



Design risk analysis: An attribute-based method



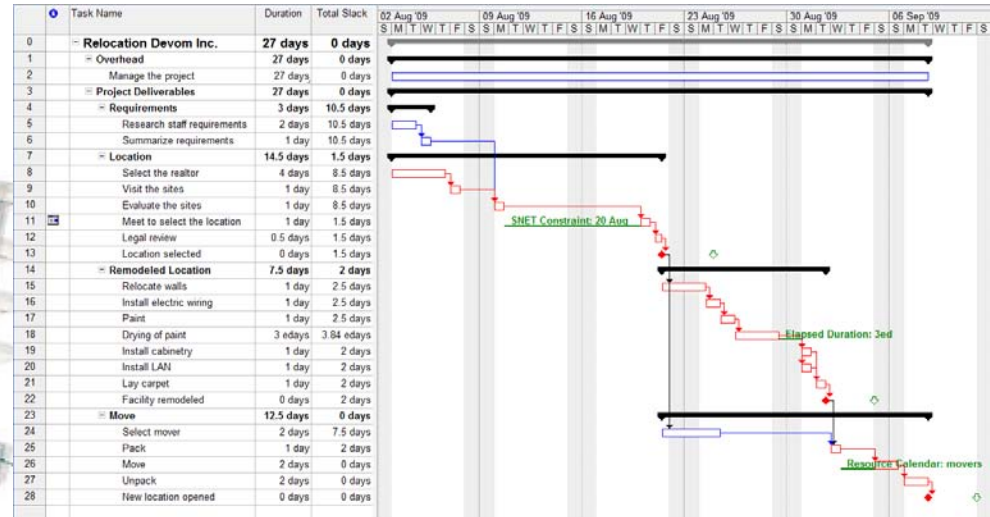
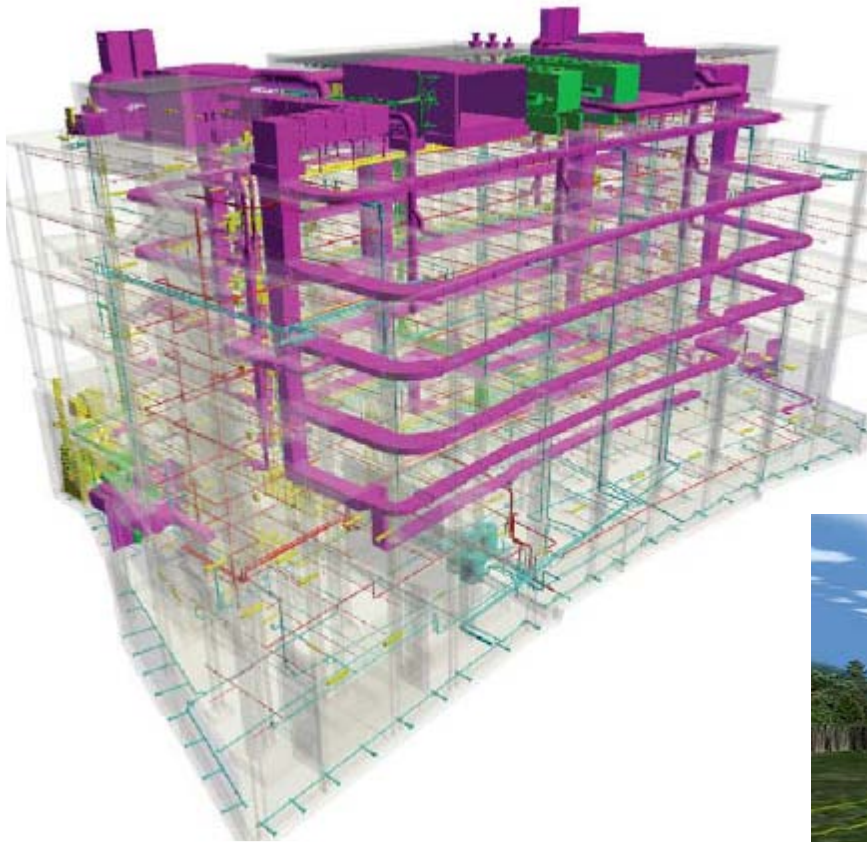
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Emerging strategies





Background

Preconstruction Safety Management

Integration of safety:

- Facility Design
- Specifications
- Schedules
- BIM

Barriers

- OSHA responsibility
- DBB delivery
- Industry fragmentation
- Lack of incentives
- Fear of liability
- Safety knowledge
- Tools

- ✓ A potential solution to these issues may be a risk-based method that incorporates valid, reliable and robust data



Risk Quantification

- ❖ Risk: A potential event that results in an outcome that is different from what is planned (e.g., an injury)
- ❖ Frequency – How often the risk event occurs (inj. / 200,000 w-h)
- ❖ Severity – Magnitude of the outcome of the risk event (\$)
- ❖ Exposure – Duration of contact with the hazardous condition (w-h)

$$\text{Risk (\$)} = \text{Frequency (inj/w-h)} \times \text{Severity (\$/in)} \times \text{Exposure (w-h)}$$

- ❖ Provides an objective measure of the importance of a particular condition





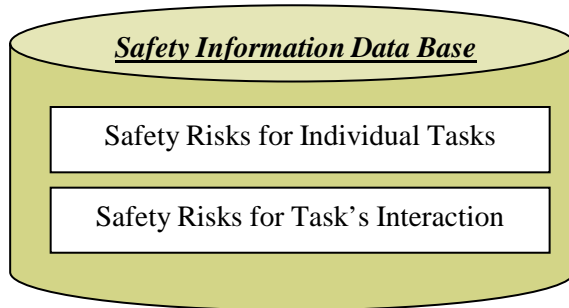
Results of risk research

- ❖ Risks can be quantified and modeled for:
 - ❖ Construction trades (Jannandi and Almishari 2003)
 - ❖ Work environments (Barandan and Usmen 2006; Navon and Kolton 2006; Rozenfield et al. 2010)
 - ❖ Specific Tasks (Hallowell and Gambatese 2009)
- ❖ Spatial and temporal interactions can be measured (Hallowell et al. 2011)
- ❖ These data can be integrated with CPM scheduling and BIM to predict high risk work periods and locations (Sacks et al. 2009)



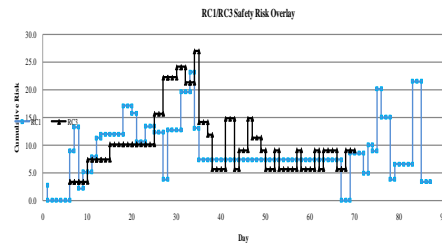


Integration



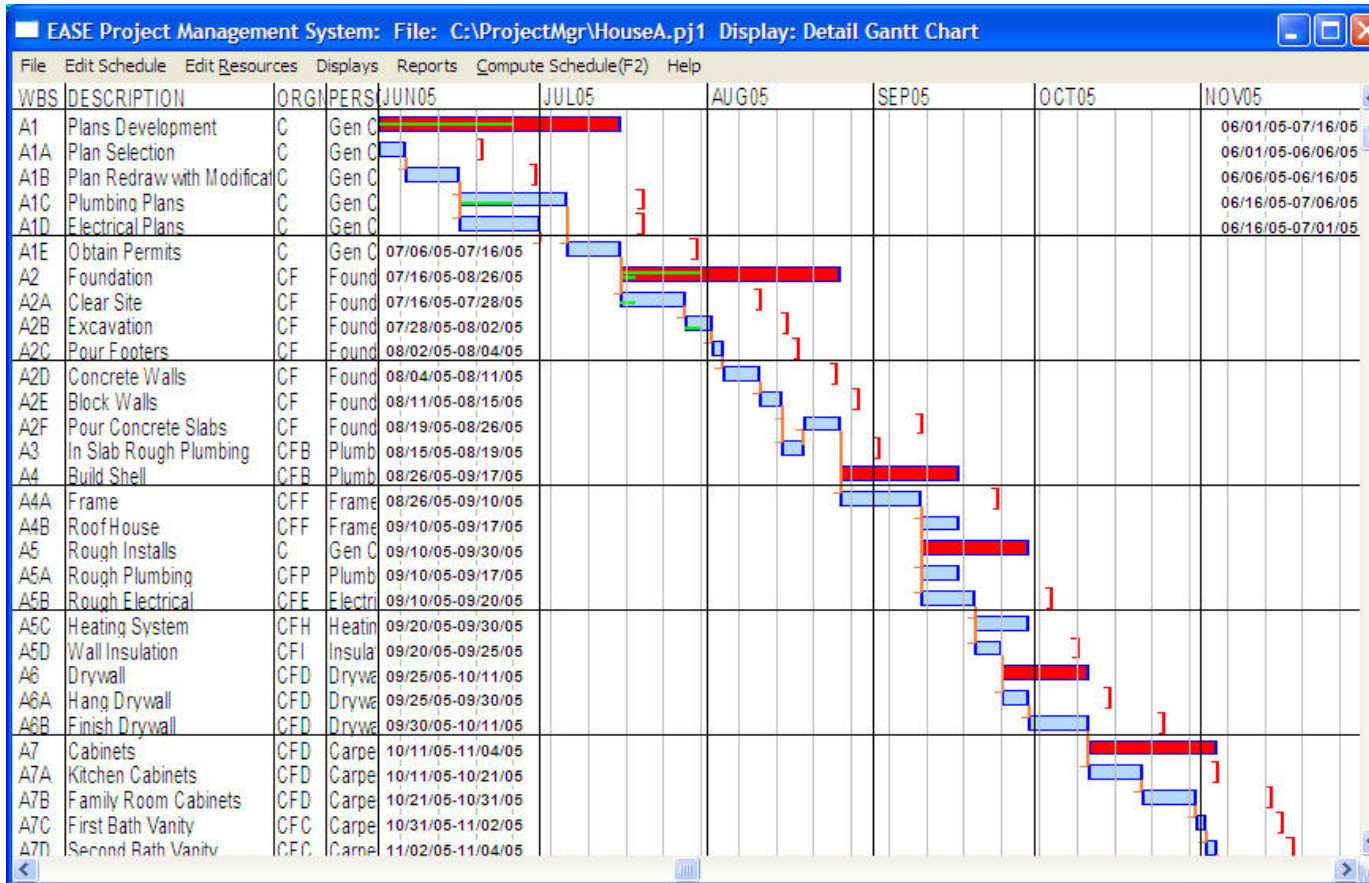
Act ID	Description	Orig Dur	Early Start	Early Finish
PRE-CONSTRUCTION				
1000	Write RFP for Architects	90	02JAN03	12JAN03
1070	Yanhill County Review of RFP	60	13JAN03	02JAN03
1090	Advise RFP for Architects	60	26JAN03	05JAN03
1040	Review Proposals from Architects	120	16JAN03	28JAN03
1000	Determine Contracting Method	200	28JAN03	25JAN03
1010	Interview Architects	10	28JAN03	28JAN03
1080	Design	500	30JAN03	08OCT03
1200	Yanhill County Vacates Upstairs Offices	100	15JAN03	28JAN03
1080	Exploration Demo (By Yanhill County)	200	02SEP03	01OCT03
1160	Asbestos Abatement (if Necessary)	150	18SEP03	08OCT03
1100	Out for Bid	200	08OCT03	09NOV03
1130	Plan Review and Building Permit	250	08OCT03	12NOV03
1120	Selection of Contractor	100	08NOV03	18NOV03
LONG LEAD PROCUREMENT ITEMS				
1180	Detention Shop Drawing Creation and Review	300	20NOV03	02JAN04
1340	MEP Submittal Creation & Review	300	20NOV03	02JAN04
1140	Detention Doors, Frames, & Hardware	600	02JAN04	29MARD4
1360	MEP Detention Equipment	600	02JAN04	29MARD4

Integrate database with project schedules to produce temporal plots of safety risk





The problem of risk integration





Results Safety Risk Interaction

Round 3

EFFECT ON

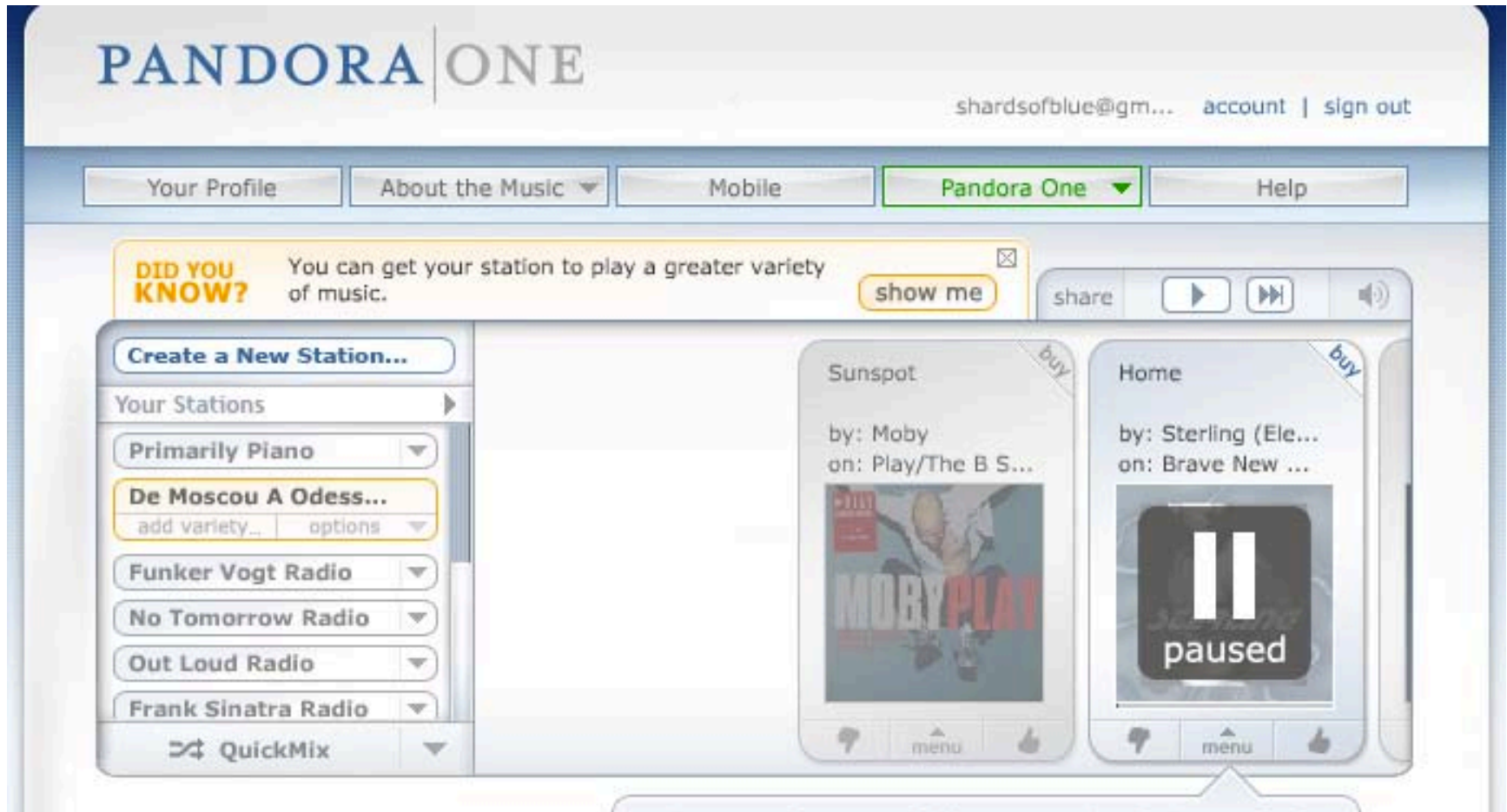
Tasks	EFFECT ON																											
	Clear and grub	Excavation	Demolition of existing pavement	Landscape	Watering and dust palliatives	Reset structures	Lay aggregate base course	Recondition bases (compaction)	Installing flexible pavement/patching	Install rigid pavement (concrete)	Heat and scarifying	Recycle cold bituminous pavement	Prime, coat, rejuvenate pavement	Seal joints and cracks	Install cribbing	Install culverts, drains, and sewers	Install curb and gutters	Install traffic control devices	Install water control devices	Install culvert pipe and water lines	Install field facilities	Survey	Mobilization/demobilization	Pavement marking	Construction zone traffic control			
Clear and grub	1	0.2	0.2	0.1	0	0.1	0.2	0.2	0.1	0	0	0	0	0	0.4	0.1	0	0	0.2	0.2	0	0.2	0	0.1	0	0.2	0	
Excavation	0.4	1	0.4	0.4	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.2	0.2	0.2	0.4	0.1	0.2	0	0.2	0.2	0.2	0.2	
Demolition of existing pavement	0.2	0.2	1	0.2	0.2	0.4	0.2	0.2	0.2	0.4	0.4	0.2	0.2	0	0	0.2	0.3	0.3	0.2	0.2	0	0.2	0	0.1	0	0.1	0.4	
Landscape	0.4	0.4	0.1	1	0.2	0	0.2	0	0.2	0	0	0	0	0	0.2	0	0	0	0.2	0.2	0	0.1	0	0.2	0	0	0	
Watering and dust palliatives	0	0.2	0.2	0	1	0.2	0.2	0.2	0	0	0.2	0	0	0	0	0.1	0	0.1	0	0	0	0.1	0	0	0	0	0	
Reset structures	0.2	0.2	0.4	0.2	0.2	1	0.2	0.2	0.2	0.6	0.4	0.3	0.6	0.2	0	0.2	0.3	0.2	0.2	0.2	0	0.2	0	0.2	0.4	0		
Lay aggregate base course	0	0.2	0.3	0.1	0	0.2	1	0.3	0.2	0.4	0.3	0.5	0.2	0	0	0.2	0.3	0.3	0.2	0.4	0	0.2	0	0.1	0.4	0		
Recondition bases (compaction)	0.2	0.2	0.3	0.2	0.2	0.2	1	0.2	0.2	0.4	0.2	0.3	0.3	0	0.2	0.2	0.3	0.4	0.2	0.2	0	0.2	0	0.2	0.2	0.2		
Installing flexible pavement/patching	0	0.2	0.2	0.2	0.2	0.4	0.2	0.5	1	0.5	0.4	0.5	0.5	0.4	0.2	0.2	0.2	0.4	0.1	0.2	0	0.1	0	0.2	0.4	0		
Install rigid pavement (concrete)	0	0.2	0.2	0.1	0.2	0.2	0.2	0.4	0.2	1	0.4	0.4	0.2	0	0	0.2	0.6	0.3	0.2	0.2	0	0.1	0	0.2	0.6	0		
Heat and scarifying	0	0.2	0.2	0.1	0.2	0.2	0.1	0.3	0.2	0.2	1	0.3	0.2	0.2	0	0.1	0.3	0.3	0.2	0.2	0	0.1	0	0.2	0.2	0.2		
Recycle cold bituminous pavement	0	0.2	0.3	0.2	0.1	0.1	0.2	0.4	0.2	0.2	0.2	1	0.4	0.2	0.2	0.2	0.3	0.2	0.2	0.4	0	0.1	0	0.1	0.4	0		
Prime, coat, rejuvenate pavement	0	0	0.2	0.1	0	0.2	0.2	0.4	0.2	0.3	0.4	0.3	1	0.2	0	0.2	0.3	0.2	0.1	0.2	0	0.2	0	0.2	0.4	0		
Seal joints and cracks	0	0	0.3	0	0	0.3	0.2	0.2	0.2	0.4	0.2	0.4	0.4	1	0	0.2	0.1	0.2	0.1	0.2	0	0	0.2	0.2	0.4	0		
Install cribbing	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0	0.2	0.2	0	0.2	0	0	1	0.2	0.1	0.1	0.2	0.2	0	0.1	0	0.2	0.2	0.2		
Install culverts, drains, and sewers	0.2	0.4	0.4	0.2	0.2	0.3	0.2	0.4	0.2	0.3	0	0	0.2	0.2	0.2	1	0.4	0.1	0.2	0.2	0	0.2	0	0.2	0.2	0.2		
Install curb and gutters	0	0.2	0.4	0.2	0.2	0.3	0.2	0.4	0.2	0.6	0.4	0.4	0.2	0.2	0	0.3	1	0.3	0.2	0.2	0	0.2	0	0.2	0.2	0.2		
Install traffic control devices	0	0.2	0.2	0.2	0	0.2	0.4	0.3	0.3	0.6	0.1	0.2	0.2	0	0.3	0.4	1	0.2	0.2	0	0	0.1	0.2	0.3	0.4	0		
Install water control devices	0.2	0.4	0.2	0.2	0.2	0.1	0.1	0.1	0	0.2	0	0.1	0	0	0.2	0.2	0.3	0.1	1	0.2	0	0	0	0.1	0.2	0.2		
Install culvert pipe and water lines	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.3	0.2	0.3	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0	0.2	1	0	0.2	0.2	0.2	0.2	0.2		
Install field facilities	0	0	0.1	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.2	0	0	0		
Survey	0	0.2	0.2	0.1	0	0	0.2	0	0.1	0	0.2	0	0.2	0	0	0	0	0	0.2	0	0	1	0.1	0	0	0		
Mobilization/demobilization	0	0	0.1	0.1	0	0	0.2	0.1	0.1	0	0	0	0	0	0	0.2	0	0	0.1	0	0	0	1	0.2	0	0		
Pavement marking	0	0	0.2	0.1	-0	0.2	0.1	0.3	0.2	0.2	0.4	0.4	0.3	0.5	0	0.1	0.3	0.3	0	0.2	0	0.2	0	1	0.2	0		
Construction zone traffic control	0	0.2	0.4	0	0.3	0.2	0.4	0.4	0.5	0.5	0.5	0.5	0.2	0.6	0	0.2	0.3	0.6	0.2	0.2	0	0.3	0.2	0.4	1	0		

EFFECT OF



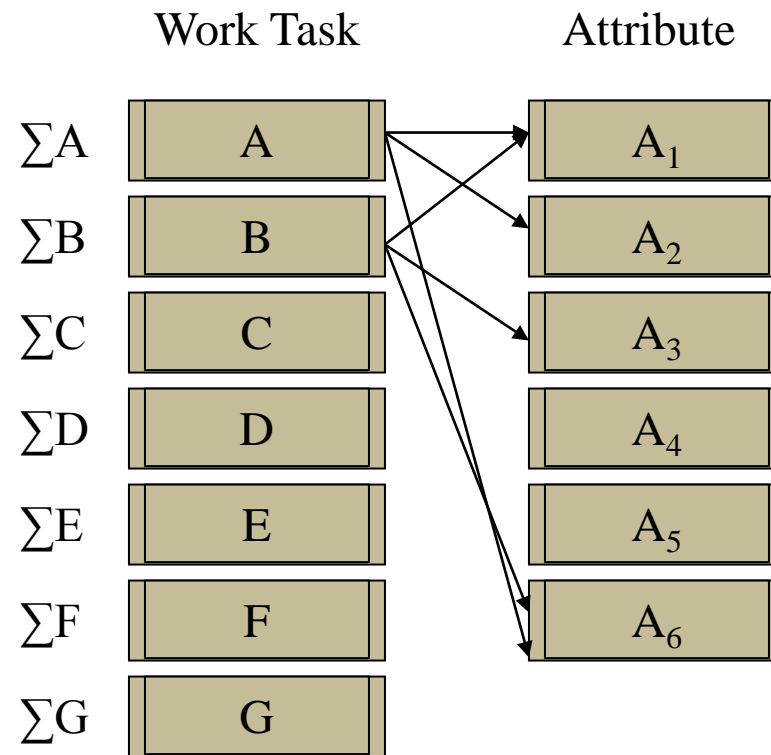


Potential solution





Potential solution





Research Questions



- ❖ What are the shared attributes of tasks and designs that fundamentally cause injuries?
- ❖ What is their relative magnitude?
- ❖ How do they interact?
- ❖ How can they be prevented and managed?

Research Objectives

1. Identifying safety risk attributes that lead to fall fatalities and quantifying their relative safety risks;
2. Using cluster analysis to identify the most efficient safety intervention for a particular case.



Content Analysis



**Social Network
Analysis**



Research Methods: Attribute Identification

Phase I

- ❖ *Content analysis* is a scientific method that provides valid inferences from a textual data, is empirically grounded, and helps researchers to quantify the frequency and distribution of content in text (*Krippendorf 2004*).
- ❖ NVIVO
 - ✓ Attributes are latent
 - ✓ Must recognize complex patterns in the text,
 - ✓ All contextual
- ❖ Fatality Assessment and Control Evaluation (**FACE**) reports provided by NIOSH have been used for the study (**105 reports**).
- ❖ Started with falls



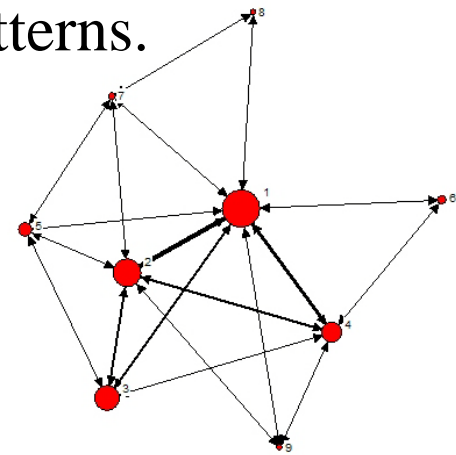


Research Methods: Cluster Analysis

Phase II

- ❖ Interactions among attributes can be strategically modeled to quantify relationships in past cases
- ❖ Social Network Analysis (SNA) was employed
- ❖ SNA has been chosen for this study because:
 1. Strong mathematical background;
 2. Visualization techniques to study patterns.

UCINET5



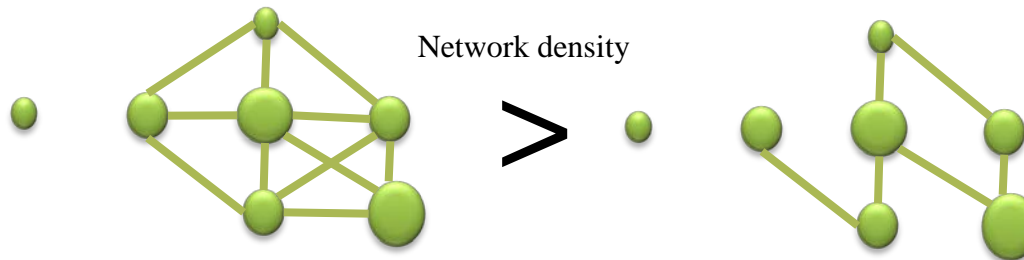


Research Methods

Phase II

➤ Network Density

- ❖ **Network density:** measures the volume and intensity of the interactions among network actors.
 - ✓ The ratio between the actual number of links and the maximum number of possible links.
 - ✓ Arrangement of the links?



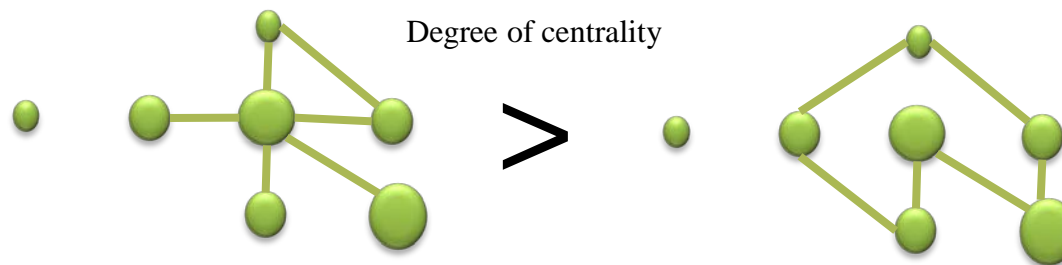


Research Methods

Phase II

➤ Degree of Centrality

- ❖ ***Degree of centrality***: indicates how interactions are distributed in the network.
 - ✓ measures the importance of an attribute as defined by its relationships with the others



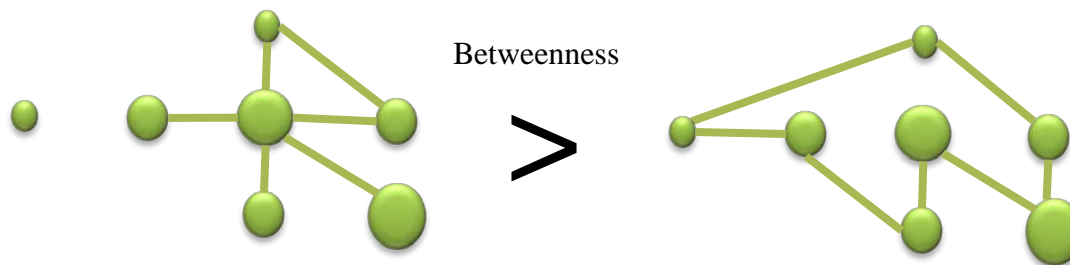


Research Methods

Phase II

➤ Betweenness

- ❖ **Betweenness:** is a measure of the number of attributes that has been connected via a specific attributes.
 - ✓ Which attributes make a bridge between other attributes to cause accidents.
 - ✓ “Chain of events”





Results and Analysis

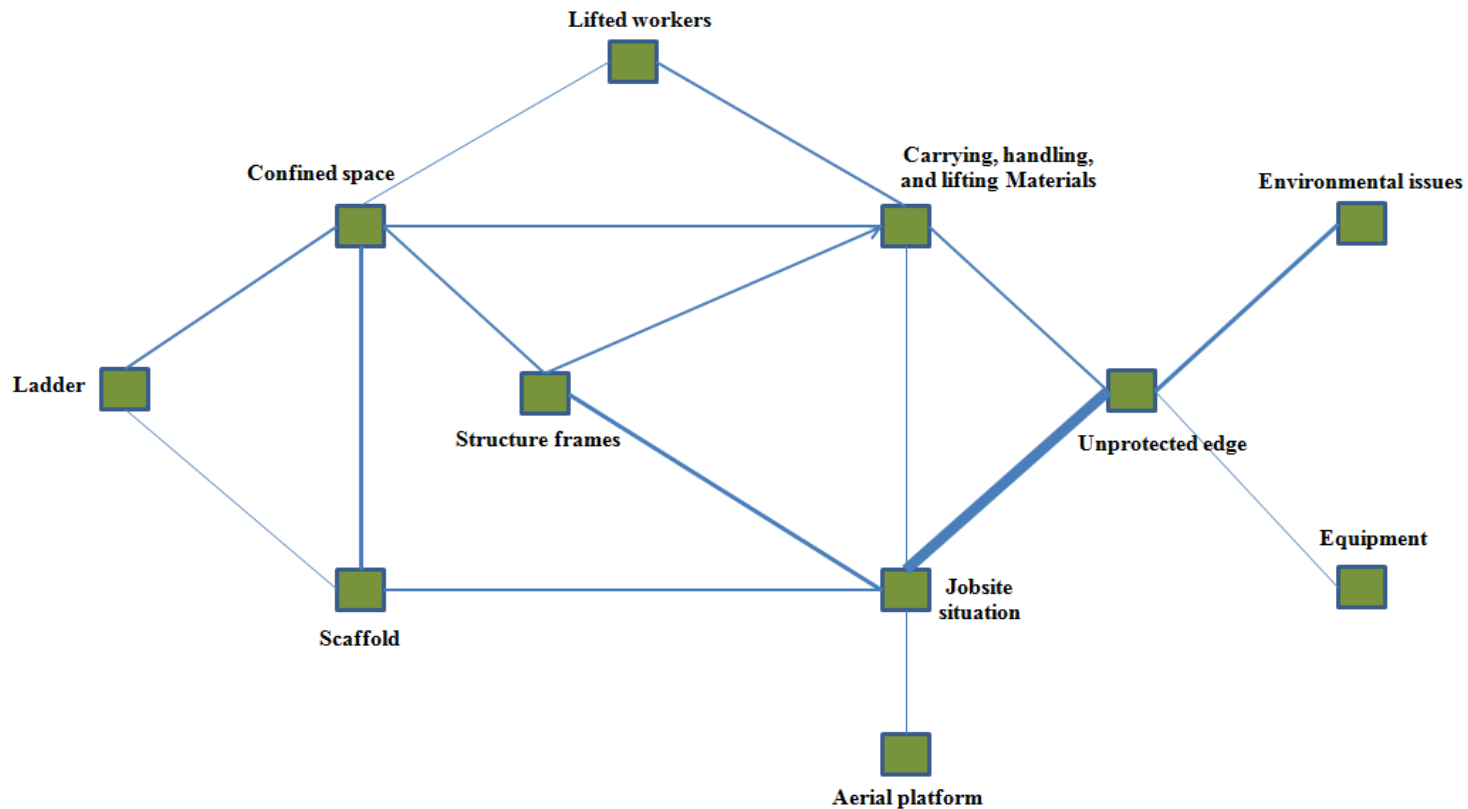
Table 1. Risk distribution of safety attributes

Safety Attributes		Safety Risks (%)		
		All (73)	Primary (21)	Secondary (51)
Working at Elevation	Ladder	2.07	4.41	0.80
	Unprotected edge	11.40	32.35	-
	Scaffold	6.22	12.50	2.81
	Structure frames	6.99	16.18	2.01
	Lifted workers	5.44	0.74	8.03
	Aerial platform	1.30	2.94	0.40
	Confined space	2.85	7.35	0.40
Job site situation		6.74	12.50	3.61
Carrying, handling, and lifting Materials		4.92	8.09	3.21
Equipment		1.55	0.74	2.01
Environmental issues		0.78	2.21	-
Managerial issues		11.44	-	17.67
Workers behavior		10.62	-	16.47
Insufficient injury prevention practices		27.46	-	42.57
Other		0.26	-	-
Total		100	100	100





Results and Analysis

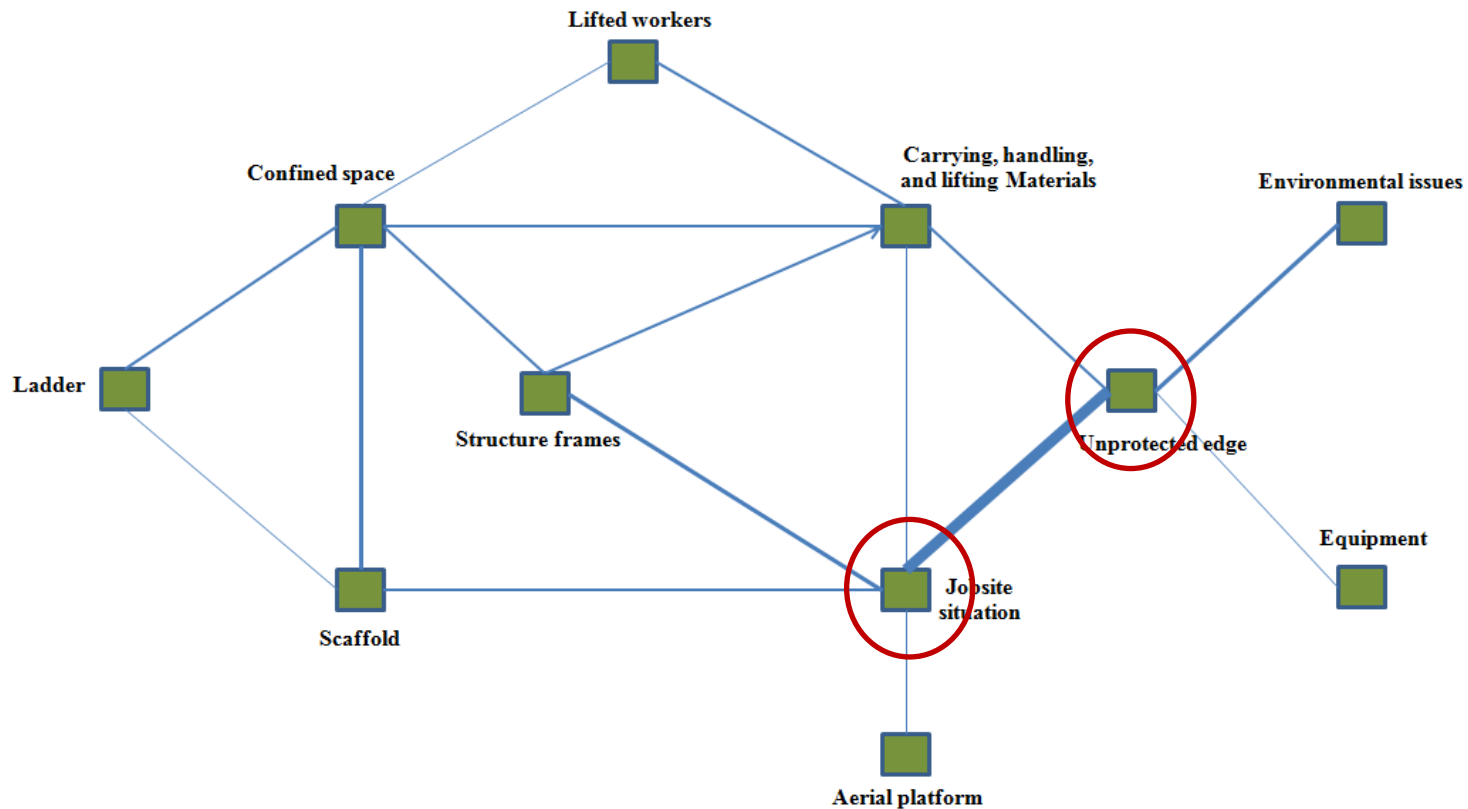


Sociogram of primary attributes





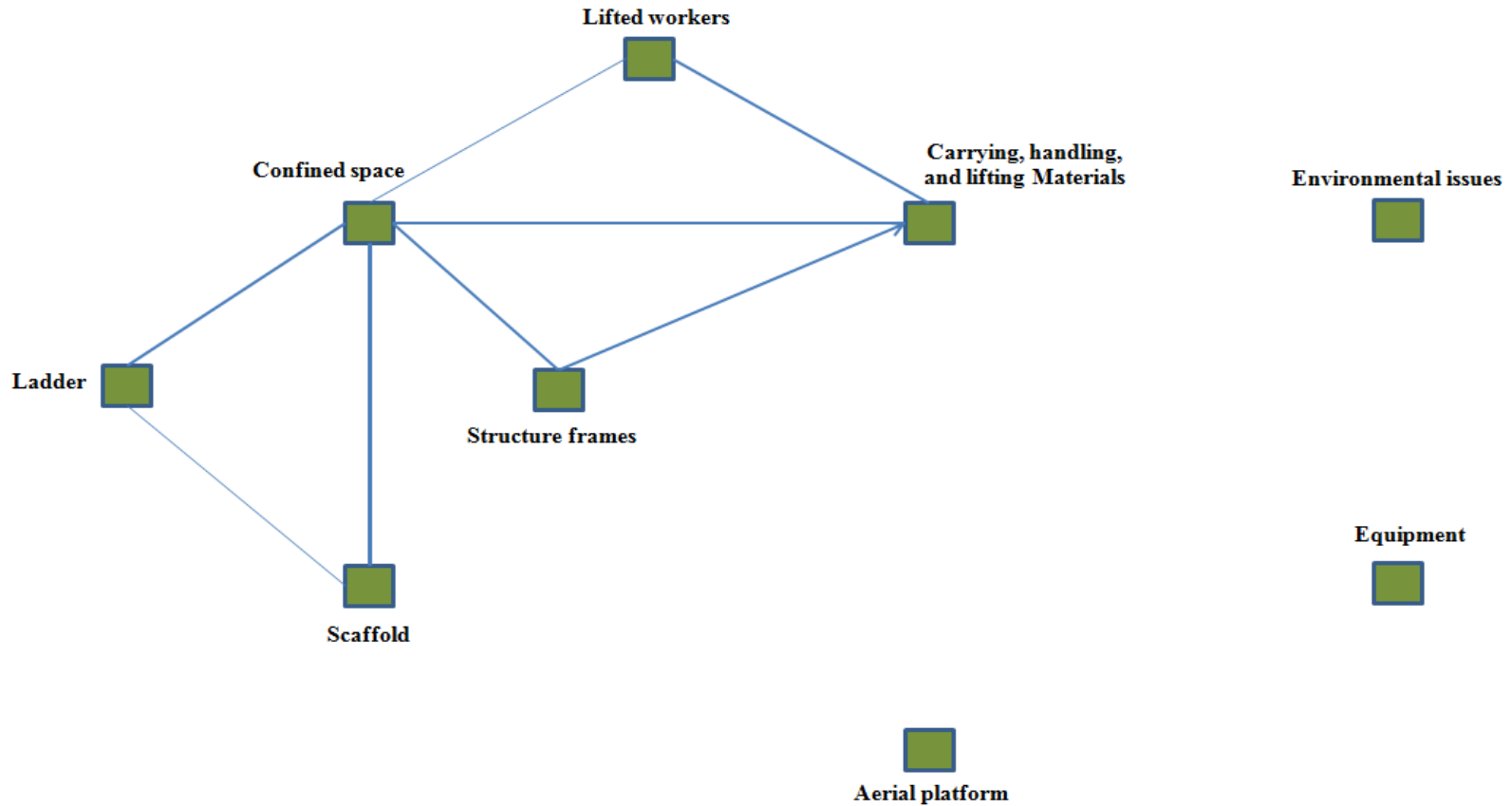
Results and Analysis



Sociogram of primary attributes



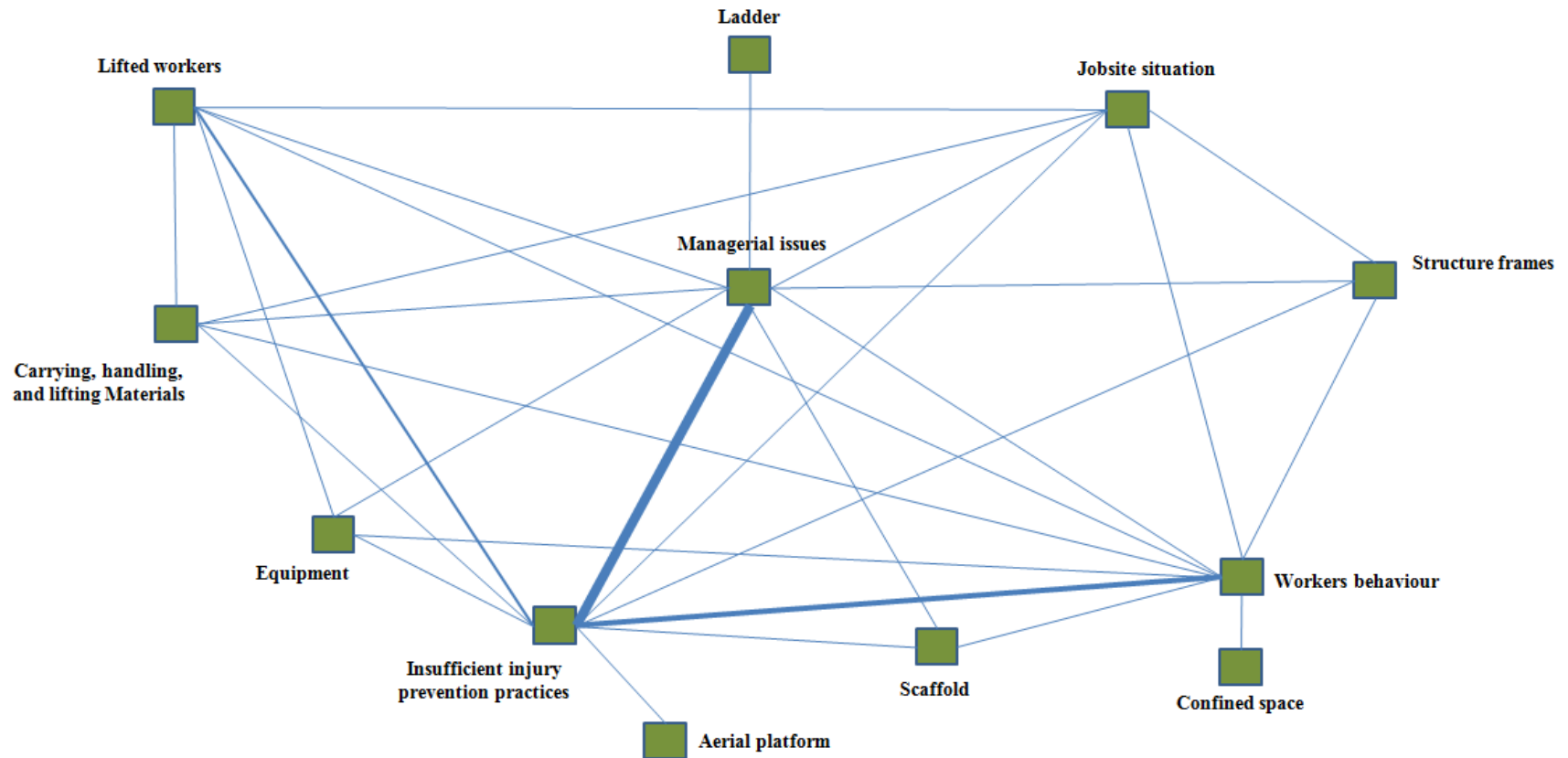
Results and Analysis



Sociogram of primary attributes after removing critical attributes



Results and Analysis

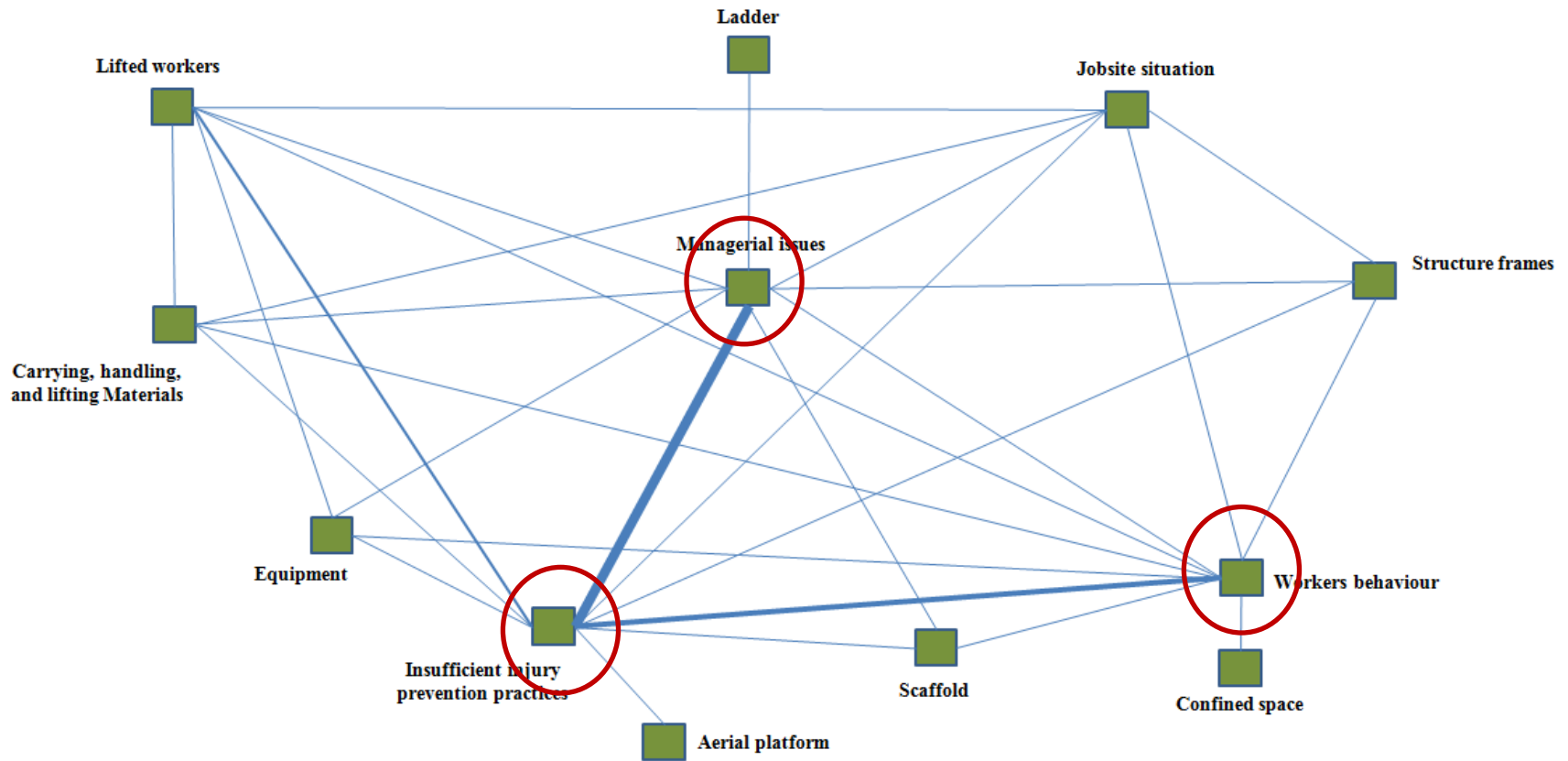


Sociogram of secondary attributes





Results and Analysis

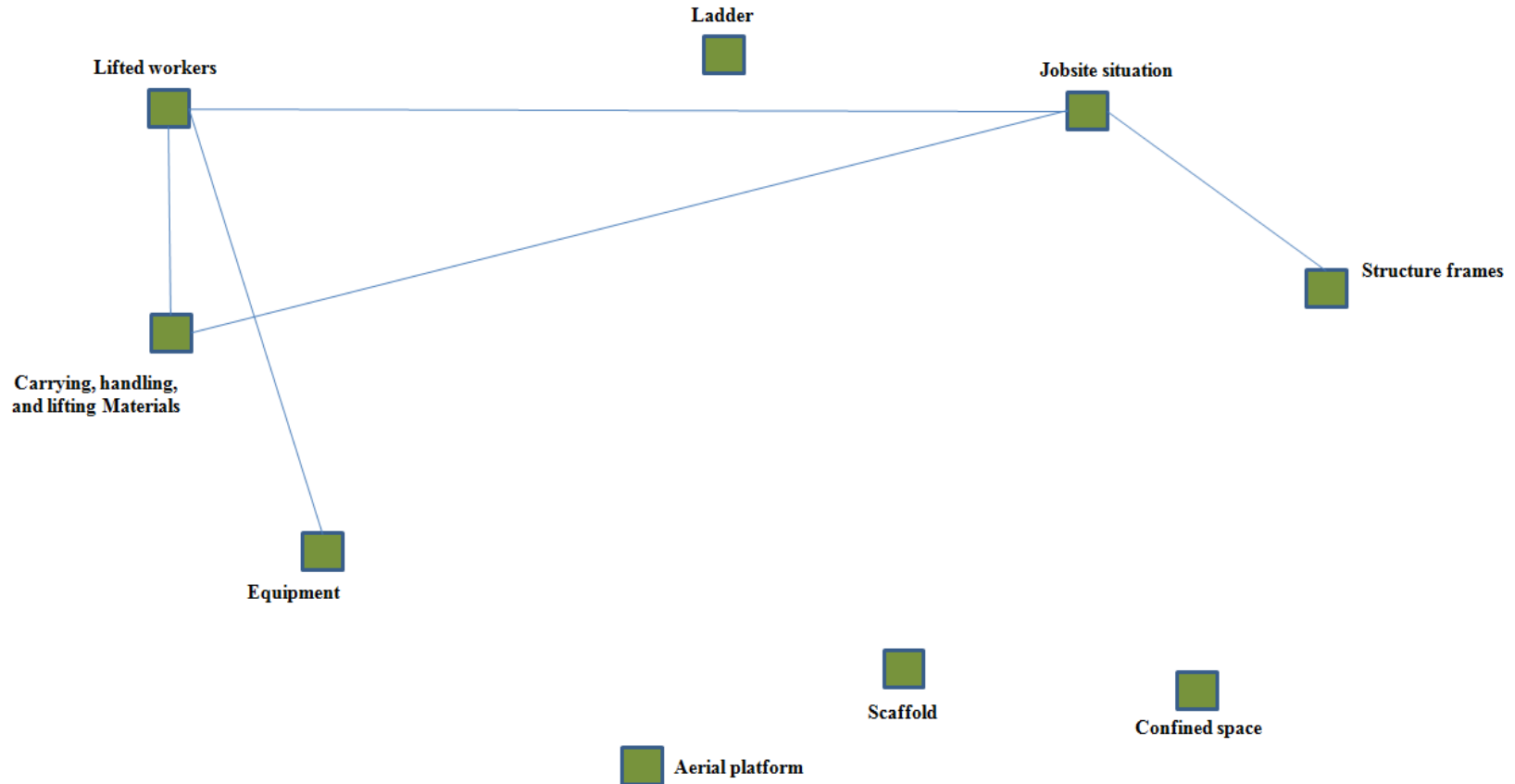


Sociogram of secondary attributes





Results and Analysis



Sociogram of secondary attributes after removing critical attributes





Advantages of this strategy

1. Hazards can be identified and risk can be quantified in early phases of the project;
2. There is a unique focus on relationships among attributes;
3. The method is capable of illustrating the relationships among attributes in a graphical form;
4. The flexibility of the presented approach makes it an applicable platform to be used for integrating safety risk data in to sensing technology (e.g. RFID) and Building Information Modeling (BIM).



Questions





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Research Methods

Phase I

➤ Reliability

- ❖ **CA's reliability** is defined as the extent of achieving the same results in repeated trials by following a certain measuring procedures (*Carmines and Zeller 1979*).
- ❖ Using multiple coders ensures that the results are not one individual's subjective judgment (*Tinsley and Weiss 1975*).
- ❖ One of the common methods of measuring inter-coder reliability is simple percent agreement (*Neuendorf 2002*):
$$PA_0 = A/n$$
- ❖ Wimmer and Dominick (1994) stated that 10 to 20% of the total sample that should be used for a reliability test.
- ❖ In this study, the authors asked another expert to recode 15% (16 out of 105) accident reports.

