Towards a STAMP-Based Safety Plans Approach for Construction Projects

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Motivation

- **Accidents in Construction Industry**
- More fatalities in construction than in any other major industry in the U.S. (Data from 2014)
- That is the situation in many countries
- In Greece the number of fatalities has dropped due to the economic recession - but it is still considered high

- **STAMP Applied to Construction Site Safety**
- Up to now no works available!

Construction Projects: Safety Policies and SMS

Two layers:

1. Laws and regulations
   - Define system elements, their responsibilities and tools (i.e. a "top level" SMS) to ensure a minimum safety level
2. Construction companies with "in house" SMS

The Situation in Greece

Two sets of national laws and regulations in relation to construction safety

- The first set define:
  - The components of the "Top Level" SMS, their roles, their responsibilities
  - A set of minimum safety requirement that should be enforced in every construction site
  - A set of tools to ensure a minimum level of safety
- The second set define:
  - Rules and constraints for specific construction activities and specific construction sites
- Owners have to submit – among other things – a Construction Safety Plan in order to receive the permit

Construction Safety Plans

- A preliminary hazard analysis of the construction project

General Description of Something That is Prerequisite to Accidents

Potential Harmful Events / Conditions

			Construction Phases	
Hazards		**Sources of Hazards**	**Phase 1**	**Phase 2**
2100	2101	Collision Vehicle - Vehicle	1	1
Vehicles and machinery	2102	Collision Vehicle - Human	1	1
movement	2103	Collision Vehicle - Obstacle	1	1
	2104	Crush Vehicle - Vehicle	1	1
	2105	Crush Vehicle - Obstacle	1	1
	2106	Uncontrolled Traffic - System Failures		1
	2107	Uncontrolled Traffic-Incomplete Immobilization		
	2108	Movement on Rails-Insaficient Protection		
	2109	Movement on Rails - Derailment		

ΦΑΣΕΙΣ ΕΡΓΑΣΙΑΣ	1) Χωματουργικά	1.1	Προετοιμασία εργοταξίου
		1.2	Καθαιρέσεις - Αποξηλώσεις
		1.3	Εκσκαφές
		1.4	Επιχώσεις
	2) Τεχνικά έργα	2.1	Σκυροδετήσεις
		2.2	Κράσπεδα-πλακοστρώσεις
	3) Λοιπές εργασίες επισκευών	3.1	Αστικός εξοπλισμός
		3.2	Δίκτυο ομβρίων

			Φάση 1				Φάση 2		Φάση 3	
Κίνδυνοι	**Πηγές κινδύνων**		**Φ1.1**	**Φ1.2**	**Φ1.3**	**Φ1.4**	**Φ2.1**	**Φ2.2**	**Φ3.1**	**Φ3.2**
6400	6401									
Άλλη πηγή	6402									
07000. Ηλεκτροπληξία										
7100	7101	Προϋπάρχοντα εναέρια δίκτυα	1				3			
Δίκτυα -	7102	Προϋπάρχοντα υπόγεια δίκτυα			3		3			
Εγκαταστάσεις	7103	Προϋπάρχοντα εντοιχισμένα δίκτυα								
	7104	Προϋπάρχοντα επίτοιχα δίκτυα								
	7105	Δίκτυο ηλεκτροδότησης έργου	1	1	1		1		1	
	7106	Ανεπαρκής αντικεραυνική προστασία								
7200 Εργαλεία	7201	Ηλεκτροκίνητα μηχανήματα	1	2	2	2	2		2	2
Μηχανήματα	7202	Ηλεκτροκίνητα εργαλεία	1	2	2	2	2		2	2
08000.Πνιγμός-Ασφυξία										
8100	8101	Υποβρύχιες εργασίες								
Νερό	8102	Εργασίες εν πλω								
	8103	Βύθιση / ανατροπή πλωτού μέσου								
	8104	Παρόχθιες / παράλιες εργασίες. Πτώση								
	8105	Παρόχθιες / παράλιες εργασίες. Ανατροπή μηχανήματος								
	8106	Υπαίθριες λεκάνες. Δεξαμενές. Πτώση	1	1	1	1	2			
	8107	Υπαίθριες λεκάνες. Δεξαμενές. Ανατροπή μηχανήματος								
	8108	Πλημμύρα. Κατάκλιση έργου			1	1				1
8200	8201	Βάλτοι. Ιλείς. Κινούμενες άμμοι								
Ασφυκτικό	8202	Υπόνομοι, βόθροι, βιολογικοί καθαρισμοί								
περιβάλλον	8203	Βύθιση σε σκυρόδεμα, ασβέστη κλπ					3			
	8204	Εργασία σε κλειστό χώρο. Ανεπάρκεια οξυγόνου								

A Proposed STAMP – Based Approach

- **Key assumption**

The construction process is brought to completion thanks to an "adaptive system"

The system must achieve different goals in each construction phase

Therefore, it has to change its structure and as result its interactive behavior, typically in its "lower" hierarchical levels

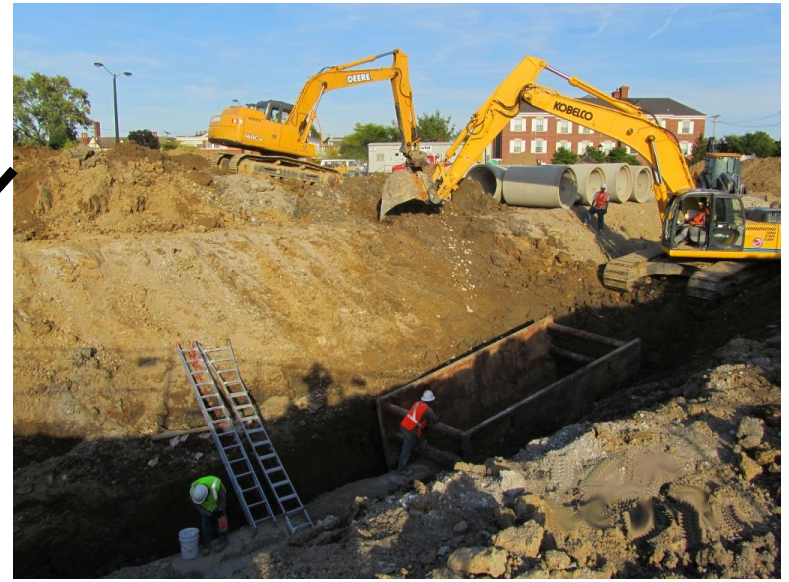
Owner / Authority X

Senior Engineer of Company Y

Supervising Engineer

Construction Site

- Phase 1

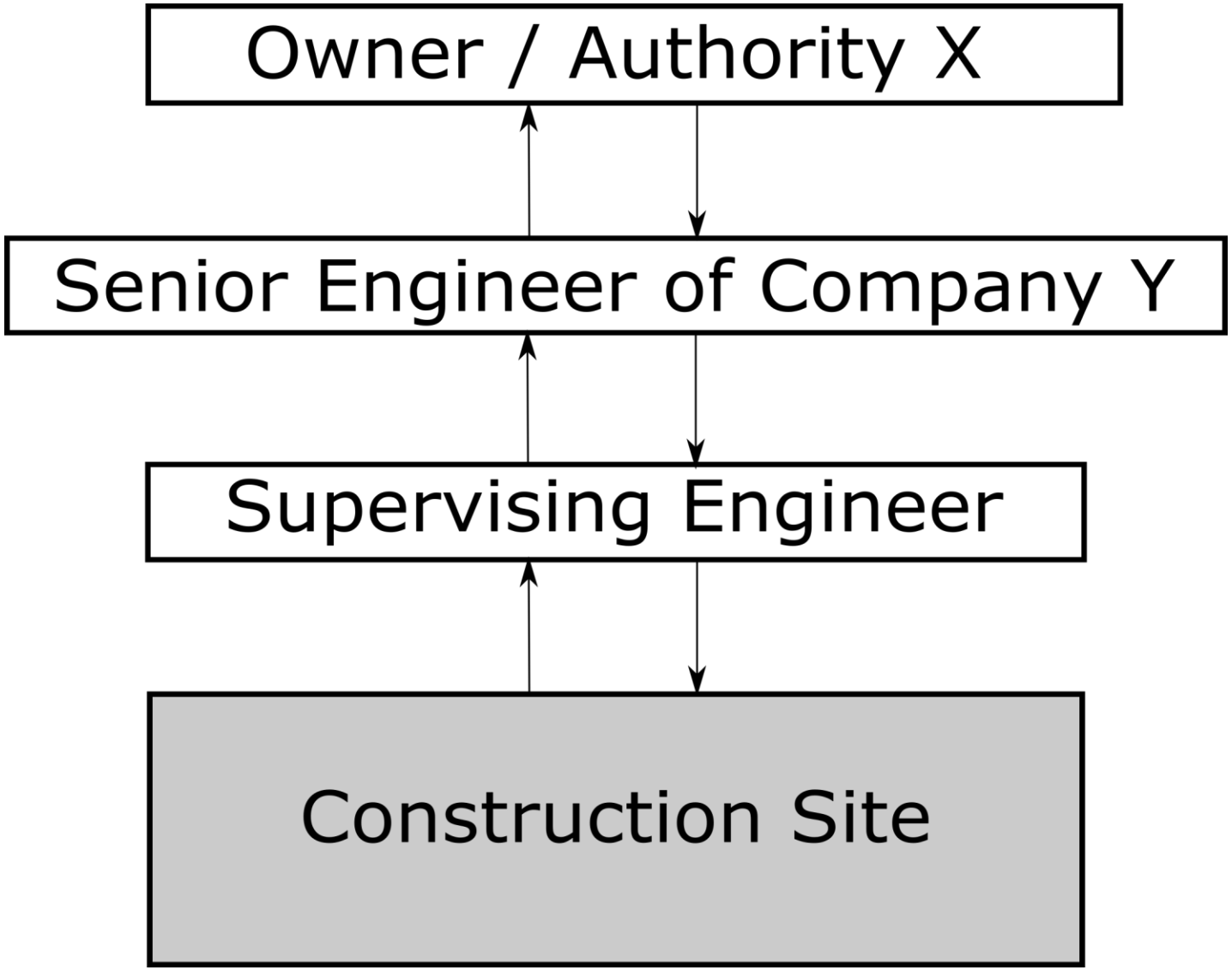


- Phase 2

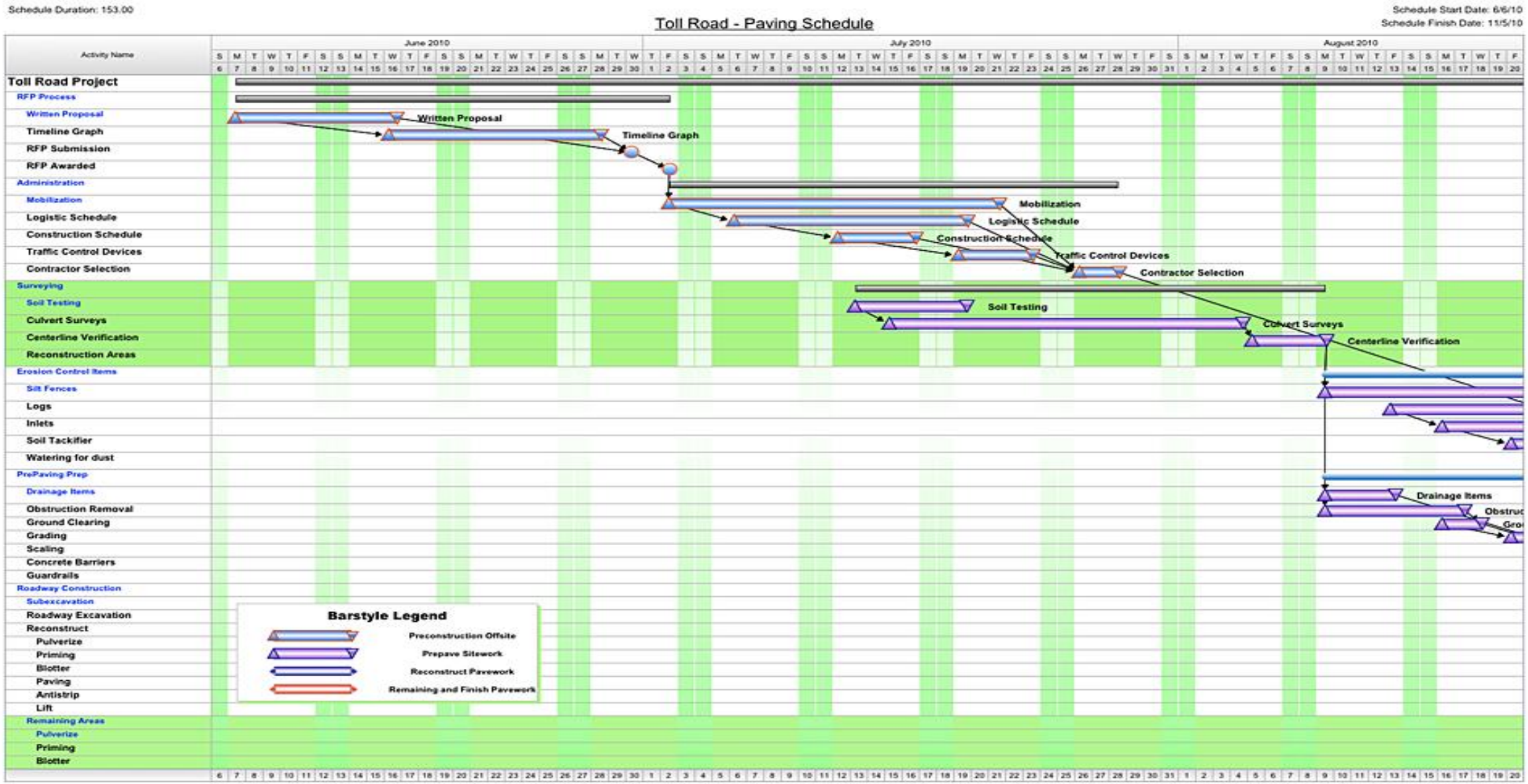
STAMP – Based Safety Plans Approach

- Identify the losses (human lives, property damage, environmental degradation, time, money)
- Define the "core" control structure
- Identify the:
  a) construction phases and sub-phases
  b) system elements of the lower hierarchical levels needed to fulfill the tasks of each phase and sub-phase (workers, equipment, machinery etc.)
  c) environmental conditions useful to the analysis (e.g. terrain)
  d) laws and regulations
- For each construction phase identify the hazards, as per the STAMP definition
- For each hazard identify:
  a) causal scenarios (do not forget to note the assumptions made)
  b) safety specification and/or possible corrective actions

A Typical “Core” Control Structure



Construction Phases and Sub-phases



Hazards

- Phase – Excavation
  - H1: A person or worker is standing/working under - or passing through - the excavators' range cycle
  - H2: Excavator within the vicinity of overhead electric lines
- Translate hazards into safety constraints

Causal Scenarios – Step 1

- Create the control structure of the "micro system" responsible for the execution of the tasks in each construction phase
- Assign to the workers and to the machineries involved in the construction phase the roles of the feedback loop elements

E.g. The worker X is the spotter of the excavation (i.e. has the role of the sensor). The operator of the excavator has the role of the controller. The excavator has the role of the actuator

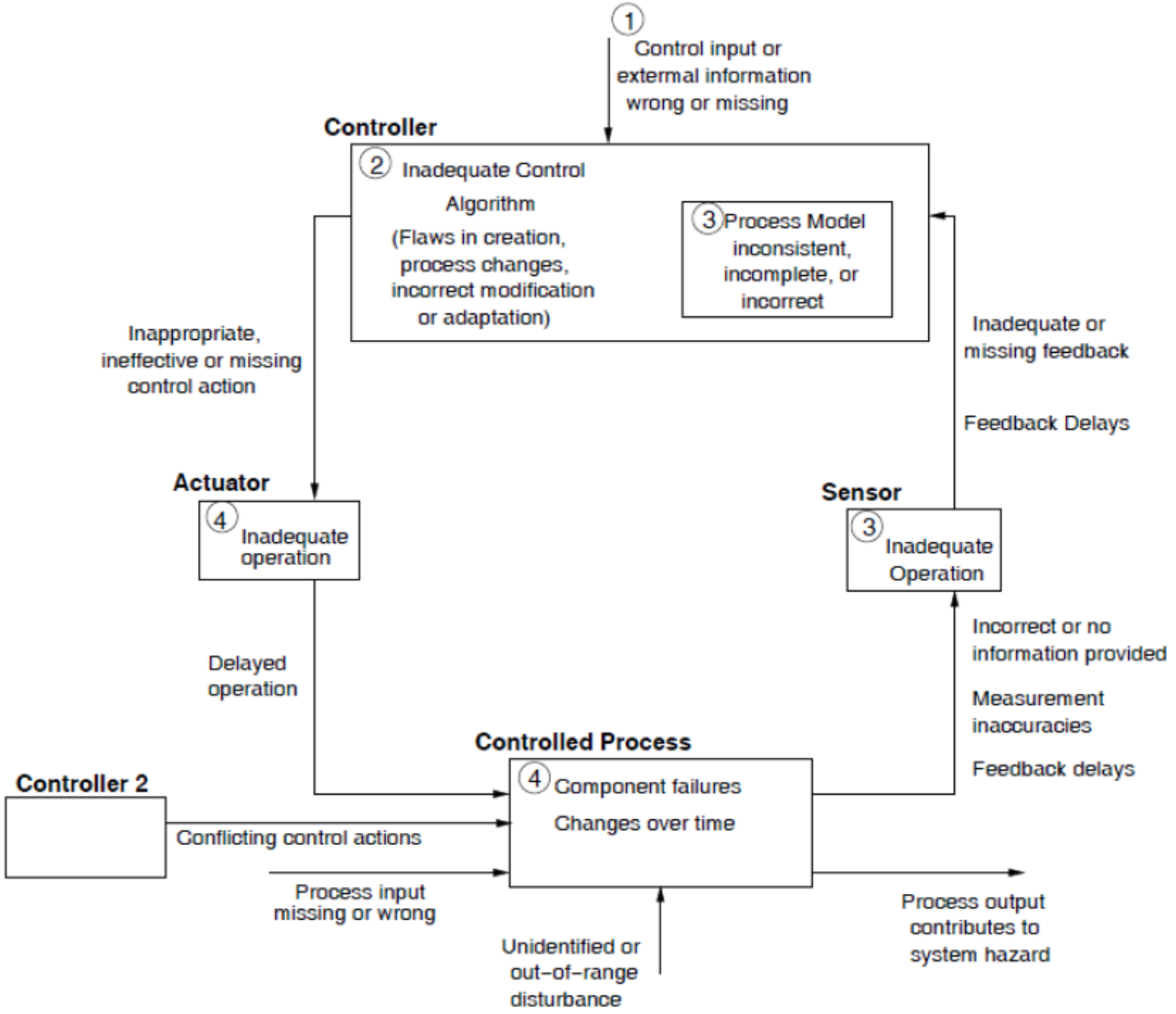


Figure 2.14 Things that can go wrong in the control loop

Causal Scenarios – Step 2

- Create scenarios on how each hazard could be realized (i.e. Apply directly STEP 2 of STPA)
- Example: H1: A person or worker is standing/working under - or passing through - the excavators' range cycle
- H1 – Sc1 The operator of the excavator is not aware that a worker is close to the machinery because: a) although the spotter detected the worker and yelled/signaled the operator to stop, the operator was not able to hear the spotter due to noise. b) although the spotter detected the worker and yelled/signaled the operator to stop, the operator was not able to hear the spotter due to noise and the spotter used a sign that was insufficient to attract the vision of the operator or he is was in a spot within operators' vision range
- H1 – Sc2 The spotter is located in a place where he/she can not see the worker entering the vicinity of the excavator

Preliminary Safety Specifications

Phase/Sub-phase	Accident	Hazard	Causal Scenarios	Safety Recommendations
Excavation	Death/Injury of worker	H1	H1-Sc1	Radio communication should be in the disposal of the spotter and the operators
				The spotter should have in his disposal visual signs to attract the attention of the operators
			H1-Sc2	The spotter should be in a positions which will provide him the maximum possible observation range and minimum blind spots

Why not Applying STEP 1 of STPA?

- You can apply it!
- It was found however to be not so practical for a preliminary hazard analysis in the context of a construction
  - Many control actions
  - Too many assumptions
- More work needs to be done however to be 100% sure of the benefits to omit STEP 1 of STPA

Initial Results

- The proposed approach was applied to a number of small construction projects
- Very promising results
  - Much better quality of results compared to the Safety Plans which were submitted by the owners to receive the construction permit
- More work needs to be done!
  - Improve the approach in various aspects
  - To assess its acceptance by the safety engineers in this domain

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