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Increasing Safety and Productivity on Egyptian Building Sites

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Abstract- Safety and productivity in construction industry of Egypt still suffers from ignorance. This low consideration of safety importance caused escalation of accident rate in construction projects. The paper aims to identify the safety factors most related to productivity, and determine their relative importance as perceived by the target audience. The questionnaire was implemented directly; included 4 specific answers (agree, strongly agree, disagree, and strongly disagree) and consists of 47 questions divided into 7 groups: inspection, monitoring, training, etc. These questions were selected from the previous questionnaires and the questions inspired by the topic of this research. The questionnaire was distributed to 67 target audiences of different categories, including Consultants, Site engineers, Site managers and Workers.

The duration of their experience ranges from 0 to more than 15 years, as well as their scientific degrees from Ph.D., Masters, and Bachelor. The following factors are the most important factors of safety and productivity. "Working 7 days per week will increase productivity", "increase productivity", "Rework will decrease safety", "Incentives based on productivity decreases safety", "Compressed schedules affect negatively safety". The results indicated that "worker problems" are the most important among the groups of productive factors followed by "personal protective equipment", "supervisors and subcontractors", "monitoring", "communication skills". The target audience is advised to work strategically to protect workers by continuing to identify, assess and mitigate hazardous conditions and activities in work sites to achieve the highest levels of safety and productivity.

Index terms: Safety; Productivity; personal protective equipment; monitoring; supervisors and subcontractors

I. INTRODUCTION

Achieving safety and productivity is a major concern in the construction industry. There is a dearth of effort in the need for simultaneous achievement of safety and productivity on construction sites. (Abdul Rehim, et al. 2008) noted that the causes of accidents were due to poor safety awareness on the part of top leaders; lack of training; poor safety awareness on the part of managers; reluctance to provide security resources; reckless operation; lack of certified skills; lack of equipment; lack of first aid measures; lack of rigorous enforcement of safety regulations; lack of organizational commitment; low educational standards. Accidents cause economic losses and

human suffering. Computing the true costs of injuries reveals that compromising safety leads to increased costs and lower profits

Also, (Toole, 2002) listed the major causes of accidents at construction. These are lack of proper training, lack of safety enforcement, lack of safety equipment, unsafe methods or sequencing, unsafe site conditions, failure to use provided safety equipment, poor safety attitude and isolated, sudden deviation from prescribed behavior. Also, highlighted the top causes of construction accidents These include a lack of sufficient training, a lack of safety enforcement, a lack of safety equipment, unsafe procedures or sequencing, unsafe site conditions, a failure to employ available safety equipment, a poor safety attitude, and isolated, unexpected deviations from prescribed conduct.

Site incidents are more likely to occur where there are insufficient organization procedures, inappropriate practices, and dangerous behaviors of building workers, weak dedication management, and sufficient knowledge of safety, and worker training (Teo, et al. 2005).

Productivity is one of the most important factors influencing the success of any construction project. There are three forms of productivity: productivity with a single component, productivity with many factors, and productivity with a total factor (Santosh & Apte 2014). According to (Adnan, et al. 2007) one of the most essential aspects influencing the overall success of any small, medium, or big construction sector is productivity. The emerging world recognizes the importance of economic progress and social welfare. The developing countries are experiencing unemployment and recession.

Also, (Aynur, et al. 2008) investigated the effect of basic motivational factors on the productivity of the construction workforce in turkey. Today, human resource also plays a strategic role in any organization's productivity increase, making it superior in industrial competition.

Safety at work is a complex phenomenon and even more so is the subject of safety attitudes and safety performance in the construction sector. Construction is simultaneously acknowledged as a huge economic force and one of the most dangerous (Adnan, et al. 2015) The strategies, in the descending order from the top to the lowest, are; training workers to carry out works properly, especially in the new types of work (under training group), supervisor should be firm with the contractor in safety conditions (under inspection group), foreman should put daily and weekly work plans and define tools that should be used (under monitoring group), drug test for workers (under monitoring group), and scheduling adequate number of workers

to complete the heavy tasks, which helps to decrease injuries, as well as to foster a spirit of teamwork and increase productivity

The Health and Safety Policy Statement of (Phi Hughes et al. 2001) will contain objectives that are not tangible and objectives that are observable by the company or organization. During policy changes, targets are likely to remain constant, while objectives are checked and altered or modified each year. Insurance providers play a significant part in the development of health and safety practices. This requirement is exempted by certain public sector organizations because any compensation is paid out of public funds. There has been a substantial rise in the number and scale of reimbursement settlements in recent years and this has placed more pressure on insurance providers.

II. RESULTS AND DISCUSSION

This section describes the study of a survey questionnaire obtained from 67 respondents. The obtained data were examined using a basic statistical analytical method such as percentages, charts, tables and an overview of the results. This questionnaire consists of 47 questions divided into 7 main groups, and each group of questions is divided into 3 sub-types: productivity and safety and both.

Group 1: Inspection

Table 1 shows the respondents' perceptions about the effect of inspections on safety and productivity and Relative importance index and also shows the relative importance index for Inspection. Determined the maximum mean for sub- criteria is Supervisor should be firm with the contractor in safety conditions because it will positively affect productivity (1.8806) and the minimum mean for sub- criteria is Coordination between the contractor and the ministry of labor increase safety standards (1.5224). This group contains five factors of inspection:

"Supervisor should be firm with the contractor in safety conditions because it will positively affect productivity" factor was ranked in the first position among inspection group with RII=0.4702 and was ranked in the 20 position among all groups factors of safety and productivity.

"Involvement of foreman in preparing schedule, increase productivity and safety" factor was ranked in the second position among inspection group with RII=0.4590 and was ranked in the 23 position among all groups factors of safety and productivity. This result indicates the importance of the foreman

in maintaining a safer and more productive job site. Because foremen have direct contact with workers and job sites, they are well- versed in safety procedures. They can advise the project manager on the ideal time to complete a work in order to complete it safety.

Group 2: Monitoring

Table 2 shows the respondents' perceptions about the effect of monitoring on safety and productivity and also determined the maximum mean for sub-criteria is Working 7 days per week will increase productivity (3.0448) and the minimum mean for sub-criteria is Foreman and supervisor should have communication skills with workers to manage safety and to obtain higher productivity(1.5672). This group contains eight factors of monitoring "Working 7 days per week will increase productivity" "factor was ranked in the first position among inspection group with RII=0.7612 and was ranked in the 1 position among all groups factors of safety and Figure: Relative Importance Histogram for monitoring productivity. This result indicates that working 7 days per week without holiday does not affect productivity.

"Working 7 days per week will decrease safety hazard" factor was ranked in the second position among inspection group with RII=0.5261 and was ranked in the 11 position among all groups factors of safety and productivity. This result indicates that working 7 days per week without holiday does not affect safety.

Group 3: Training and coordination

Table shows the respondents' perceptions about the effect of Training and coordination on safety and productivity and also determined the maximum mean for sub-criteria is The main case of the accidents on the site is the workers (2.3433) and the minimum mean for sub-criteria is Workers should be trained about dealing with changes in working conditions to get excellent productivity (1.4328) .This group contains eleven factors of training and coordination.

"The main case of the accidents on the site is the workers lack for safety knowledge" factor was ranked in the 1st position among Training and coordination group with RII=0.5858 and was ranked in the 8 position among all groups factors of safety and productivity.

"Night- shift will decrease productivity" factor was ranked in the 2nd position among Training and coordination group with RII=0.5336 and was ranked in the 10 position among all groups factors of safety and productivity.

Table 1: Effect of inspection and the relative importance index

Inspection	Frequency of occurrence				RII	Rank within group	Rank	Mean	Percentage
	Strongly agree	Agree	Disagree	Strongly Disagree					
Allocating tasks to workers increase productivity	33	32	2	0	.3843	4	43	1.5373	38.43%
Over-inspection by foreman increase productivity	23	36	6	2	.4515	3	26	1.8060	45.15%
Coordination between the contractor and the ministry of labor increase safety standards	38	24	4	1	.3806	5	45	1.5224	38.06%
Supervisor should be firm with the contractor in safety conditions because it will positively affect productivity	33	15	13	6	.4702	1	20	1.8806	47.02%
Involvement of foreman in preparing schedule, increase productivity and safety	26	29	9	3	.4590	2	23	1.8358	45.89%

Table 2: Effect of Monitoring and Relative Importance Index

Monitoring	Frequency of occurrence				RII	Rank within group	Rank	Mean	Percentage
	Strongly agree	Agree	Disagree	Strongly Disagree					
Giving workers breaks time, and urges workers to take a rest when feeling tired will increase productivity	25	33	8	1	.4444	5	29	1.7761	44.403%
Working 7 days per week will increase productivity	5	9	31	22	.7612	1	1	3.0448	76.12%
Safety program contributes to increase productivity	16	41	9	1	.4814	3	19	1.9254	48.14%
Working 7 days per week will decrease safety hazard	23	25	8	11	.5261	2	11	2.1045	52.61%
Giving workers breaks time, and urges workers to take a rest when feel tired and fatigue will increase safety	29	28	7	3	.4403	6	31	1.7612	44.03%
Monitoring the schedule of safety meeting contributes to increase productivity	26	34	4	3	.4403	7	32	1.7612	44.03%
Foreman and supervisor should have communication skills with workers to manage safety and to obtain higher productivity	41	17	6	3	.3918	8	42	1.5672	39.18%
If supervisors promote safe work habits, this will increase in productivity and safety	27	26	9	5	.4702	4	21	1.8806	47.02%

Table 3: Effect of Training and coordination and Relative Importance Index

Training and coordination	Frequency of occurrence				RII	Rank within group	Rank	Mean	Percentage
	Strongly agree	Agree	Disagree	Strongly Disagree					
Training workers to carry out works properly, especially in the new types of work, will increase productivity	38	22	7	0	.3843	10	44	1.5373	38.43%
Workers should be trained about dealing with changes in working conditions to get excellent productivity	41	23	3	0	.3582	11	46	1.4328	35.82%
When workers have experience and education, productivity will increase	34	27	4	2	.4030	9	41	1.6119	40.30%
Hot weather decrease productivity	28	31	8	0	.4254	5	36	1.7015	42.54%
Housekeeping increase productivity	36	22	7	2	.4067	8	40	1.6269	40.67%
Night- shift will decrease productivity	19	25	18	5	.5336	2	10	2.1343	53.36%

Group 4: personal protective equipment

Table 4 shows the respondents' perception about the effect of personal protective equipment on safety and productivity also shows the relative importance index for Personal protective equipment. Determined the maximum mean for sub-criteria is Use of PPE puts constraints on workers movement which decrease productivity(2.6716) and the minimum mean for sub-criteria is Improvement of equipment and tools , Improve safety and productivity(1.7164)

This group contains eleven factors of training and coordination. "Productivity is affected negatively when workers don't wear PPE" factor was ranked in the 3rd position among personal protective equipment group with RII=0.4963 and was ranked in the 14 position among all groups factors of safety and productivity.

"Use of PPE puts constraints on workers movement which decrease productivity" factor was ranked in the 1st position among personal protective equipment group with RII=0.6679 and was ranked in the 3 position among all groups factors of safety and productivity.

"Safety is affected negatively, when workers don't wear PPE" factor was ranked in the 2nd position among personal

protective equipment group with RII=0.5000 and was ranked in the 12 position among all groups factors of safety and productivity.

"Improvement of equipment and tools, Improve safety and productivity" factor was ranked in the 4th position among personal protective equipment group with RII=0.4291 and was ranked in the 35 position among all groups factors of safety and productivity.

Group 5: Communication skills

Table 5 shows the respondents' perceptions about the effect of Communication skills on safety and productivity and also shows the relative importance index.

Determined the maximum mean for sub-criteria is Incentives based on productivity decreases safety (2.4328) and the minimum mean for sub-criteria is Use of modern labor equipment, contributes to increase of safety of workers (1.6716) This group contains seven factors of training and coordination. "Incentives based on productivity decreases safety" factor was ranked in the 1st position among Communication skills group with RII=0.6082 and was ranked in the 4 position among all groups factors of safety and productivity.

Table 4: Effect of personal protective equipment and Relative Importance Index

Personal protective equipment	Frequency of occurrence				RII	Rank within group	Rank	Mean	Percentage
	Strongly agree	Agree	Disagree	Strongly Disagree					
productivity is affected negatively when workers don't wear PPE	21	29	14	3	.4963	3	14	1.9851	49.63%
Use of PPE puts constraints on workers movement which decrease productivity	6	20	31	10	.6679	1	3	2.6716	66.79%
Safety is affected negatively , when workers don't wear PPE	17	36	11	3	.5000	2	12	2.0000	50%
Improvement of equipment and tools , Improve safety and productivity	30	26	11	0	.4291	4	35	1.7164	42.91%

Table 5: Effect of Communication skills and Relative Importance Index

Communication skills	Frequency of occurrence				RII	Rank within group	Rank	Mean	Percentage
	Strongly agree	Agree	Disagree	Strongly Disagree					
Periodically safety meetings for mangers , engineers and workers, affect positively on productivity	27	29	8	3	.4515	4	27	1.8060	45.15%
Training old and new workers on preventive actions and first aid increases productivity	27	29	9	2	.4478	5	28	.7910	44.78%
Incentives based on productivity decreases safety	10	29	17	11	.6082	1	4	2.4328	60.82%
Cooperation between work groups always enhance safety climate	21	33	8	5	.4888	2	15	1.9552	48.88%
Use of modern labor equipment, contributes to increase of safety of workers	36	21	6	4	.4179	7	38	1.6716	41.79%
Experience of worker improves safety and increases productivity	28	28	11	0	.4366	6	33	1.7463	43.66%
Safety signs improves productivity	18	41	8	0	.4627	3	22	1.8507	46.27%

"Cooperation between work groups always enhance safety climate" factor was ranked in the 2nd position among Communication skills group with RII=0.4888 and was ranked in the 15 position among all groups factors of safety and productivity.

Group 6: Worker problems

Table 6 shows the respondents' perceptions about the effect of Worker problems on safety and productivity and shows the relative importance index for Worker problems. Determined the maximum mean for sub-criteria is Rework will decrease safety (2.7910) and the minimum mean for sub-criteria is Safety and productivity is affected negatively when workers perform work without supervision of a foreman (1.8308). This group contains seven factors of training and coordination

"Rework will decrease safety" factor was ranked in the 1st position among Worker problems group with RII=0.6978 and was ranked in the 2 position among all groups factors of safety and productivity.

Non fair workload distribution on workers affect productivity badly" factor was ranked in the 2nd position among Worker problems group with RII=0.5858 and was ranked in the 7 position among all groups factors of safety and productivity.

Group 7: Supervisors and subcontractors

Table 7 shows the respondents' perceptions about the effect of Supervisors and subcontractors on safety and productivity and also shows the relative importance index for Supervisors and subcontractors. Determined the maximum mean for sub-criteria is Compressed schedules affect negatively safety Compressed schedules affect negatively safety (2.4328) and the minimum mean for sub-criteria is Improvement in safety knowledge of supervisors improves safety (1.7164) This group contains seven factors of training and coordination

"Compressed schedules affect negatively safety" factor was ranked in the 1st position among Supervisors and subcontractors group with RII=0.6082 and was ranked in the 5 position among all groups factors of safety and productivity.

"Compressed schedules affect negatively productivity" factor was ranked in the 2nd position among Supervisors and subcontractors group with RII=0.5933 and was ranked in the 6 position among all groups factors of safety and productivity.

The Analytic network Process (ANP)

ANP is the most powerful synthesis methodologies for combining judgment and data to effectively rank options and predict outcomes. A network can be grouped into source clusters, intermediate clusters, and sink clusters. Arcs reflect relationships in a network, and the directions of the arcs indicate directional dependence (Chang et al., 2006 and Sarkis, 2002). The analytic network process (ANP) is more general from of the analytic hierarchy process (AHP) used in multi- criteria decision analysis.

The Analytic Network Process (ANP)'s lies in its use of ratio scales to capture all types of interactions and make accurate predictions, and even better decisions. So far, it has proven to be a success when expert expertise has been combined with it to forecast sports results, economic turns, industry, social, and political events. The 3 contractors refer to 3 levels of solutions which are high, medium and low as expected to achieve both safety and productivity.

ANP Model

ANP represents a decision-making problem as a network of criteria and options (collectively referred to as elements) that are organized into clusters. All of the parts in the network can be linked in any way feasible, i.e. a network can have feedback and interdependence interactions inside and between clusters. This allows for more realistic modeling of complex situations.

Table 6: Effect of Worker problems and Relative Importance Index

Worker problems	Frequency of occurrence				RII	Rank within group	Rank	Mean	Percentage
	Strongly agree	Agree	Disagree	Strongly Disagree					
Non fair workload distribution on workers affect productivity badly	10	28	25	4	.5858	2	7	2.3433	58.58%
Absence of workers without cause will decrease productivity	21	38	6	2	.4590	4	24	1.8358	45.90%
Rework will decrease safety	6	18	27	16	.6978	1	2	2.7910	69.78%
Safety and productivity is affected negatively when workers perform work without supervision of a foreman	21	36	6	4	.4577	5	25	1.8308	45.77%
Personal and family problems of worker affect negatively on safety and productivity	18	34	12	3	.5000	3	13	2.0000	50%

Table 7: Effect of Supervisors and subcontractors and Relative Importance Index

Supervisors and subcontractors	Frequency of occurrence				RII	Rank within group	Rank	Mean	Percentage
	Strongly agree	Agree	Disagree	Strongly Disagree					
If more time and money are available for supervising this will improve productivity	22	39	6	0	.4403	5	30	1.7612	44.03%
Accidents frustrate workers which would decrease productivity	15	42	8	2	.4888	4	16	1.9552	48.88%
Compressed schedules affect negatively productivity	14	19	29	5	.5933	2	6	2.3731	59.33%
Compressed schedules affect negatively safety	16	26	23	2	.6082	1	5	2.4328	60.82%

A super matrix can be used to illustrate the influence of network elements on other network elements. Figure 1 shows an overview of the new decision network model. In this model, the main difference from the original is the presence of a feedback loop in the level of selection criteria. It is assumed that the seventh selection criteria are interrelated.

Super decisions Software

The Analytic Network Process (ANP) for decision making with reliance and feedback, invented by Thomas L. Saaty, is implemented in the Super Decisions software.

The Super Decisions software is a simple and easy-to-use tool for constructing decision models with dependence and feedback and computing results using the Analytic Network Process's super matrices. This software was designed to run in a variety of computing environments other than Windows. There is also a web-based version.

Use of the proposed ANP model

Figure 1 depicts the network model used to determine the weights of the factors to be used in the Information Manufacturing System Performance Indicator. ANP comprises four main steps:

- (1) Conducting pair-wise comparisons on the elements at the cluster and sub-cluster levels;
- (2) Placing the resulting relative importance weights (eigenvectors) in sub matrices within the super matrix;
- (3) Adjusting the values in the super matrix so that the super matrix can achieve column stochastic; and
- (4) Raising the super matrix to limiting powers until the weights have converged and remain stable.

ANP's Advantages and Disadvantages

One of the advantages of ANP over other MCDM techniques is that it examines interactions inside clusters of

elements and within clusters, as well as feedback between them.

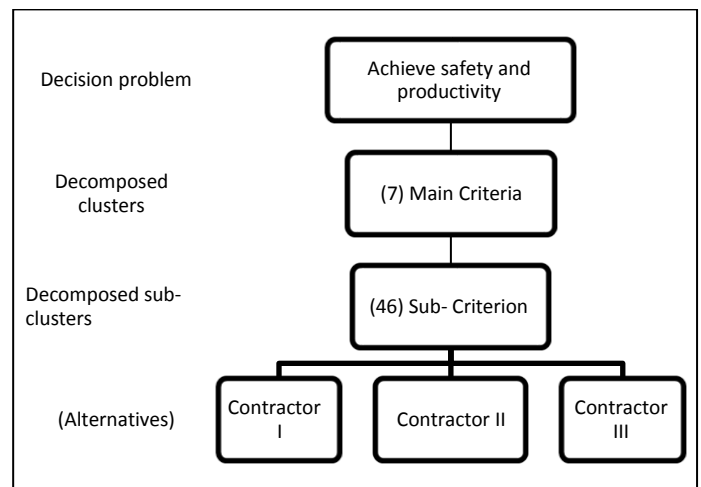


Figure 1. The ANP model

Another advantage of the ANP is that it evaluates decision accuracy. If the decisions are inconsistent, they should be re-judged in order to attain the appropriate level of consistency.

Outlines some **advantages** of AHP/ANP over other MCDM methods:

1. Mathematically demonstrated, eigenvector approach, and accurate methodology.
2. Variable interrelationships between factors
3. Allows for the presence of dependency between criteria.
4. Evaluation consistency.
5. Interdependence and feedback loops between network layers

Outlines some **disadvantages** of AHP/ANP over other MCDM methods:

1. It is difficult for the general population to populate the supermatrix.
2. Hierarchy isn't always as rigorous as it should be.
3. Factor interrelationships are rigid.
4. When the decision structure is mostly hierarchical, AHP is more effective mathematically.

Concepts of the Analytic Network Process

- 1- Feedback, inner and outer dependency
- 2- Influence in relation to a criterion.
- 3- The command and control hierarchy or system.
- 4- The supermatrix.
- 5- The limiting supermatrix and priorities
- 6- Primitiveness, irreducibility, and cyclicity.
- 7- Generate a stochastic limiting supermatrix: this is why clusters must be compared.
- 8- Synthesis of control hierarchy or control system criteria.
- 9- Control hierarchies for benefits, costs, opportunities, and hazards to compute the limit.
- 10- Formulation.
- 11- Relationship to the Neural Network The continuous case is being fired.
- 12- The density of neuronal firing and distributions, as well as their applicability to visual reproduction graphics as well as orchestral compositions. More research in this area is required.

Fundamental ideas in support of the ANP are:

- 1-The ANP is built on the AHP.
- 2- By allowing for dependence, the ANP goes beyond the AHP by including independence and hence also the AHP as a special case;
- 3- Deals with dependence within a set of elements (inner dependence), and among different sets of elements (outer dependence);
- 4- The looser network structure of the ANP makes possible the representation of any decision problem without concern for what comes first and what comes next as in a hierarchy;
- 5- The ANP is a nonlinear structure that deals with sources, cycles, and sinks. A hierarchy is linear, with a goal in the top level, and the alternatives in the bottom level;
- 6- Prioritizes not just elements but also groups or a cluster of elements as is often necessary in the real world;
- 7- Utilizes the idea of a control hierarchy or a control network to deal with different criteria, eventually leading to the analysis of benefits, opportunities, costs, and risks. By relying on control elements, the ANP parallels what the human brain does in combining different sense data as for example does the thalamus.

III. Conclusion

The primary objective of this questionnaire was to identify and study the relative importance of safety and productivity factors, according to the perception of the target audience. Forty-seven factors have been identified and arranged, which are also grouped under seven major categories. Table (8) shows the top five factors that are closely related to safety and productivity based on the overall ranking. The element "working 7 days per week will increase productivity" ranked highest in terms of importance in preserving the project's safety and productivity, according to the findings. This factor belongs

to Monitoring. Results show that skilled workers enhance safety. This factor shows the significant linkage between safety and productivity.

The results showed that the factor "rework will reduce safety" was ranked second. This factor belongs to the group of workers' problems. This factor of productivity is analogous to the factor of "unfair distribution of workload among workers badly affects productivity". This indicates that the unfair distribution of work negatively affects productivity. Showing the daily activities of workers helps to avoid inconsistencies with safety regulations.

The results showed that "the use of personal protective equipment places restrictions on the movement of workers which reduces productivity" ranked third. This factor indicates the importance of a productivity program in maintaining a safe workplace environment. Indicates that a safety program enhances productivity by reducing accidents and injuries.

Table 8. The most important factors that relate to safety and productivity

Factors of productivity and safety	Related group	RII	Rank
Working 7 days per week will increase productivity.	Monitoring	.7612.	1
Rework will decrease safety	Worker problems	.6978	2
Use of PPE puts constraints on workers movement which decrease productivity	Personal protective equipment	.6679	3
Incentives based on productivity decreases safety	Communication Skills	.6082	4
Compressed schedules affect negatively safety	Supervisors and Subcontractors	.6082	5

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