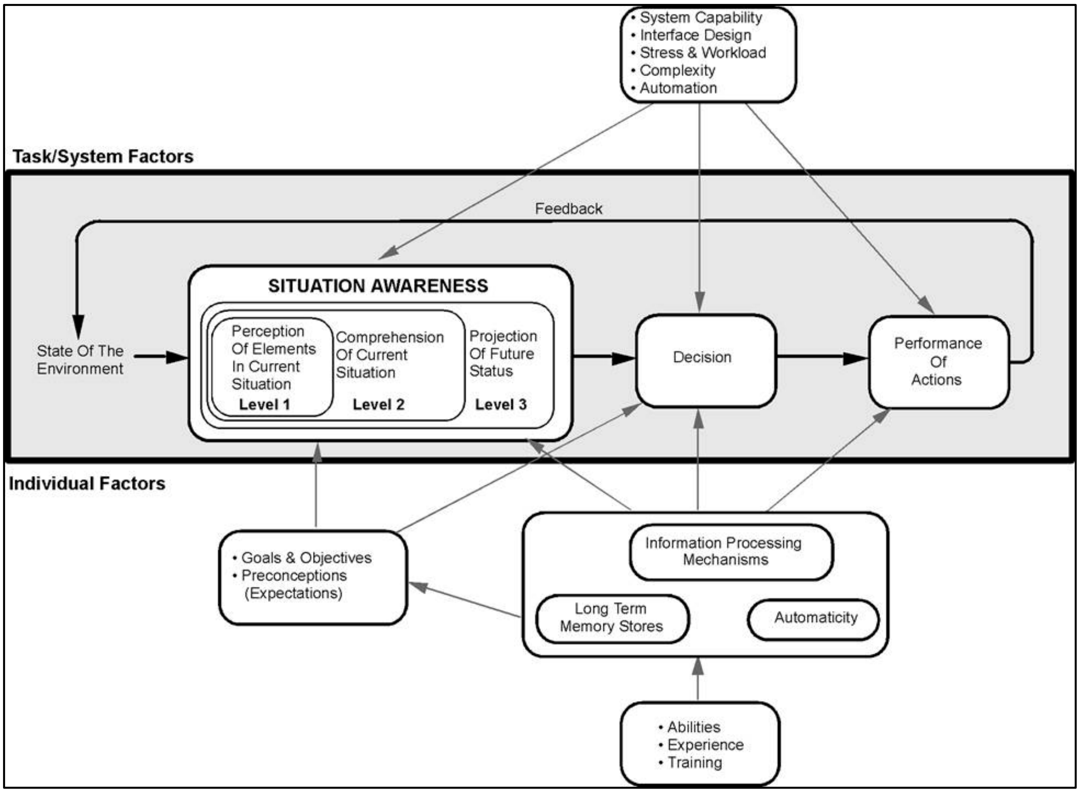


Figure 3. Situation Awareness model of Endsley (1995) (quoted from Martinussen & Hunter, 2010).

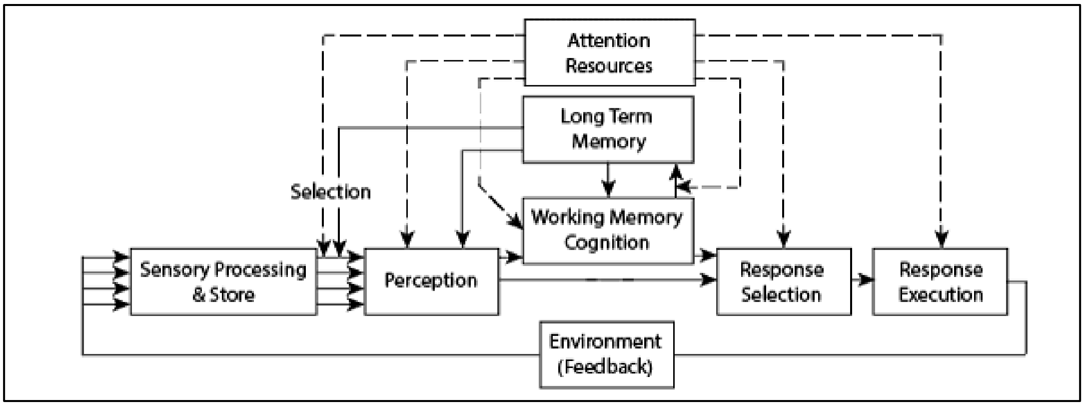
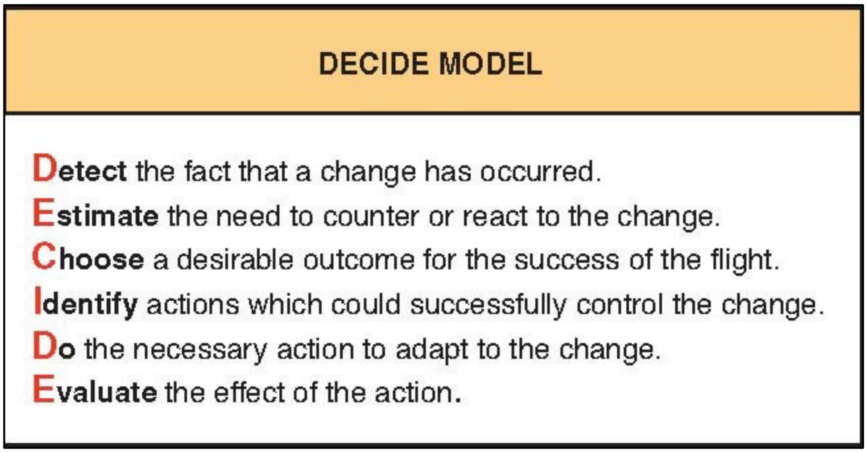


Figure 4. Human Information Processing model of Wickens (Wickens & Hollands, 1992) (quoted from Martinussen & Hunter, 2010).



DECIDE MODEL

Detect the fact that a change has occurred.
Estimate the need to counter or react to the change.
Choose a desirable outcome for the success of the flight.
Identify actions which could successfully control the change.
Do the necessary action to adapt to the change.
Evaluate the effect of the action.

Figure 5. DECIDE model of Clarke (1986) (retrieved from https://www.americanflyers.net/aviationlibrary/pilots_handbook/chapter_16.htm).

Table 3. Connection of STAMP/STPA components with Human Factors models

STAMP/STPA components (Leveson N. , 2011)	Situation Awareness (Endsley, 1995)	Information Processing (Wickens & Hollands, 1992)	DECIDE (Clarke, 1986)
Control algorithm	Comprehension, Projection, Decision, Information processing mechanisms, Goals and Objectives, Long term memory stores, Preconceptions, Expectations	Working Memory, Long Term Memory, Cognition, Response selection	Estimate, Choose, Identify, Evaluate
Control action(s)	Performance of Actions	Response Execution	Do
Actuator(s)	(Human body parts)	(Human body parts)	(Human body parts)
Controlled process	n/a	n/a	-
Sensor(s)	(Human senses)	(Human senses)	(Human senses)
Feedback	Feedback	Feedback	Detect
Process/mental model	Perception, Preconceptions, Expectations	Perception & Storage, Selection	Detect
Conditions and System States	State of the Environment, System capability, Interface design, Complexity, Automation	Environment	Detect
Variables and Causal factors	Abilities, Stress and & Workload, Experience, Training	Attention resources	-
Other controllers	Elements of the Environment	Environment	Detect
Process input(s)	Elements of the Environment	Environment	Detect
Process output	State of the Environment	Environment	Detect
External disturbances	State of the Environment	Environment	Detect

In regard to task analysis methods, Table 4 shows the terms used in the two methods reviewed along with the principal STAMP/STPA components. The underlying concept of Table 4 is that the overall task of an operator (i.e. focus of the task analysis methods) is to control a process (i.e. focus of STAMP/STPA).

Table 4. Categories of task analysis methods against STAMP/STPA categories

STAMP/STPA components (Leveson N. , 2011)	Task Decomposition (Kirwan & Ainsworth, 1992)	Tabular Task Analysis (Kirwan, 1994)
Control algorithm	Description of the task, type of activity, task verb, task performance, function/purpose, sequence of activity, critical values, decisions, success criteria	Task description
Control action(s)	Actions, responses, speed, accuracy	Action, possible errors
Actuator(s)	Controls	Controls
Controlled process	(task)	(task)
Sensor(s)	Displays	Displays
Feedback	Feedback	Feedback
Process/mental model	Initiating cue/event, information	
Conditions and System States	Adverse conditions/states	-
Variables and Causal factors	Skills/training, manning, hardware location, complexity, difficulty, criticality, attention, errors	Errors
Other controllers	Coordination, communication	-
Process input(s)	Job aids	-
Process output(s)	Output, error consequences	Error consequences
External disturbances	-	-

Table 5 shows the correspondence of human error categories with the types of Unsafe Control Actions (UCAs) of STPA, which have been coded as follows:

1: Control action is not provided
2: Unsafe control action is provided
3A: Control action is provided too late
3B: Control action is provided too early
3C: Control action is provided out of sequence
4A: Control action is stopped too soon
4B: Control action is applied too long

Table 5. Correspondence between Types of UCAs in STPA and Human Error Categories

SHEPRA (Embrey, 1986)		TRACEr (Shorrock & Kirwan, 2000)		HET (Marshall, et al., 2003)	
Category	UCA	Category	UCA	Category	UCA
S1. Operation too long	4B	T1. Omission	1	H1. Fail to execute	1
S2. Operation too short	4A	T2. Action too much	-	H2. Task execution incomplete	4A
S3. Operation in wrong direction	2	T3. Action too little	-	H3. Task executed in wrong direction	2
S4. Misalign*	3A, 3B, 3C	T4. Action on wrong direction	2	H4. Wrong task executed	2
S5. Right operation on wrong object	2	T5. Wrong action on right object	2	H5. Task repeated	2
S6. Wrong operation on right object	2	T6. Right action on wrong object	2	H6. Task executed on the wrong interface element	2
S7. Operation omitted	1	T7. Wrong action on wrong object	2	H7. Task executed too early	3B
S8. Operation incomplete	4A	T8. Extraneous act	2	H8. Task executed too late	3A
S9. Wrong operation on wrong object	2	T9. Action too long	4B	H9. Task executed too much**	-
S10. Check omitted	-	T10. Action too short	4A	H10. Task executed too little**	-
S11. Check incomplete	-	T11. Action too early	3B	H11. Misread information	-
S12. Right check on wrong object	-	T12. Action too late	3A	H12. Other	n/a
S13. Wrong check on right object	-	T13. Action repeated	2		
S14. Check mistimed	-	T14. Mis-ordering	3C		
S15. Wrong check on wrong object	-	T15. Unclear info transmitted	-		
S16. Information not obtained	-	T16. Unclear info recorded	-		
S17. Wrong information obtained	-	T17. Info not sought/obtained	-		
S18. Information retrieval incomplete	-	T18. Info not transmitted	-		
S19. Information not communicated	-	T19. Into not recorded	-		
S20. Wrong information communicated	-	T20. Incomplete info transmitted	-		
S21. Information communication	-	T21. Incomplete info recorded	-		
S22. Selection omitted	1	T22. Incorrect info transmitted	-		
S23. Wrong selection mode	2	T23. Incorrect info recorded	-		

* Interpreted as temporal misalignment

** Interpreted as force and not time related

Discussion

The information depicted in Table 2 reveals that STAMP addresses plenty of the human factors topics referred in the literature reviewed and convincingly demonstrates a transition from the view of human error as a failure, as it is widely seen in traditional safety and reliability theories, to a more systemic view of safety. However, it is noted that the work of Leveson (2011) does not include those topics as system variables or factors contributing to accidents in a distinctive list. Instead, human factors subjects are mentioned either in the discussion of accident cases or as concerns of the safety analyst/engineer in the context of system design, operation and management. Furthermore, Table 2 shows that the coverage of human factors in STAMP is highly variant when considering their categories. On one hand, individual mental/cognitive factors, effects on the individual, the technical/technological environment, organizational factors, and work resources are adequately discussed. On the other hand, individual physiology factors, personality/emotion factors, and the physical working environment are underrepresented in STAMP. When considering the correspondence of the human factors topics with the principal components of the STAMP model, it seems that the (non)reference of human factors subjects across those components is at the same level. All human factors that are linked to the controlled process and the external disturbances are mentioned in STAMP.

When viewing the correspondence of STAMP with the human factors models and task analysis methods reviewed, as presented in Tables 3 & 4, it is observed that the core requirement of STAMP, and systems engineering in general, for feedback provision is common. In terms of system components, the repetition of various elements of human factors models and task analysis methods in their correspondence with STAMP components (i.e. other controllers, process input(s), process output and external disturbances) indicates that STAMP is more descriptive. However, human factors models decompose further the control algorithm and process model; this is expected since the emphasis of such models is on the cognition/mental components and processes. The task analysis methods specifically concerned, it seems that external disturbances are not addressed and human errors are viewed rather as failures than symptoms of poor system design and management. Nevertheless, the Task Decomposition method is more descriptive regarding the control algorithm and includes variables that are not explicitly discussed in STPA (e.g., accuracy, speed, difficulty). The Tabular Task Analysis is less descriptive than both the STPA and Task Decomposition methods.

From the perspective of analytical power, TRACEr and SHEPRA include all cases of STPA UCAs. HET is the least inclusive model in comparison with

STPA and the two aforementioned human error categorizations. However, the glossary of STPA does not address errors related to force application, checking, and information provision, retrieval and recording. STPA addresses only the actions a user needs to perform in order to control/activate a process and overlooks that during operations more types of actions are required as part of (b) obtaining and maintaining information, which is connected to the operator's process model (e.g., a pilot retrieves information from a display by selecting a specific tab), and (b) transmitting information, which is part of the feedback provided to other controllers (e.g., a pilot reports the position of an aircraft to the air traffic controller) or data entered in systems such as the Flight Management Systems of aircraft. Those action types are still subject to the cases of UCAs, so their exclusion from the STPA analysis deprives it from inclusiveness. Also, TRACEr and SHEPRA decompose further UCA No 2 (i.e. Unsafe control action is provided) and the categorization of UCAs in STPA do not address the cases that higher or lower force is applied to a control. Nonetheless, when comparing TRACEr, SHEPRA and HET it seems that those are complementary rather than exhaustively inclusive in terms of the human error types listed.

Concerning the process charting methods reviewed and used in human factors (i.e. Event Tree Analysis and Fault Tree Analysis), those are derived from system reliability literature and emphasize on discrete tasks in isolation of the system states. Event Tree Analysis examines sequences of actions and, in a deterministic way, connects their success or failure to definite outcomes. In contrast, STPA handles unsafe actions as preconditions of hazardous states that might or might not result to unwanted outcomes depending on the conditions. For example, a failure to check flap setting during landing does not mean that an accident will occur since the flaps might be already in the right position or another controller might perform this action (e.g., automation or the co-pilot). Fault Tree Analysis starts with a top event and, under the concept that reliability equals to safety, the analyst through reductionism traces failures within the system that lead to the top event. Once more, this approach excludes system states that might render reliable components ineffective; example given, in the brake failure scenario discussed in Kirwan (1994) the top event is attributed to various failures of system components, but the case that the braking system might perfectly function and the brakes will not be effective due to slippery road conditions is not depicted. Certainly, as STAMP/STPA theory underlines, the boundaries of the system to be studied must be defined based on what can be controlled, without though neglecting external effects. The latter become part of the assumptions of the system design, operation and management and, instead of ignoring them, mechanisms must be in place in order to validate those.

Conclusions

Although STAMP aims mainly at safety engineers, it encompasses human factors topics at an adequate level and views modern socio-technical systems in a more holistic manner, beyond classic human performance reliability approaches. The human factors subjects discussed in STAMP might be enriched with the ones mentioned in the literature, and be catalogued in a distinctive part of a future publication as system variables and/or accident contributing factors. This will enable safety analysts to consider a comprehensive set of human factors and refer to specialists for integration of those into studies of systems.

The high level concept of system structure, as suggested by STAMP and systems engineering, is found in the human factors models and tasks analysis methods reviewed, the latter though being less descriptive than STAMP. Human factors scientists and practitioners can elaborate such models and tools based on the glossary of STAMP as a means to represent systems and processes in more detail and foster analysts' understanding and consideration of the fundamental system components.

From a perspective of methodology, STPA offers a more structured and holistic way in the analysis of systems by dealing with both unsafe system states due to uncontrolled interactions an interdependencies (i.e. STPA step 1) and causal factors (i.e. STPA step 2). However, the types of unsafe actions contemplated in STPA must be enriched with other types of actions as discussed in the previous section. Moreover, although most of the human factors engineering tools and methods aim at examining scenarios, in addition to single tasks, the relevant literature does not refer to methods for the development of such scenarios. STPA does not stop at the identification of hazards and causal factors. It requires from the analyst to apply a specific method for building scenarios and test the system against those by considering all possible system states and conditions.

Another significant part of STPA, which human factors science needs to consider, is that when factors cannot be addressed in terms of engineering risk controls (e.g., due to budget constraints or immature technology), those become assumptions of system design and operation and must be continuously monitored, not ignored. Although, equivalently, in human factors research the limitations are acknowledged, the latter are not explicitly required to be revisited in the future and, perhaps, included in following studies when the circumstances allow.

Certainly, there are many human factors books, methods and tools that were not reviewed in this paper. The scope was not to compare STAMP against all available human factors theories, but to offer an indication how close STAMP, as a safety engineering model, and human factors discipline sit and the way those can mutually benefit from their respective strengths and weaknesses. From a pragmatic view, safety and human factors science must consider than the plethora of theories, models, methods and tools does not help practitioners in speaking a common language and jointly design solutions. The complexity embedded and surrounding modern socio-technical systems dictates that human factors and safety scientists escape from their individual and group silos and cooperate within and between them so to suggest few, customizable and inclusive tools that will assist the design, management and operation of safe, yet financially viable, systems.

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