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TRIZ Supporting the Project Management Effectiveness

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Abstract

The project management (PM) techniques were created during the 1950s in the United States to increase the probability of success in large military projects and have been developed and applied in other areas since then. The Russian scientist Heinrich Altshuller and colleagues have been developing TRIZ (Theory of Inventive Problem Solving) since the 1940s to create a method to find innovative solutions for technical problems. In an organization already using a standard project management procedure to deliver quality projects but having still been missing the planned schedules in a higher rate than desirable, the TRIZ tools were used to improve those results. This paper shows how to apply a structured version of TRIZ to a typical PM procedure bringing innovative alternatives to solve the hidden contradiction that is how to accelerate projects without compromising the delivered systems quality. TRIZ supports the practitioner to go beyond the standard project risk analysis, offering innovative solutions focused not only on threats and opportunities but mainly on the contradiction elimination, increasing the probabilities of delivering projects in time and with quality.

Keywords: contradiction, effectiveness, inventive, problem solving, project management, TRIZ

1. Introduction

The Guide to the Project Management Body of Knowledge (PMBOK), organized by the Project Management Institute (PMI, 2013) is among the most effective standard procedures to plan and execute any kind of project. It covers several processes to manage a project, like scope, time, cost, human resource, quality, risk, communication, integration and so on. The guide is focused on delivering the planned scope with the specified quality in the time and costs proposed that is delivering projects with high efficacy. The reference scenario in this article considered there is a standard PM procedure based on the PMBOK and a team able to deliver the systems with the quality needed in an industrial environment. However, some projects have been running late in a higher rate than the desirable one. That is, despite a good PM maturity level has been achieved, there is an opportunity related to time and quality managements to explore, reason why an additional method was used. According to the Pulse of Profession Report (PMI, 2013), the best performing organizations (with high PM maturity level and training along the projects execution) have only reached limited percentage of successful projects among the completed ones: met the goals=66%, within budget= 62% and on schedule= 58%. For each project not reaching the goals in time there are opportunities not converted in value or problems not solved, draining value from any system. The reported limited achievement average percentages in time (58%) and quality (66%) are already enough to demonstrate the real importance of looking for additional support to improve the results.

Based on extensive analysis of a patents collection, the scientist Heinrich Altshuller and colleagues tried to identify a method for sustainable and innovative solutions related to technical problems, called TRIZ (Altshuller, 1999). With the political events in the former Soviet Union, part of the research group moved to Europe and USA spreading the TRIZ knowledge since 1990. TRIZ is based on the pursuit of ideality (higher availability of functions with the lowest resource use) and is supported on five conceptual pillars: contradictions, ideality, functionality, resources and time / space (Mann, 2010). As illustrated in Fig. 1, the method translates the "specific problem" in a more general manner ("a problem like mine"), enabling the use of solution patterns ("generic solutions") identified by Altshuller in similar problems. Among these generic solutions, the ones capable of solving the specific problem ("specific solution") will be selected, avoiding the usual trial and error and non-focused brainstorming approaches. TRIZ operates by identifying the contradiction associated with the problem under evaluation offering a shortcut to find alternative solutions in different knowledge areas than those immediately related to the problem (Silverstein, Decarlo and Slocum, 2008). For that purpose, one may use several available tools. Some of them are Identification of available resources, Thinking in Time and Space, Ideal Final Result, Contradiction Matrix & 40 Inventive Principles, Size-Time-Cost, Function Analysis, 76 Standard Solutions and the 8 Trends of Evolution.

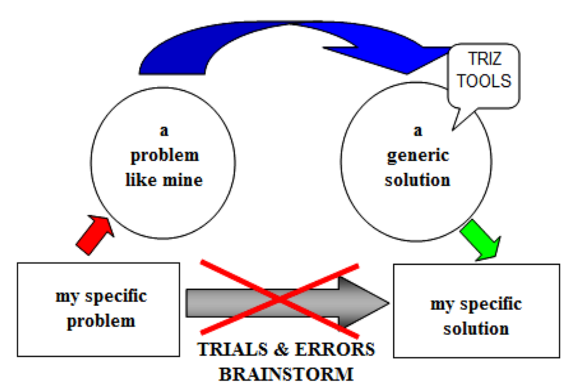

Fig. 1. TRIZ Basic Method (Mann, 2010)

Among the mentioned tools, the Matrix Contradictions is considered the first stage tool by the ease of use treating the technical contradictions (when one tries to improve a feature, there is a second independent feature/parameter that gets worse). Therefore, at least two features (the one we need to improve and the one getting worse with our attempt to improve the first) express each identified technical contradiction. According to Altshuller´s research (1999), for each combination, a number of suggested inventive principles that have already solved the same contradiction in other fields of knowledge are available. The traditional list contains 39 parameters and 40 inventive principles combined in a matrix. Originally focused on technical issues, the use of TRIZ also expanded to the management area. Through additional research, Darrell Mann has developed a similar matrix focused on managerial issues, the Business Contradiction Matrix (Mann, 2009), which we will use in this paper. To enrich the proposed alternatives, additional TRIZ tools will be used. The whole group has been integrated to facilitate the use by beginners (Fig. 3). Although there are other different integrated views, the applied approach was based on the proposals by Mann (2010) and Gadd (2011).

The link between the PMBOK and TRIZ has already been considered through the risk management process. Such a process includes the analysis to identify potential threats and opportunities, generating preventive actions to improve the probability of success for the projects (Wideman, 1992; Smith and Merit; PMI, 2013). Some of the TRIZ tools have been proposed to be applied directly to the project risk management trying to modify and boost this specific process (Barsano, 2008). In this article, the TRIZ tools were used in a different way, focusing on an existing PM procedure facing a specific problem related to projects delays. The several tools were taken as an additional support to the PM procedure, searching for new solutions, always based on the schedule's perspective. In that sense, the TRIZ tools were used in a reactive mode not intending to modify the risk management process but trying to eliminate the speed x quality contradiction. They add a specific solutions package to the PM procedure to treat an existing schedule problem. If incorporated to the PM procedure, such a package may be used in a preventive way on future individual projects, reinforcing the standard risk management to search for improvement in the success rates in time and quality. Considering the limited success rates reported in the Pulse of Profession Report (PMI, 2013), the TRIZ tools might be used in other projects environments like a support to the PM procedure to eliminate the hidden contradictions that keep organizations with lower achievements.

It is relevant to mention that one of the key attractiveness for using TRIZ on such a delicate situation is the basic concept associated to this method in which no compromise will be accepted to solve the problem. That is, the hidden conflict is identified and it guides the search for inventive solutions.

2. Context

The project management current practice applies most of the processes in the Guide to the Project Management Body of Knowledge (PMI, 2013) and has progressive decision stages (Fig. 2). In the first stages until the Filter 3, alternatives are evaluated with the selection of one of them to move forward to the detailing in order to support the final decision. At Filter 3, with no doubts left and all data available, the decision to implement the project until the delivery and results review it is confirmed.

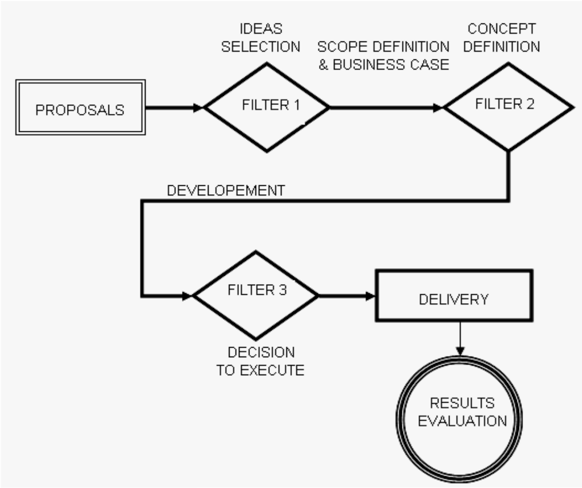

Fig. 2 Simplified Summary of Current Practice

Theoretically, the higher the effort applied to the stages before Filter 3, the higher likelihood of a good quality result. However, getting deeper in these first stages consumes financial resources and mainly takes time, exposing the basic contradiction through the TRIZ lenses: how to speed up the whole project while maintaining the desired final quality?

In that context, the TRIZ tools are not applied to the projects individually but only once to the PM current procedure and to the environment in which the projects are managed. They allow identifying harms and opportunities related to the mentioned conflict. The most effective proposed reactions/solutions should be incorporated to the PM procedure as support for all future projects in that environment.

3. Development

Regarding the TRIZ application to the PM procedure and its managing environment, it will be used the integrated sequence in Fig. 3 (adapted from Gadd, 2011 & Mann, 2010) that illustrates the problem definition and the progressive use of several TRIZ tools.

The workflow in Fig. 3 is divided in convergent and divergent stages, according to their nature, broadening the evaluation and generating alternatives or focusing and selecting the best ones. The whole flow starts with listing all preliminary ideas (first to come, with no critics) to solve the identified problem. It consists of four steps:

a. Define the problem (the real situation)

The real situation is checked using the six critical questions (What is the problem? Why is there such a situation? Why is it a problem? Why is it necessary to solve it? What do we really want-What is our ideal? What is holding us to solve the problem?). The context is expressed in the time and space diagram (9 boxes). A map of the available resources is prepared (9 boxes). The ideal outcome is clearly defined (What do we really want?). The gap between the real and the ideal situations is explored. A first evaluation of the preliminary ideas can be performed to identify harmful aspects. The function analysis can be performed in this stage or after the contradiction identification, as considered in this article.

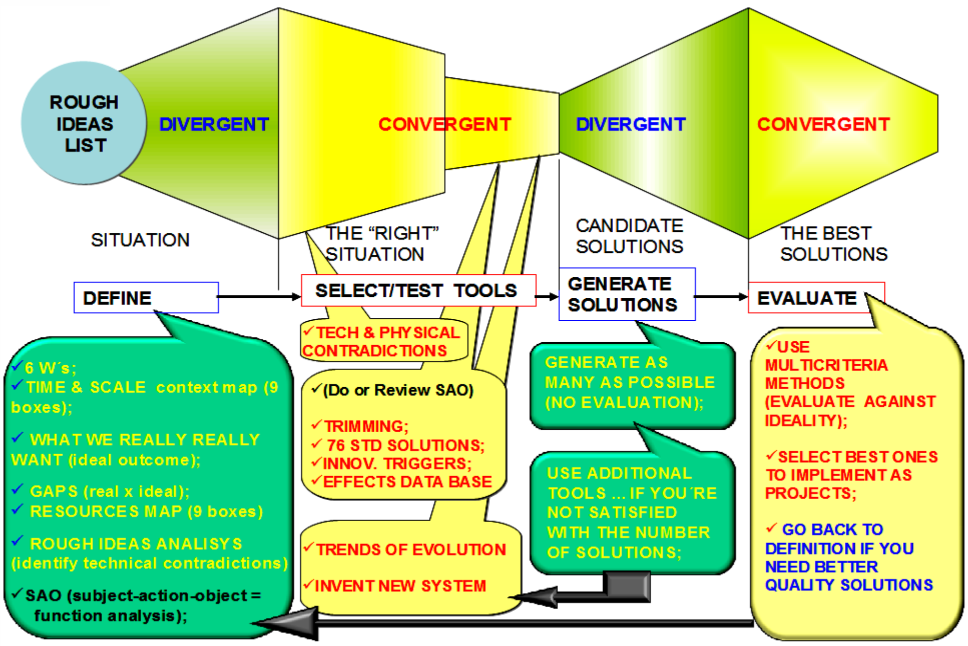

Fig. 3 TRIZ Integrated Workflow

b. Select tools to use (the right situation)

This stage is divided in other two parts. The first is the basic one in which the basic tools can be applied (contradictions). The second one must follow the function analysis and will enable additional tools, if the practitioner thinks they are necessary. The tools application starts by the technical contradiction identification and treatment with the inventive principles. The physical contradiction identification and treatment is done in the sequence, completing the first part. The function analysis and the subject-action-object list can be prepared now. With the analysis completed, the trimming and 76 standard solutions can be applied. Additionally, the innovative triggers (X-Factor; Life and Death analogies; Smart Little People; Time-Size-Cost; Subversion), the effect database and the trends of evolution may be tested. Inventing new systems is only used in specific cases.

c. Generate solutions (candidate ones)

Using the selected tools, all possible candidate solutions are generated.

d. Evaluate solutions (the best ones)

Those solutions that fit the better to the ideality criteria are selected (multi-criteria selection to support the decision-making). The criteria and their weights can be adjusted to the user's need.

This cycle can be repeated, if necessary, and establishes a way for anyone (or any organization) to contribute systematically to solve complex problems and to develop new products and systems (develop anything through identifying and breaking its hidden contradictions). How deep one should go to find alternative solutions will certainly depend on the type of problem being treated and on the practitioner needs. More than that, Fig. 3 shows a big picture of the available tools and a suggested workflow that helps TRIZ beginners to find their own way and gain confidence in the method.

4. Applying the TRIZ workflow to the problem

The TRIZ tools were applied treating the problem as any other but using the business & management adaptation (Mann, 2009). The workflow itself is a structure adapted from two authors' contribution in their published books and papers (Gadd, 2011 and Mann, 2009). For the case under focus, there are two main groups of processes: the development of information and details until the authorization to execute and the execution itself. The solution proposals were generated covering both groups.

4.1 Preliminary Ideas (spontaneous)

10 solution proposals were listed.

INCREASE THE PROJECT MANAGERS TEAM
INCREASE THE FIELD SUPERVISING TEAM
HAVE 2 ASSEMBLY CONTRACTORS AVAILABLE
HAVE 2 CIVIL CONSTRUCTION CONTRACTORS AVAILABLE
INCREASE THE PROJECT ENGINEERS TEAM
HAVE AN ENGINEERING DESIGN CONTRACTOR NEAR THE PLANT
PERFORM THE PRELIMINARY SCHEDULE RISK ANALYSIS & SIMULATION
HAVE A BUYERS TEAM DEDICATED TO THE PROJECTS
HAVE A SCAFFOLDING CONTRACTOR DEDICATED TO THE PROJECTS
HAVE A SAFETY TECHNICIAN SUPPORTING ALL WORK PERMITS TO PROJECTS

Fig. 4 Preliminary Ideas List

4.2 Definition

-Description of the problem

Projects are delivered late against the planned finish date, causing potential additional costs and delays in the expected results. When trying to accelerate the execution there is a risk to lose quality.

(As the problem and its consequences were completely clear, the 6W´s were not detailed)

-Main desired result

Systems are delivered early or on schedule and with the desired quality and specifications demanded by customers.

-Ideal Final Result (what they really want)

Critical (must have)

-Finish projects in the planned month
-Get the procurement activities done as scheduled
-Have effective field supervision during execution
-Have effective frame contracts
-List of pre-approved suppliers
-Work permits released until 9 AM daily
-Effective continuous work permits
-Costs fully managed and controlled.

Desirable (nice to have)

-Have a schedule risk simulation done before the project approval
-Have certified project managers
-Dedicated procurement team
-Scaffolding contract dedicated to the projects
-Do not depend on a single engineering support contractor

-Have at least one engineering support contractor near the plant

-Do not depend on a single assembly contractor

-Do not depend on a single civil construction contractor.

-Problem Context Map

The Fig. 5 shows a typical 9 boxes diagram with the problem context.

	TIME -2 YEARS	TODAY	+2 YEARS
ENVIRONMENT / CONTEXT	PROCUREMENT TEAM NOT STRUCTURED	STRUCTURED PROCUREMENT TEAM	PROCUREMENT TEAM DEDICATED TO PROJECTS
	CONTRACTS EXTREMELY SLOW	TIME TO SIGN THE CONTRACTS STILL TOO LONG	STANDARD CONTRACTS PRE APPROVED BY LEGAL TEAM
	MANY CRITICAL TASKS DEPENDING ON PROCUREMENT AND LEGAL TEAMS	MANY CRITICAL TASKS DEPENDING ON PROCUREMENT AND LEGAL TEAMS	NO DELAY DUE TO PROCUREMENT AND LEGAL TASKS
	NO FRAME CONTRACTS AVAILABLE	PRESSURE TO REDUCE COSTS LEAD TO NOT WELL STRUCTURED SUPPLIERS	FRAME CONTRACTS WITH GOOD QUALITY SUPPLIERS
	CAPEX MANGT PROCEDURE UNDER TRAINING	CAPEX MANGT PROCEDURE STILL NEEDS SUPPORT	CAPEX MANGT PROCEDURE COMPLETELY UNDER USE
	NO SCAFFOLDING CONTRACT	SCAFFOLDING CONTRACTOR NOT ABLE TO SUPPORT ALL DEMANDS	SCAFFOLDING CONTRACT SPECIFIED TO SUPPORT THE PROJECTS
	MAXIMUM PRIORITY FOR SAFETY NOT CLEAR	HIGH PRIORITY TO SAFETY	TOTAL PRIORITY TO SAFETY
PROBLEM		PROJECTS ARE DELIVERED WITH DELAY AGAINST THE PLANNED DATE	
	SCHEDULES NOT PROPERLY PREPARED	LOW SKILL TO DEAL WITH SCHEDULES	MS PROJECT SW FULLY APPLIED
	NO RISK ANALYSIS / SIMULATION FOR THE SCHEDULE	NO QUANTITATIVE SIMULATION FOR THE SCHEDULE	USING RISK SIMULATION FOR THE BIGGER PROJECTS
	TECHNICAL SPECIALISTS MANAGING PROJECTS	TECHNICAL SPECIALISTS MANAGING PROJECTS	HIGHER NUMBER OF SKILLED PROJECT MANAGERS
	WORK PERMITS TAKE TOO LONG TO BE ISSUED	WORK PERMITS TAKE TOO LONG TO BE ISSUED	QUICK WORK PERMITS OR CONTINUOUS WP
RESOURSES/PEOPLE	PROJECT TEAM WITH DIFFERENT SKILL LEVELS IN THE CAPEX PROCEDURES	PROJECT TEAM TRAINED IN THE CAPEX PROCEDURES	PROJECT TEAM FULLY SKILLED IN THE CAPEX PROCEDURES
	REDUCED PROJECT TEAM	BIGGER PROJECT TEAM BUT STILL BASED ON THE TECHNICAL SPECIALISTS	PROJECT TEAM INCLUDING MORE PROJECT MANAGERS
	HIGH NUMBER OF NOT SKILLED CONTRACTOR PROJECT MANAGERS	NOT SKILLED CONTRACTOR PM STILL PRESENT	SKILLED PROJECT MANAGERS TEAM
	HIGH NUMBER OF THIRD PARTY PROFESSIONALS	LOW NUMBER OF OWNER COMPANY PROFESSIONALS	PM TEAM ONLY BY THE OWNER COMPANY

Fig. 5 Context Map - The problem discussed in time and space (9 boxes diagram)

-Problem Resources Map

Fig. 6 shows the typical 9 boxes diagram with the identified available resources in time and space.

	TIME -2 YEARS	TODAY	+2 YEARS
ENVIRONMENT/ CONTEXT	NO ASSEMBLY FRAME CONTRACT	ASSEMBLY FRAME CONTRACT AVAILABLE	2 ASSEMBLY CONTRACTORS AVAILABLE
	NO CIVIL CONSTRUCTION FRAME CONTRACT	CIVIL CONSTRUCTION FRAME CONTRACT AVAILABLE	2 CIVIL CONSTRUCTION CONTRACTORS AVAILABLE
	SCAFFOLDING CONTRACT SUPPORTING MAINTENANCE AND PROJECTS	SCAFFOLDING CONTRACT SUPPORTING MAINTENANCE AND PROJECTS	SCAFFOLDING CONTRACT SPECIFIED FOR PROJECTS
	SMALL PROCUREMENT TEAM	PROCUREMENT TEAM NEAR THE PROJECTS TEAM	PROCUREMENT TEAM INTEGRATED TO THE PROJECTS TEAM
	NO LEGAL CONTRACT SUPPORT	LEGAL SUPPORT NEAR THE PROJECTS TEAM	LEGAL SUPPORT INTEGRATED TO THE PROJECTS TEAM
	REDUCED FIELD SUPERVISING	FIELD SUPERVISING PROVIDED BY THIRD PARTY	FIELD SUPERVISING COORDINATED BY OWNER PROFESSIONAL
	ONLY 1 CONTRACT FOR ENGINEERING EXTERNAL SUPPORT	ONLY 1 CONTRACT FOR ENGINEERING EXTERNAL SUPPORT	ADDITIONAL CONTRACT WITH A LOCAL ENG. CONTRACTOR
PROBLEM		PROJECTS ARE DELIVERED WITH DELAY AGAINST THE PLANNED DATE	
	MANY PROJECTS WITHOUT SCHEDULE	SCHEDULES ON THE MS PROJECT	SCHEDULES ON THE MS PROJECT
	NO PLANNING PROFESSIONAL	SPECIALIZED THIRD PARTY PLANNER	PLANNER INTEGRATED TO THE PROJECT TEAM AND PERFORMING THE RISK ANALYSIS
RESOURCES/ PEOPLE	JUST A FEW PROJECT MANAGERS BY THE OWNER	NEW PROJECTS MANAGERS BY THE OWNER	OWNER PROJECT MANAGERS FULLY SKILLED WITH INTERNAL PROCEDURES
		THIRD PARTY PROJECT MANAGERS	NO THIRD PARTY PROJECT MANAGERS
	ENGINEERING SUPPORT CONTRACTOR FROM ANOTHER STATE	ENGINEERING SUPPORT CONTRACTOR FROM ANOTHER STATE	MAIN ENG. SUPPORT CONTRACTOR AT THE SAME CITY
	TECHNICAL SPECIALISTS AVAILABLE	TECHNICAL SPECIALISTS AVAILABLE	ADDITIONAL SAFETY SPECIALIST INCLUDED IN THE PROJECTS TEAM
	O SW FOR SCHEDULES RISK SIMULATION	SW FOR SCHEDULE RISK SIMULATION AVAILABLE	SW FOR SCHEDULE RISK SIMULATION FULLY USEFUL BY THE PLANNER AND THE PROJECT TEAM
	NO SCHEDULE STANDARD	SCHEDULE STANDARD IN USE	MILESTONE PROPERLY USED IN THE SCHEDULES
	NO CAPEX PROCEDURE INTERNAL AUDIT	SEVERAL AUDIT RECOMMENDATIONS TO IMPROVE	AUDIT RECOMMENDATIONS DONE

Fig. 6 Resources Map - Available resources examined considering time and space. (9 boxes diagram)

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As the present situation and the ideal one were already clear, the ideality audit (real x ideal) was not detailed.

4.3 TRIZ Tools Selection

As it comes to managerial situations with easily identifiable contradiction, it was used the Business Matrix Contradictions (Mann, 2009) and the adapted inventive principles to treat them. For more alternative proposals, one should identify the associated physical contradiction (to get the desired result we need a variable that has simultaneous contrary behaviors, for example, the temperature should be high and low, the system must be fast and slow at the same time).

-Identifying the "Technical Contradiction"
Improving feature: speed of projects execution
Adapted TRIZ parameter: Production Time.

Worsening feature: quality, cost and risk of the final system

Adapted TRIZ parameters: specification of production, costs of production, production risk.

In Fig. 7, we can see a section of the business contradiction matrix indicating the suggested inventive principles (arrows intersection = green painted cells).

BUSINESS MATRIX	Improving Parameter	5	6	7	8	9	10	11
		R&D Interfaces	Production Spec/ Capability/ Means	Production Cost	Production Time	Production Risk	Production Interfaces	Supply Spec/ Capability/ Means
Worsening Parameter		5	6	7	8	9	10	11
4	R&D Risk	6; 29; 15; 14; 17; 25	24; 35; 10; 3; 13; 11	5; 35; 40; 23; 1; 12	5; 40; 20; 15	11; 23; 39; 7; 9; 33	7; 3; 17; 23; 24	5; 35; 13; 26; 6
5	R&D Interfaces	5 see physical contrad.	5; 6; 17; 40; 33; 10; 26	15; 23; 29; 5; 13	15; 40; 23; 3; 24; 13	7; 5; 3; 37; 10	28; 40; 6; 29; 13; 31; 30	6; 35; 15; 13; 14
6	Production Spec/ Capability/ Means	5; 6; 17; 40; 33; 10; 26	6 see physical contrad.	15; 25; 3; 10; 5; 8	**1; 35; 21; 15; 4; 10**	6; 27; 35; 22; 12; 37	3; 25; 17; 35; 12	7; 13; 22; 6; 35
7	Production Cost	15; 23; 29; 5; 13	15; 25; 3; 10; 5; 8	7 see physical contrad.	**1; 24; 19; 10; 27; 3; 14**	26; 10; 1; 3; 25; 12	26; 1; 37; 25; 2; 28	5; 2; 30; 35; 17; 8; 25
8	Production Time	15; 40; 23; 3; 24; 13	1; 35; 21; 15; 4; 10	1; 24; 19; 10; 27; 3; 14	8 see physical contrad.	10; 27; 15; 6; 3; 22; 29	10; 15; 38; 20; 27; 6; 3	5; 17; 16; 3; 10
9	Production Risk	7; 5; 3; 37; 10	6; 27; 35; 22; 12; 37	26; 10; 1; 3; 25; 12	**10; 27; 15; 6; 3; 22; 29**	9 see physical contrad.	5; 6; 23; 20; 7; 10; 25	5; 25; 3; 35; 2; 10
10	Production Interfaces	28;40; 6; 29; 13; 31; 30	3; 25; 17; 35; 12; 13	26; 1; 37; 25; 2; 28	10; 15; 38; 20; 27; 6; 3	5; 6; 23; 20; 7; 10; 25	10 see physical contrad.	6; 2; 37;40; 10

Fig. 7 Business Contradiction Matrix –suggested inventive principles (Mann, 2009)

The meaning of the suggested inventive principles can be seen in Fig. 8. *Additional Principles suggested by Darrel Mann (Mann, 2009). The focus on the problem through each of the suggested inventive principles, one at a time, led the solution proposals generation. # 52 (fifty-two) solution proposals were listed based on the Contradictions Matrix, as shown in Fig. 9. (See section 6 for comments on using the selected best proposals).

IMPROVING	WORSENING	INVENTIVE PRINCIPLES				
PRODUCTION TIME	PRODUCTION SPECIFICATION	1= SEGMENTATION	35= PARAMETERS CHANGE	21= HURRYING	4= ASYMMETRY	10= PRIOR ACTION
PRODUCTION TIME	PRODUCTION COST	24= INTERMEDIARY	19= PERIODIC ACTION	27= CHEAP DISPOSABLE	3= LOCAL QUALITY	14= CURVATURE
PRODUCTION TIME	PRODUCTION RISK	15= DYNAMIZATION	6= UNIVERSALITY	22= BLESSING IN DISGUISE	29= FLUIDITY	
PRODUCTION TIME	ALWAYS USED *	5= MERGING	25= SELF SERVICE			
PRODUCTION TIME	OTHERS TO CHECK *	13= THE OTHER WAY ROUND	2= TAKING OUT / SEPARATION			

Fig. 8 Inventive principles suggested by the Matrix

TECH	ASSEMBLING TEAM PARTICIPATES IN THE PROJECT DEFINITIONS
TECH	CONSTRUCTION COORDINATION WITH AUTONOMY
TECH	CUSTOMERS AND ASSEMBLING CONTRACTORS MUST BE HEARD IN THE PROJECT DEFINITIONS
TECH	USE FLEXIBLE DAILY TIME SCHEDULE FOR ASSEMBLING SERVICE
TECH	USE STANDARD DOCUMENTATION
TECH	USE A CELL BASE STRUCTURE FOR PROCUREMENT AND ASSEMBLING
TECH	PREPLANNING OF THE ASSEMBLING SERVICE
TECH	START ADVANCED QUOTING WITH POSSIBLE SUPPLIERS BEFORE FINAL PROJECT AUTHORIZATION
TECH	CUSTOMER AND HSEQ MUST BE HEARD DURING THE ASSEMBLING
TECH	INCREASE THE SYSTEM FINAL USER PARTICIPATION IN THE INTERFACE WITH ENGINEERING
TECH	CELL BASED EXECUTION (PROCUREMENT, ASSEMBLING, CONSTRUCTION) FOR EACH CUSTOMER AREA
TECH	CREATE A TASK FORCE FOR EXPRESS EXECUTION (PROCUREMENT & ASSEMBLING)
TECH	CREATE TASK FORCES TO QUICK RESPONSES TO SMALL PROBLEMS
TECH	USE THE MORE EXPERIENCE PROFESSIONALS TO SUPPORT ALL PROJECTS CONCEPTS
TECH	USE STANDARD SOLUTIONS FOR TYPICAL PROJECTS
TECH	USE ASSOCIATION OF MATERIALS AND SERVICE SUPPLIERS
TECH	PROJECTS MEETING SCHEDULES MUST BE ADJUSTED TO THE PROJECT COMPLEXITY
TECH	INCLUDE MATERIALS IN THE ASSEMBLING AND CONSTRUCTION CONTRACTS
TECH	PERFORM CRITICAL TASKS IN ADVANCE
TECH	QUICK ANSWER TO ANY CUSTOMER COMPLAINING
TECH	USE ONLY PRE EVALUATED MATERIALS SUPPLIER
TECH	USE REFERENCE PRICES ACCORDING TO MARKET VALUES
TECH	MONTHLY FEEDBACK FOR PROJECT TEAMS AND CONTRACTORS
TECH	USE A ASSEMBLING/CONSTRUCTION SUPPLIERS ASSOCIATION
TECH	ELIMINATE ALL BARRIERS BETWEEN ENG AND THE INTERNAL CUSTOMERS
TECH	COMBINE EXPERIENCED AND NEW PROFESSIONALS IN THE PROJECT TEAMS
TECH	SMALL ASSEMBLIES COORDINATED DIRECTLY BY CUSTOMER TEAM
TECH	ALLOW SUBCONTRACTING TO OTHER ASSEMBLING CONSTRUCTION COMPANIES WITH SAME EXPERIENCE (LOCAL CONSTRUCTION POOL)
TECH	HAVE ALL CONSTRUCTIONS IN ONE SINGLE CONTRACT
TECH	ESTABLISH 30% PAYMENT WITH PO APPROVAL AND THE REST ONLY AGAINST THE FINAL DELIVERY
TECH	REINFORCE THE CONSTRUCTION TEAM WITH THIRD PARTY SUPERVISORS
TECH	PERFORM SEVERAL ASSEMBLING/CONSTRUCTION SIMULTANEOUSLY
TECH	CONTRACT SPECIALIZED COMPANY FOR CONSTRUCTION MANAGEMENT
TECH	INTRODUCE PERIODIC CONTRACT REVIEWS
TECH	INTRODUCE PERIODIC PERFORMANCE REVIEWS IN THE CONTRACTS
TECH	RETURN RETIRED PROFESSIONALS WITH CRITICAL KNOWLEDGE
TECH	USE FLOATING LIMIT DELIVERY DATE AS FUNCTION OF UNEXPECTED FUTURE EVENTS
TECH	SEGREGATE SMALL GROUP FOR DIRECT SMALL ASSEMBLING (ONLY SAFETY REVIEWS AND DOCS AS BUILT)
TECH	BE OPENED TO PROVOCATIONS = NEW IDEAS
TECH	USE WBS WITH MATERIALS/EQUIP AND SERVICES FOR BIGGER PROJECTS
TECH	USE INTRANET FOR PROJECTS COMMUNICATION
TECH	TAKE THE QUICKEST WAY TO THE INTERNAL CUSTOMER AVOIDING TOO MUCH BUROCRACY
TECH	ESTABLISH NEW MEETING ROOMS
TECH	PROJECT TEAM MUST ADJUSTED QUICKLY
TECH	REDIRECT PERSONAL ATTACKS TO THE PROBLEMS
TECH	ACCELERATE FAILURE TO ACCELERATE CORRECTIONS
TECH	USE DISPOSABLE MATERIALS IN THE ASSEMBLING AND CONSTRUCTIONS
TECH	BLAME THE PROCESS NOT THE PROFESSIONALS
TECH	ELIMINATE THE FEAR
TECH	ELIMINATE CHANGES FEAR WITH THE COMPETITION FEAR
TECH	USE MATERIALS SUPPLYING JUST IN TIME
TECH	REDUCE LONG TERM CONTRACT PRICES USING THE PREFERENCE OPTION CLAUSES

Fig. 9 Solution proposals using the Contradiction Matrix

-Identifying the "Physical" Contradiction

To ensure quality is necessary to go deeper in the details, reducing the overall speed. To guarantee the finish date, the speed must be high. We need to be fast and slow, showing a physical contradiction. To address this radical contradiction, the separation principles must be used according to the nature of the situation (in time, in space, condition or in scale).

-Separation type selected

The separation by scale was selected since the separations based on time, in space and on condition were not applicable to this situation. That is, the situation requires high and low speed at the same time, in the same location/space and in any condition. Fig. 10 shows the suggested inventive principles available, excluding the ones already used before. The suggested inventive principles led the search for additional solution proposals.

#14 (fourteen) solution proposals based on the physical contradiction were listed as shown in Fig. 11. (See section 6 for comments on using the selected best proposals).

FAST x SLOW	INVENTIVE PRINCIPLES (SEPARATION BY SCALE)				
SCALE- SUPERSYSTEM	6= UNIVERSALITY	12= EQUIPOTENTIALITY (REMOVE TENSION)	33= HOMOGENEITY	40= COMPOSITE MATERIALS	ALREADY USED
SCALE- SUBSYSTEM	ALREADY USED				
SCALE- INVERSE SYSTEM	ALREADY USED				
SCALE- ALTERNATIVE SYSTEM	8= ANTI WEIGHT	ALREADY USED			

Fig. 10 Inventive Principles suggested – Physical Contradiction

PHY	PROJECT AND PROCUREMENT TEAMS FULLY INTEGRATED
PHY	SELECT AND USE A MORE EXPERIENCED TEAM TO SUPPORT THE PROJECTS
PHY	MAXIMUM INTEGRATION BETWEEN PROJECT TEAM AND INTERNAL CUSTOMER
PHY	USE A STANDARD SCHEDULE AS REFERENCE FOR ALL PROJECTS SCHEDULES
PHY	INCREASE THE NUMBER OF OWNER PROFESSIONALS IN THE PROJECT TEAMS
PHY	PROCUREMENT TEAM PARTICIPATING IN THE PROJECTS PLANNING
PHY	INCLUDE PROCUREMENT AND WAREHOUSE REPRESENTATIVES IN THE PROJECT TEAM
PHY	TRAIN ALL TECHNICAL SPECIALISTS IN PROJECT MANAGEMENT
PHY	PLANNING MUST ISSUE A RISK REPORT FOR EACH PROJECT
PHY	USE EVA TO EVALUATE MONTHLY THE BIGGER PROJECTS
PHY	WAREHOUSE AND ENGINEERING FULLY INTEGRATED
PHY	PROJECTS TEAMS FULLY INTEGRATED
PHY	COMBINE DIFFERENT SPECIALIST IN EACH PROJECT
PHY	USE EXTERNAL EXPERIENCE IN PROJECT MANAGEMENT

Fig. 11 Solution proposals generated based on the Physical Contradiction

At this point, the basic cycle of TRIZ was concluded generating 66 (sixty-six) proposals. One could go directly to the evaluation against the ideality or expand the search for new solution proposals using additional tools. The second option was chosen.

-Trimming and 76 Standard Solutions

By choosing to broaden the search for alternatives using these two additional tools, one must return to the definition phase and perform the function analysis that gives a better view of the characteristics of the specific problem and its relationships.

-Function Analysis

The most problematic relationships were identified in the analysis (Shown in Fig. 12). They will allow the TRIZ tools to be focused on the real issues.

The analysis summary, focusing only on the problematic relationships, can be seen in Fig. 13 (SAO: Subject – Action – Object) and they will be the basis for the additional tools application.

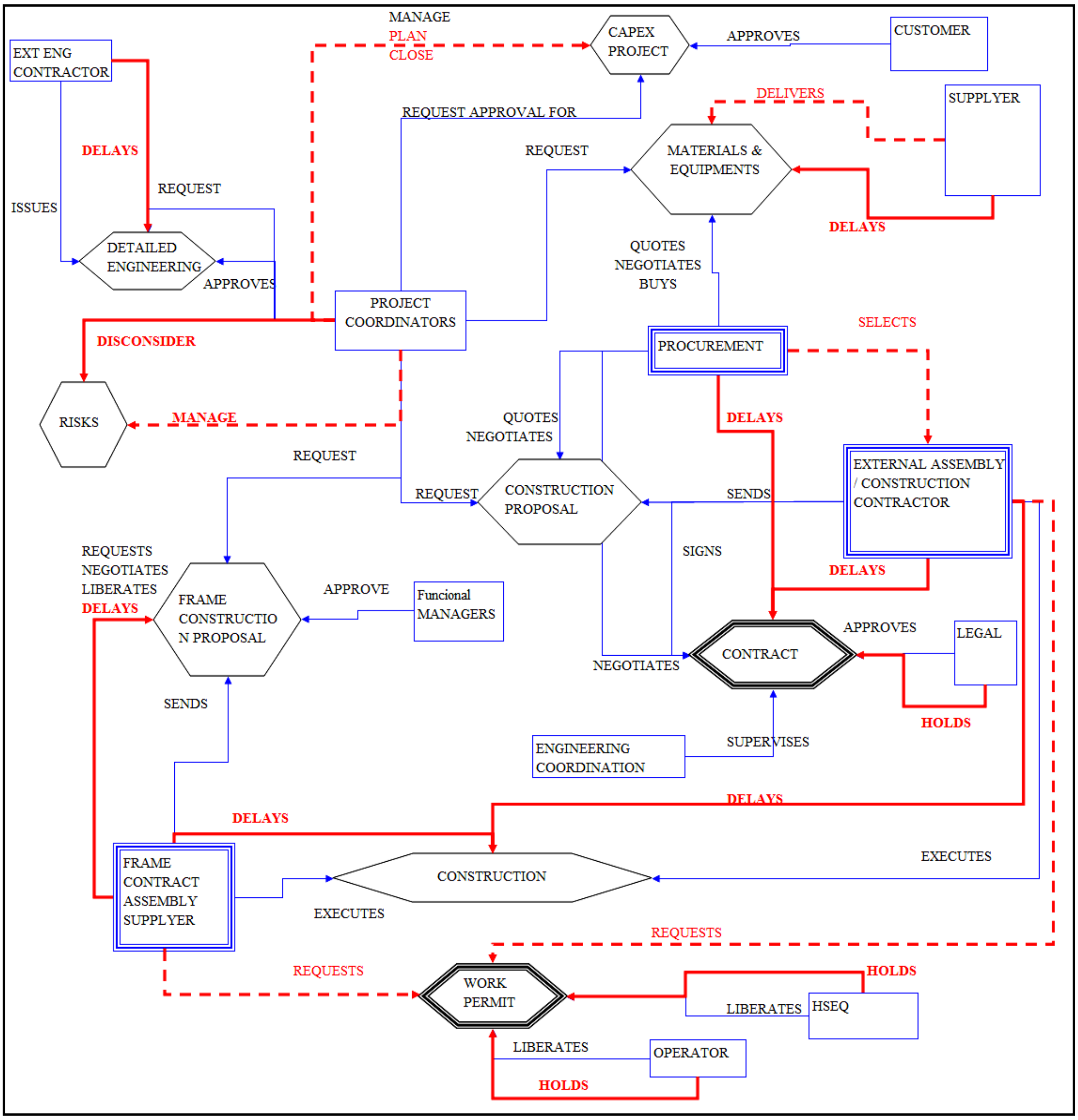

Fig. 12 Function Analysis (threats or insufficiencies in red dotted or thick lines)
Note: Red dotted lines = insufficiencies; Red thick lines = harms/threats; Blue thin lines = satisfactory

CAT	SUBJECT	ACTION	OBJECT	FUNCTION	TYPE
I	PROJ COORDINATORS	PLAN	CAPEX PROJECT	PLANNING	INSUFFICIENT
I	PROJ COORDINATORS	CLOSE	CAPEX PROJECT	CLOSING	INSUFFICIENT
TH	PROJ COORDINATORS	DISCONSIDER	RISKS	RISK MANGT	THREAT
TH	MAT&EQT SUPPLIER	DELAYS	MAT & EQUIP	DELIVERY	THREAT
I	PROCUREMENT	SELECTS	EXT ASSEMBLY CONTRACTOR	SELECTION	INSUFFICIENT
TH	PROCUREMENT	DELAYS	CONTRACT	BUYING	THREAT
TH	LEGAL	HOLDS	CONTRACT	APPROVAL	THREAT
TH	EXT ASSEMBLY CONSTRUCTION CONTRACTOR	DELAYS	CONTRACT	SIGNING	THREAT
TH	EXT ASSEMBLY CONSTRUCTION CONTRACTOR	DELAYS	CONSTRUCTION	EXECUTION	THREAT
I	EXT ASSEMBLY CONSTRUCTION CONTRACTOR	REQUESTS	WORK PERMIT	WORK PERMIT REQUISITION	INSUFFICIENT
TH	FRAME CONTRACT ASSEMBLY SUPPLIER	DELAYS	FRAME CONTRACT PROPOSAL	PROPOSING	THREAT
TH	FRAME CONTRACT ASSEMBLY SUPPLIER	DELAYS	CONSTRUCTION	EXECUTION	THREAT
I	FRAME CONTRACT ASSEMBLY SUPPLIER	REQUEST	WORK PERMIT	WORK PERMIT REQUISITION	INSUFFICIENT
TH	HSEQ	HOLDS	WORK PERMIT	WORK PERMIT LIBERATION	THREAT
TH	OPERATOR	HOLDS	WORK PERMIT	WORK PERMIT LIBERATION	THREAT
I	EXT ENG CONTRACTOR	ISSUES	DETAILED ENG	ENG DETAILING	INSUFFICIENT
TH	EXT ENG CONTRACTOR	DELAYS	DETAILED ENG	ENG DETAILING	THREAT
I	PROJ COORDINATORS	CLOSE	CAPEX PROJECT	CLOSING	INSUFICIENT

Fig. 13 SAO: Identified Problematic Relationships

-Trimming

This tool operates questioning each of the problematic relationship as follows.

-Can we eliminate the function?

-Could the object perform the function itself?

-Is it possible to remove the subject / the agent or the object?

-Is it possible to get rid of the agent / the subject after the function performed?

-Is it possible to remove any system parts?

-Can any other agent or other object perform that function?

-Any available resource could perform the function?

The answers to the questionnaire generated 6 (six) solution proposals as shown in Fig. 14. (See section 6 for comments on using the selected best proposals)

TRIM	PREFERENCE FOR THE FRAME CONTRACTS SUPPLIERS
TRIM	USE PRE EVALUATED SUPPLIERS ONLY
TRIM	ALLOW THIRD PARTY TRAINED PROFESSIONALS TO LIBERATE WORK PERMITS
TRIM	CONTINUOUSLY EVALUATE THE FRAME CONTRACT SUPPLIER
TRIM	WORK PERMIT RESPONSIBLE MUST BE INFORMED ABOUT THE PROJECT SINCE THE PLANNING
TRIM	USE CLEAR KIP'S FOR EACH SERVICE SUPPLIER

Fig. 14 Solution proposals generated based on the Trimming tool and SAO

-76 Standard Solutions

From the same list of problematic relationships, one can test the standard suggested principles for each of the categories identified in the problem. It was used the Oxford Standard Solutions adapted from the traditional 76 Standard Solutions re-arranged into three categories: harm, insufficiency and measurement (Gadd, 2011).

The tool guided us in treating both identified categories, as the follows.

a) Threat (Harm)

Four basic strategies for dealing with harms.

a1. Eliminate – trim out the harm (already tested in Trimming)

a2. Stop – block the harm.

a3. Transform the harm – turn harm into good.

a4. Correct – put right the harm.

b) Insufficiency

Two basic strategies to improve, change or enhance functions by changing:

b1. The components (subject / object or their surroundings)

-Add something to the subject and/or object or to the environment.

-Change/evolve the subject or/and object.

b2. The action or field that acts between components.

This tool returned 26 (twenty-six) solution proposals as shown in Fig. 15. (See section 6 for comments on using the selected best proposals).

STD	PRE APPROVED STANDARD CONTRACT
STD	ENGINEERING PARTICIPATES IN THE SUPPLIERS SELECTION CRITERIA
STD	CONTINUOUS WORK PERMITS
STD	USING PRE APPROVED SUPPLIERS ONLY
STD	CONSTRUCTION CONTRACTOR MUST INFORM 1 DAY EARLY ALL TASKS PLANNED
STD	IMPROVE SUPPLIERS SELECTION CRITERIA
STD	USE SUPPLIERS THAT ARE AWARE OF THE OWNER INTERNAL PROCEDURES AND STANDARDS
STD	ACCELERATE THE PROPOSALS FROM SERVICE SUPPLIERS
STD	SUPPLIERS RANKED CONSIDERING HIGH WEIGHT ON DELIVERY DATE HISTORY
STD	HAVE A CHAMPION SUPPORTING ALL RISK MANAGEMENT SINCE TH EARLY PLANNING
STD	USE INTEGRATED CONTRACTS FOR THE MOST COMMON MATERIALS
STD	INCLUDE DETAILED SCHEDULE IN THE ASSEMBLING PROPOSALS
STD	EXECUTE SCHEDULE RISK SIMULATION BEFORE FINAL PROJECT AUTHORIZATION
STD	INCLUDE A SAFETY TECHNICIAN IN THE ENGINEERING TEAM
STD	USE PROJECT RISK KIP'S
STD	ENGINEERING COORDINATOR MUST MANAGE THE PORTFOLIO RISKS
STD	PROCEDURES FOR WORK PERMIT MUST BE INFORMED TO ALL
STD	TRAIN THE PROJECTS COORDINATORS IN RISK MANAGEMENT
STD	UPDATE WORK PERMIT PROCEDURES
STD	HAVE 2 FRAME CONTRACTORS AVAILABLE
STD	CONTRACTORS MUST KEEP SAFETY TECHNICIAN GUIDING ITS OWN TEAM
STD	KEEP LIST OF ALTERNATIVE HIGHLY QUALIFIED SUPPLIERS FOR EMERGENCIES
STD	CONTRACT THIRD PARTY PLANNER WITH RISK MANAGEMENT EXPERIENCE
STD	APPLY DELAYS PENALTIES IN THE CONSTRUCTION CONTRACTS
STD	INCLUDE DELIVERY CONDITIONS IN THE INDIVIDUAL EVALUATION FOR EACH PROJECT COORDINATOR
STD	CONSIDER ALL DELAYS POSSIBILITY IN THE PRELIMINARY SCHEDULE

Fig. 15 Solution proposals generated based on the Std. Solutions tool

4.4 Other Tools

In order to exhaust the alternatives, the Inventive Triggers were used (X-Factor; Life and Death analogies; Smart Little People; Time-Size-Cost; Subversion). The most effective one was the "size / time / cost" - minimum & maximum in which each of these three critical dimensions is radically overstated (zero to infinite) for the alternatives generation.

The tool generated more 7 (seven) solution proposals as shown in Fig. 16. (See section 6 for comments on using the selected best proposals).

As a last tool, the Trends of Evolution were quickly tested (increasing ideality; S-curve; non–uniform evolution of parts; matching and mismatching; less human involvement; increasing complexity followed by simplicity; increasing dynamism & controllability) returning more 4 (four) solution proposals shown in Fig. 17 (See section 6 for comments on using the selected best proposals).

However, many redundant solutions were generated, if compared to the alternatives already identified, indicating some degree of exhaustion.

TRI	LONG TERM FRAME ASSEMBLY/CONSTRUCTION CONTRACT
TRI	CONTROL ALL SERVICES THROUGH SERVICE ORDERS TO APPROVE BEFORE ANY COMMITMENT
TRI	ALL PURCHASE ORDERS MUST INCLUDE ALL CONDITIONS TO BE FOLLOWED FOR THE SERVICE EXECUTION
TRI	PARTNER SUPPLIERS SIGN ONE SINGLE RESPONSABILITY MOU TO COVERS ALL SERVICES TO EXECIUTE
TRI	USE ALWAYS THE SAME EXECUTION TEAM FOR ALL PROJECTS
TRI	EVALUATE TO AUTHORIZE PROJECTS BASED ON THE DEFINED SCOPE
TRI	CONTRACT EXTERNAL ENGINEERING AND CONSTRUCTION COMBINED

Fig. 16 Solution proposals generated based on the inventive triggers

TRENDS	PROCUREMENT & LEGAL FOLLOWING THE PROJECT SCHEDULES
TRENDS	CUSTOMER ENGINEERING LEADS ITS OWN SMALL PROJECTS
TRENDS	PROJECT TASKS PERFORMED 24 X 7 AROUND THE WORLD
TRENDS	ASSEMBLING RESOURCES DEFINED ACCORDING THE APPROVED PROJECT PORTFOLIO

Fig. 17 Solution proposals generated based on the Trends of Evolution tool

5. Assessment against the ideality

Until now, the proposals were generated without any formal evaluation. At this step, it is necessary to rank the proposals in order to identify the best ones and those easier to implement. As a reference for decision-making, the assessment was done using multiple criteria selection based on the concepts of ideality (Rantanen& Domb, 2008):

-Were threats eliminated?

-Are useful features retained and new benefits added?

-Have new threats arisen?

-Did the system become more complex?

-Was the main physical contradiction eliminated?

-Were free or ignored resources used?

By adding a criterion related to the ease of implementation, one can prioritize proposals according to the ideality ranking starting by the easiest one to put in practice (Fig. 18). Depending on the environment in which the projects are executed, other criteria and individual weights may be used.

As an exhaustive process, many repeated proposals came through different tools. Eliminating redundancies/repetitions, there were 109 additional proposals over the 10 preliminary ones. Of the total 119 proposals, 61 ones reached ideality rating

SOURCE	IDEALITY CHECK	HARMS DISAPPEAR?	USEFUL FEATURES KEPT? NEW BENEFITS APPEAR?	NEW HARMS APPEAR?	SYSTEM BECOMEs MORE COMPLEX?	PRIMARY PHYSICAL CONTRADICTION SOLVED?	IDLE, EASILY AVAILABLE, IGNORED RESOURCES USED?	OTHER: EASE TO IMPLEMENT?	TOTAL
	WEIGHT	3	1	2	1	5	1	1	
	Ideal	10	10	0	0	10	10	10	TOTAL
TRI	LONG TERM FRAME ASSEMBLY/CONSTRUCTION CONTRACT	10	10	0	0	9	7	9	91,8%
STD	PRE APPROVED STANDARD CONTRACT	10	8	0	0	9	5	8	87,3%
STD	ENGINEERING PARTICIPATES IN THE SUPPLIERS SELECTION CRITERIA	8	8	0	0	9	3	7	79,1%
TECH	ASSEMBLING TEAM PARTICIPATES IN THE PROJECT DEFINITIONS	7	8	0	0	9	5	8	79,1%
STD	CONTINUOUS WORK PERMITS	7	10	1	0	9	5	7	78,2%
PHY	PROJECT AND PROCUREMENT TEAMS FULLY INTEGRATED	7	10	0	0	9	3	5	76,4%
TRENDS	PROCUREMENT & LEGAL FOLLOWING THE PROJECT SCHEDULES	7	8	1	1	8	6	6	70,9%
STD	USING PRE APPROVED SUPPLIERS ONLY	6	7	0	0	8	5	7	70,0%
TRENDS	CUSTOMER ENGINEERING LEADS ITS OWN SMALL PROJECTS	8	6	5	1	8	10	7	69,1%
TECH	CONSTRUCTION COORDINATION WITH AUTONOMY	6	7	1	0	8	5	5	66,4%
STD	CONSTRUCTION CONTRACTOR MUST INFORM 1 DAY EARLY ALL TASKS PLANNED	7	9	0	3	8	0	6	66,4%
TECH	CUSTOMERS AND ASSEMBLING CONTRACTORS MUST BE HEARD IN THE PROJECT DEFINITIONS	6	8	0	0	7	5	7	66,4%
STD	IMPROVE SUPPLIERS SELECTION CRITERIA	5	8	0	0	8	3	7	66,4%
PHY	SELECT AND USE A MORE EXPERIENCED TEAM TO SUPPORT THE PROJECTS	6	7	0	0	7	5	7	65,5%
TECH	USE FLEXIBLE DAILY TIME SCHEDULE FOR ASSEMBLING SERVICE	2	10	0	1	8	8	9	65,5%
TECH	USE STANDARD DOCUMENTATION	2	10	0	0	8	7	9	65,5%
STD	USE SUPPLIERS THAT ARE AWARE OF THE OWNER INTERNAL PROCEDURES AND STANDARDS	5	9	3	0	9	3	5	64,5%
TRIM	PREFERENCE FOR THE FRAME CONTRACTS SUPPLIERS	10	8	5	0	6	5	7	63,6%
TRI	CONTROL ALL SERVICES THROUGH SERVICE ORDERS TO APPROVE BEFORE ANY COMMITMENT	0	9	0	0	9	7	9	63,6%
TECH	USE A CELL BASE STRUCTURE FOR PROCUREMENT AND ASSEMBLING	4	10	3	0	9	5	3	62,7%
STD	ACCELERATE THE PROPOSALS FROM SERVICE SUPPLIERS	7	8	0	0	7	0	5	62,7%
STD	SUPPLIERS RANKED CONSIDERING HIGH WEIGHT ON DELIVERY DATE HISTORY	5	7	0	0	7	5	7	62,7%
TRIM	USE PRE EVALUATED SUPPLIERS ONLY	6	9	1	3	8	0	7	62,7%
PHY	MAXIMUM INTEGRATION BETWEEN PROJECT TEAM AND INTERNAL CUSTOMER	5	10	0	0	7	3	5	61,8%
TECH	PREPLANNING OF THE ASSEMBLING SERVICE	6	10	2	1	8	0	5	61,8%
PRE	PROCUREMENT TEAM DEDICATED TO PROJECTS	4	10	3	1	9	7	0	60,9%
TRI	ALL PURCHASE ORDERS MUST INCLUDE ALL CONDITIONS TO BE FOLLOWED FOR THE SERVICE EXECUTION	8	7	3	0	6	7	5	60,9%
PHY	USE A STANDARD SCHEDULE AS REFERENCE FOR ALL PROJECTS SCHEDULES	5	5	0	0	6	7	10	60,9%
TECH	START ADVANCED QUOTING WITH POSSIBLE SUPPLIERS BEFORE FINAL PROJECT AUTHORIZATION	6	10	1	0	7	0	5	60,0%
PHY	INCREASE THE NUMBER OF OWNER PROFESSIONALS IN THE PROJECT TEAMS	5	7	2	0	7	5	8	60,0%
STD	HAVE A CHAMPION SUPPORTING ALL RISK MANAGEMENT SINCE TH EARLY PLANNING	3	8	0	0	7	5	9	60,0%

Fig. 18 Evaluated Solution Proposals Summary (>/=60% ideality ranking)

above 50% as a first filter. The proposals show corrective and preventive approaches that could be used as a specific filter, if needed. The rest of the proposals should also be examined because it contains ideas whose immediate execution may be difficult but with significant positive impact if implemented in the future.

A summary containing the higher-ranking 31 solution proposals (complying >/=60% to ideality and ease to implement) is shown in the Fig. 18. (See section 6 for comments on using the selected best proposals).

Note: The identified sources are TRI (triggers), STD (standard solutions), TECH (technical contradictions), PHY (physical contradictions), TRENDS (trends of evolution), TRIM (trimming), PRE (preliminary solutions). Confirming the TRIZ contribution to reveal new possibilities one can see only one proposal coming from the preliminary proposal list (PRE) in this higher-ranking group.

As a preliminary guidance on similar situations and based on the number of solutions generated (Fig. 19), the most effective tools to treat such problems were the elimination of the technical contradictions (48%) and the 76 standards solutions (24%) followed by the elimination of the physical contradictions (13%). It shows that the basic cycle of the workflow was capable of generating half of the potential solutions (51%). Being quicker and effective, the basic cycle becomes the best option for similar cases in which the speed is critical and the time may be short to develop the whole workflow.

	TOTAL	WITHOUT TRIZ	With TRIZ	TECH. CONTR.	STD. SOL.	PHYS. CONTR.	TRIGGERS	TRIMM.	TRENDS EVOL.
Nr. Ideas	119	10	109	52	26	14	7	6	4
				48%	24%	13%	6%	6%	4%

Fig. 19 Number of Ideas x TRIZ tools

6. *The best proposals and their expected effect*

Consolidating the figures 4, 9, 12, 14, 15, 16 and 17, the figure 18 summarizes the best proposals already ranked using the proposed multi-criteria. This section presents additional comments and explanation about the context, how to implement and the expected effects derived from each of the best proposals highlighted in Fig. 18. Note that those solutions have derived from the typical contradiction (speed x quality in project management) and specific threats, insufficiencies and opportunities identified in the function analysis (Fig. 12). The projects used as reference are the ones found in a typical industrial environment. That is, most of the proposals could have direct use in other project management environments but some of them will only be useful in the mentioned context. The ranking criteria themselves, as reference for decision-making, may change according to each situation and type of project. As a quick option to use the best proposals list (>50% ideality compliance), consider taking it as a checklist. Such checklist must be evaluated against your real project and environment during the project planning phase aiming the project acceleration. The multi-criteria and weights may be adjusted to your own situation, generating a different ranking, your own one. Another option would be to expose your PM procedure and environment to the TRIZ workflow. It would generate your own set of best proposals to apply to future projects, reinforcing the risk management process.

See the below comments about each of the best proposal in Fig. 18.

Long term assembly/construction contract: when dealing with several small and medium size projects at the same time, this type of frame contract will speed up the contracting phase of execution, usually keeping the same construction partner for most of the jobs.

Pre-approved standard contracts: where is not possible to use the frame contract, the availability of a standard contract form already evaluated and approved by legal department and all other internal stakeholders will speed the contracting process and the project execution.

Engineering participating in the suppliers' selection criteria: the engineering team directly in charge of the projects management must participate in defining which criteria should be used to select suppliers for the vendor list updating by the procurement team. It would avoid contracting a supplier without the skills and means necessary to execute the job in that specific environment. Problematic contractors may stop or delay the job execution delaying the project delivery.

Assembling team participates in the projects definitions: where there is a team directly responsible by the assembling and construction execution, this team must be involved since the definition phases to identify opportunities to speed up the construction and to avoid future problems and restrictions. It would avoid having to deal with problems during the construction when is much more difficult to solve them without spending additional time.

Continuous work permit: when executing projects in an industrial environment with the presence of flammable products, dangerous substances or any other aggressive fluids, the standard safety procedure requests a formal work permit for every job to be done day by day. Usually this permit must be issued by operational team overloaded with the production routines and the maintenance daily demands. In this scenario, it is easy having a delay in the assembling or construction work permit. If the problem keeps repeating day after day, the whole project schedule will certainly delay. One of the solutions would be having a continuous work permit valid for a week if the safety conditions were under control. This would avoid the daily work permit eliminating the time needed to start the tasks daily.

Project and procurement team fully integrated: considering the importance of preliminary cost estimates and all other procurement tasks executed according to the project schedule it becomes clear that the two teams must work together since the planning phases to avoid unreal budgets and schedule. Since the planning phase, the procurement team must be aware of the impact of every package to be bought or contracted in the whole project. The procurement team must also be allowed to contribute with its experience in the project planning. The integration is critical for generating the best budget and schedule and for having the commitment of both teams with the final schedule.

Procurement & legal following the project schedules: when dealing with contracts there will be an interface with the legal team. The integration of the procurement team in the planning can bring together the legal team to the commitment with the projects schedule.

Using preapproved suppliers only: using suppliers and contractors not fully prepared to work in the specific environment can delay all the project execution. In that sense, using only a pre-approved suppliers list is critical for the schedule.

Customer's engineering leads its own small projects: when dealing with small and low complexity projects, if the customer' s engineering structure has enough skill in PM, these small projects can be managed by that structure with some support from the engineering team. This option would allow solving specific customer's problems in a faster way with an accelerated project delivery.

Construction coordination with autonomy: it is usual to have an engineering structure in which the construction/assembling team has its own coordination. The autonomy to participate and interfere in the project-planning phase is critical to have a construction phase running as quick as possible with minimum unexpected problems and the project delivered in time.

Construction contractor must inform 1 day early all tasks planned: this item is related to the daily work permit. If the construction contractor has a schedule to followed and it updates the future tasks one day before it turns the work permit issue and control much easier for all stakeholders, avoiding delays.

Customers and assembling contractors must be heard in the project definitions: if the customers' and assembling contractors' representative are both heard during definitions phase, they not only can contribute avoiding unreal assumptions but also bringing options to accelerate the schedule.

Improve suppliers' selection criteria: the selection criteria must always be improved including factors that can identify the suppliers with the better conditions and historical in delivering the tasks safely and in the time contracted to avoid projects delays.

Select and use a more experienced team to support the projects: if the team has a number of more experienced professionals, the idea is having part of the time of this group available to the less experienced group in order to identify and correct potential problems early in the planning phase as a type of internal coaching and support.

Use flexible daily time schedule for assembling service: sometimes it is impossible to have the assembling tasks starting in the beginning of the workday with the rest of daily routines, meaning projects delays. In those situations, a special daily schedule would be used for the assembling, starting 2 hours later and adding 2 hours at the end of the day, for example.

Use standard documentation: all projects need a huge amount of formal documentation. The use of the same standard forms in all projects accelerates the team skill and helps avoiding mistakes and misunderstandings. Fewer mistakes mean lower probabilities of delays.

Use suppliers that are aware of the owner internal procedures and standards: In complex industrial environments, it is usual that companies have their own procedures about every critical aspect for their operational routines. The potential suppliers must be aware of these procedures and critical requests before issuing their work proposals once the compliance may affect the costs. A financial unbalance during the execution may generate potential delays in the job.

Preference for the frame contracts suppliers: it is usual to develop partners for specific kinds of jobs negotiating and signing frame contracts with them. These contracts establish the commercial and general conditions. At each job to be done, a specific proposal is issued covering the specific scope and schedule but referring the general conditions already negotiated. The frame contracts accelerate the contracting phase and so the execution in each project.

Control all services through service orders to approve before any commitment: considering an environment with valid frame contracts, it is critical that each job has its own service order based on a proposal covering scope, cost and schedule. It avoids misunderstandings during execution and so delays for the whole project.

Use a cell base structure for procurement and assembling: this option considers having a small procurement group ("cell") dedicated to small projects. The same concept applies to the assembling cell. The idea is that these cells would have autonomy to develop the tasks related to small projects contributing to higher delivery speed.

Accelerate the proposals from service suppliers: the time to obtain the formal proposals for services and goods is critical for the schedules. The time requested to return the proposal must be planned in the schedule and must be considered by the procurement teams.

Suppliers ranked considering high weight on delivery date history: the delivery time history must be a critical factor when selecting the potential suppliers to avoid the ones not capable of following the schedule.

Use pre evaluated suppliers only: having a suppliers list with updated evaluation related to the schedule commitment is critical to avoid general delays.

Maximum integration between project team and internal customer: this integration is critical for the definition and planning phases. Without this integration, the probability of having an incomplete or wrong solution defined is higher, increasing the possibility to spend more time during the execution trying to fix the problems.

Pre planning the assembling service: the assembling must be planned to avoid potential problems during the execution, leading to delays.

Procurement team dedicated to projects: the ideal situation is having a procurement group dedicated to the projects not executing tasks for other areas to avoid waste of time in this interface.

All purchase orders must include all conditions to be followed for service execution: the suppliers must be informed before the proposal of all the requests and risks in the environment in which the job will be executed. It avoids surprises that are time consuming to solve during the execution.

Use a standard schedule as reference for all projects schedules: as all other standard forms, using a standard schedule structure for all projects turns easier to prepare it and to understand it avoiding time-consuming misunderstandings.

Start advanced quoting with possible suppliers before final project authorization: the advance quoting is critical to generate better budgets for the projects. An understated budget will make a project short of funds leading to interruptions in execution and delays.

Increase the number of owner professional in the project teams: the higher number of owner project professionals in the team compared to third part ones may increase the commitment with projects problem solutions. In that sense, keeping an owner project professional's core group is critical for the commitment with cost and schedule.

Have a champion supporting all risk management since the early planning: having an experienced risk professional available to support all the project team when dealing with potential threats and opportunities in the schedule management is critical for good results. This professional could also support the TRIZ tools application.

7. Conclusions

If the solutions derived from the current project management procedure are satisfactory, just apply them, you don't need TRIZ. In more complex cases, when results are not reaching the desirable level and the current PM procedure is limited to compromising options, the TRIZ tools support the search for inventive solutions, identifying the hidden contradiction and developing the specific situation analysis.

In the evaluated case, one can see clearly that the preliminary ideas had not the same coverage as those ones generated through TRIZ. That is, the contribution of TRIZ to accelerate projects while maintaining the quality was significant in quantity and focus. As a general conclusion and based on 109 solutions generate using the TRIZ tools, we might say that the project management practice, like any other group of processes, can also benefit from the exposure to the TRIZ concepts, mainly for problems in which the usual solutions may lead to a compromise.

TRIZ can take the standard PM procedure beyond the usual limits to deal with real problems in executing any project. It does it by turning clear the harms and insufficiencies and focusing on solving the main contradiction without compromises.

Based on the number of solutions obtained through each tool, the most effective ones for similar cases were the elimination of the technical and physical contradictions. Being part of the proposed workflow's basic cycle, they were quicker and generated 51% of the entire contribution. They can be considered the best option for similar cases in which the schedule is critical and the time to develop the whole workflow is short.

The solutions derived from this paper can be applied in other similar cases as a checklist to evaluate the situation regarding speed and quality of the projects under planning. However, some of the solutions are specific to the situation and environmental under analysis and may be not relevant to other cases.

Due to the characteristics of the TRIZ workflow, it can be adjusted (using part of the available tools) according to the situation's complexity or the dissatisfaction with the amount and / or quality of the solution proposals obtained so far. The workflow facilitates the use of the tools by beginners.

For better results, a multidisciplinary group, including members with deep knowledge of the problem, should perform the exercise of TRIZ.

One thing that becomes clear along the process is that the structured and progressive TRIZ workflow used in this paper turns quickly available strong means to identify the real critical problems. Around these critical points, all energy and inventiveness are concentrated to generate a huge amount of possible solutions in a very short time period.

It is important to make clear that the TRIZ tools were not meant to replace the project management procedures. Their application only makes sense over an established project management methodology when facing a real problem or limitation in getting the desired projects results. If there is no project management procedure in use, the first step would be to introduce it, otherwise TRIZ would only generate solutions that certainly would already be part of any consolidated project management good practice.

As seen, TRIZ can be a powerful support to improve the PM practices if one considers that PM is about delivering quality results under restrictions of time, cost, and scope, a typical scenario with contradictions and compromises.

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