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Practical Risk Management Plan of Wi-Fi Network Deployment; Case Study

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***Abstract*— Over the last four years, instability and unrest in Libya raised risk analysis topic to a very sensitive grade that it might affect any business. This imposed more attention at identifying and assessing of potential risks in a very early stage of any project, which is highly important for planning the most appropriate strategies to minimize threats and exploit opportunities.**

This paper demonstrates the risk management plan for phase one of RAPIDCOM Wi-Fi Project designed and constructed by Ericsson AB, Libya branch. RAPIDCOM is a new Libyan internet services provider, based in Tripoli, recently received the license from the Ministry Of Telecommunications and Informatics. RAPIDCOM is focusing on Wi-Fi deployment for providing internet services and applications to users. Their tight time plan targeted launching services in four months' time.

Results showed that having very early risk analysis in conception stage with good tracking of response strategies and countermeasures applied reduced area of uncertainty associated with business performance and decreased the catastrophic risks percentage from 23% to 2%. Significant risks also decreased from 54% to 14%. This reflected in satisfying key stakeholder expectations and saving money and time.

Keywords*— *practical case study; risk management; Wi-Fi deployment, risk register; risk matrix; response strategies; applying countermeasures

I. INTRODUCTION

Telecommunications is a highly competitive sector, growing and changing every day, characterized by very rapid development and relatively short time for identifying threats, analyzing, assessing and mitigating their associated risks. This imposes big challenges on the expected service level from telecom services providers.

In order to remain competitive in such an environment, these organizations must stay abreast of technological advances including a constant revision of their product and service offerings [1].

Organizations should implement comprehensive risk management approaches to ensure all internal and external risks are considered in a holistic way. Organizations must manage risks as a system, while considering the underlying factors that directly impact organizational effectiveness and mission success [2].

Organizations in the telecom sector are constantly looking for methods and solutions to streamline their processes as a means of reducing organizational risks [3]. Towards this, organizations face challenges reducing planning time through multistage overlapping and paralleling of different activities, ensuring information is consistent across channels and training agents and prepare them to handle such cases.

Risk management is the process for identifying, analyzing, and communicating risk and accepting, avoiding, transferring, or controlling it to an acceptable level considering associated costs and benefits of any actions taken [2].

The general objective of this study is to find out how risk is managed during the construction of the telecommunication networks. The specific objectives are (a) to find out the types of risks associated with the construction of RAPIDCOM Wi-Fi network in Tripoli, Libya, (b) to explore the benefits of applying the proper response strategies to the different risks in order to reduce threats impact and get the maximum of the opportunities, and (c) to have a closer look on how telecommunications project managers are managing the associated risks during the project life cycle. Moreover, this practical case shows in real project to what extent that:

- Effective management of risk is essential to achieve goals and objectives and to satisfy key external stakeholder expectations.
- Managing risk reduces the area of uncertainty associated with business performance and gives greater freedom to plan and use resources for innovation and measured risk taking.

- Managing risk directly contributes to profitability by reducing additional costs and assisting to improve certainty around revenue achievement.
- Potential opportunities hidden by areas of uncertainty can be explored and utilized to increase the project value.

II. PROJECT OVERVIEW

RAPIDCOM is a new Libyan ISP focusing on Wi-Fi deployment to provide internet and applications to users. Their plan is to cover whole Tripoli, in two phases, starting the first phase in Hay-Andalus district (Figure 1), the area comprising the majority of business spots, also considered as the most crowded place in the city, followed by other areas in later phases. The first phase scope includes four squared kilometers coverage in four months' time. Within this time frame, an end –to-end Wi-Fi solution will be designed and implemented including, data center, internet gateway, microwave (MW) towers and links, Wi-Fi controller, clusters and access points.

Fig. 1. Targeted geographical area (Hay-Andalus district) to be covered in phase 1.

A. *Network Architecture:*

The agreed on Wi-Fi network solution in this project consists of three main parts, including; (a) core network or data center, (b) transport network and (c) Wi-Fi access network.

***The Data Center* (*DC*)**: also named the core site of the network. It comprises the core equipment including border network gateway (BNG), domain name server (DNS), network management system (NMS), Wi-Fi controller, billing and charging nodes, and the power system. The architecture and the high level configuration of the data center is shown in Figure 2. Network management and most of operation and maintenance activities and tasks are performed at this site.

The Transmission Network: represents the transport layer used in the network and it is the means by which all of the main radio sites are connected together and backhauled to the data center. The MW links and the fiber connections used in the transmission network are shown in Figure 3. In this figure, the blue lines are MW links, while the blue rectangles represent the MW sites, each is planned to feed around 25 to 30 Wi-Fi sites. The data center and the main MW site are co-located, and the gray circle represents the core site or the data center. Connecting the internet source to the data center is done using a fiber cable connection shown in red dotted line in Figure 3.

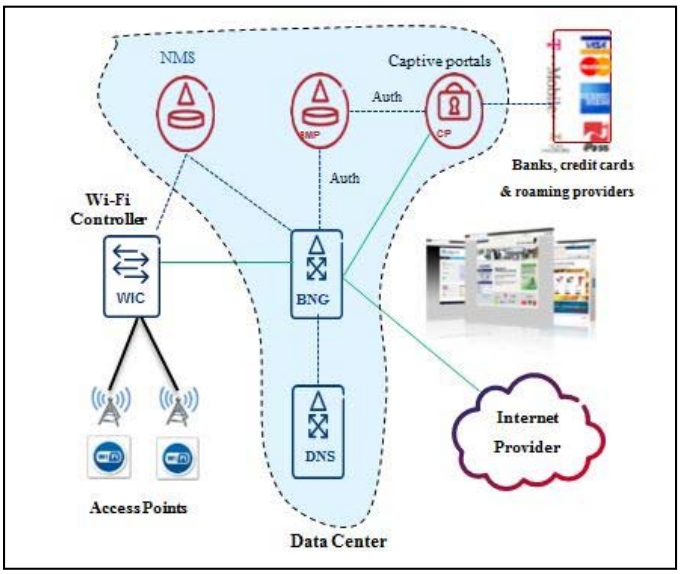

Fig. 2. The structural design of the data center

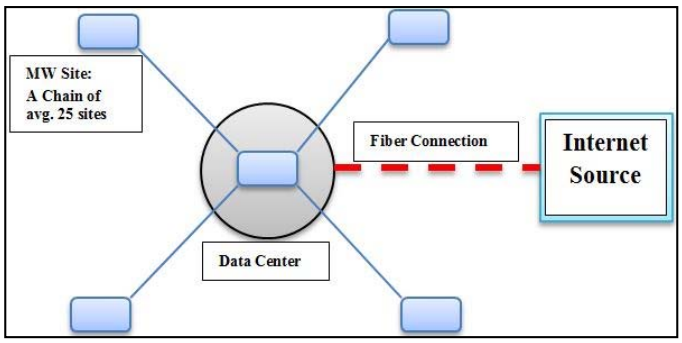

Fig. 3. Microwave (MW) and fiber connections in the transmission network

The Wi-Fi Access Network: The access part of the network provide direct internet access to users through a number of five to seven point-to-point (P2P) access points linked to each of the point-to-multipoint (PMP) clusters. All the access points and the 25 planned clusters are operating at 5GHz and distributed over the targeted geographical area. Figure 4 shows an example of a Wi-Fi cluster with the connected access points.

B. ***Service Overview***: the services and the activities included in this Wi-Fi project can be classified as follows:

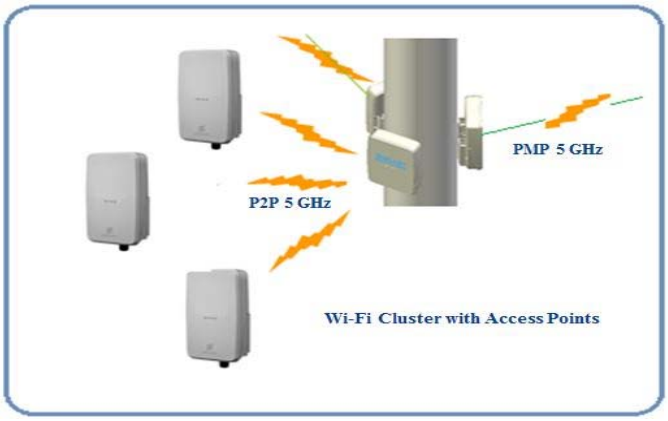

Fig. 4. Wi-Fi cluster in the access network.

Baseline (Contracted): Wi-Fi equipment; MW equipment for backhauling; service platform; high and low level network design including technical site visits; site preparations including civil works and material; installation and commissioning of all network equipment (Wi-Fi, MW, DC, BNG and NMS); engineering and documentation services; project management; babysitting; customer support.

Extra Required (Optional): Main MW tower and civil works for data center; DC-to-IGW fiber or MW connection.

Assumptions: Customer responsibilities include: providing power connection on site; building and construction permits; preparation of equipment room with all needed accessories and furniture; air conditioning system and relevant accessories; fire detection and extinguishing system, when applicable; acquisition of telecommunications equipment permits for installation of MW links and access points; grant the availability of radio frequency channels/bands required to set up the network; all intermediate connections between data center and internet gateway; available space in existing premises.

Activities and Responsibility: (a) site acquisition (Customer): candidate search, negotiations, ranking, granting site access and contracting; (b). civil works (Ericsson): technical site visits, load calculations, low level design, execution, lightening protection and grounding; (c). electrical power (Ericsson): technical site visit, mains, counter, power distribution box, connections, testing; (d). Wi-Fi and transmission networks (Ericsson): technical site visits and survey, high and low level design, installation and integration, network management; (e). engineering and documentation (Ericsson): location layout and drawings, site design, site installation documents, acceptance documents and reports.

C. *Project Time Plan:*

The big challenge in this project is the agreed time frame of four months to provide complete end-to-end solution. Planning, design, delivery and execution including acceptance tests with all administrative and logistic activities must all completed in four months' time starting from receiving the letter of credit.

The project manager considered time plan as the most critical part of the project plan where the committed time frame was relatively very short. This message has been very clearly communicated to all stakeholders and project team, also to every single person connected to the project in any way. Synchronization of many concurrent activities and best utilization of each resource was the key to have every single task completed on time and correct from first time. No delay allowed, supporting customer activities was another key in achieving goals and realizing the agreed timing.

Moreover, in order to speed up the process and gain the manufacturing and shipment time, internal early start of the project was also considered in the time plan in parallel with much effort to have the letter of credit at the right time. Figure 5 illustrates the timeline of the project. Red inverted triangles representing critical business decision milestones, while blue diamonds are indicating the project progress milestones. The yellow parts are representing technical operative activities and tasks, while red color is for decisions and actions at senior management level and blue are considered as project management tasks and responsibilities.

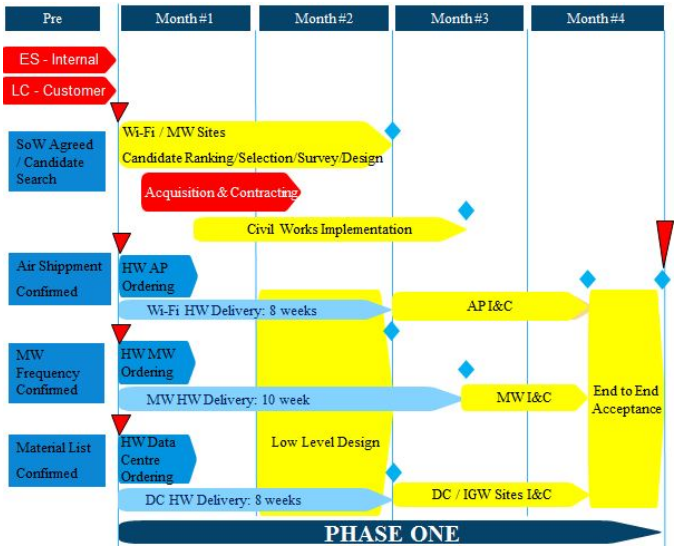

Fig. 5. The timeline of the project

III. PROJECT RISK MANAGEMENT PLAN

Telecommunication networks have evolved to become the backbone through which we conduct our daily lives and transact our businesses. The operation of this complex infrastructure involves risks of loss ranging from damage to the infrastructure's physical components, such as towers and switching equipment, the corresponding interruption of services provided to worker injuries, and liability claims associated with maintaining these networks [4].

Introductory Definitions:

- Risk is an uncertain event identified in advance that may or may not happen, and may have a positive or negative impact on the project. Risks with negative consequences are called threats, and risks with positive consequences are called opportunities [5].

- Threat is a natural or man-made occurrence, individual, entity, or action that has or indicates the potential to harm life, information, operations, the environment, and/or property [2].
- Likelihood is the chance of something happening, whether defined, measured or estimated in terms of general descriptors, frequencies, or probabilities [2].
- Consequence, or impact, is the effect of an incident, event, or occurrence, whether direct or indirect [2].

Through risk management, we work to increase the probability and impact of opportunities on the project (positive events), and to decrease the probability and impact of threats to the project (negative events) [5]. On the other hand, the goal of risk management is to be more proactive and less reactive.

A project manager's work should not focus on dealing with problems; it should focus on preventing them. How would it feel to say, "No problem; we anticipated this, and we have a plan in place that will resolve it." Performing risk management helps prevent many problems and helps make other problems less likely [5]. Practically, the risk management process in this project consists of five steps illustrated in Figure 6.

First, Identifying Risks: In order to identify all the potential risks, the initial project risk register shown in Table 1 has been developed and continuously being updated on weekly bases through brainstorming sessions in different managerial levels, with different departments and stakeholders.

Second, Risks Assessment: Performing likelihood and impact rating to get all expected risks quantified, and classified according to calculated score and severity. In other words, when assessing risks, we need to answer two questions [6]:

1. How likely is it to happen? And;
2. If it does happen, how much will it hurt?

There is a simple way of doing this. We multiply the two numbers (for likelihood and impact) to create a risk factor [7].

Third, Planning Response Strategies: Once we have assessed the various risks to our business, we can decide what we want to do about them, prioritizing our actions based on the risk rating. Clearly, we will want to concentrate first on those significant risks that fall in the top right hand corner of our risk matrix (Figure 7). We may also choose to address some of the less significant risks, particularly, if it is easy or inexpensive to do so. As we move towards the bottom left hand corner there may well be risks that we choose to accept [6].

Fourth, Applying planned countermeasures: Once we have selected the countermeasures to be implemented, it is important that the implementation process is properly managed. It is may also be that some countermeasures are fairly quick and easy to implement. Whereas, others may require significant effort, cost or time. The later type will probably need to be managed as a formal project, with all that entails. Either way, it is important to allocate responsibility for implementing specific countermeasures, whether to a particular director or manager, a project manager or a member of staff. Often, risks are not properly mitigated because it was wrongly assumed that the proverbial 'someone else' had dealt with it [6]. At this stage, response strategies and countermeasures are to be applied to the associated risks.

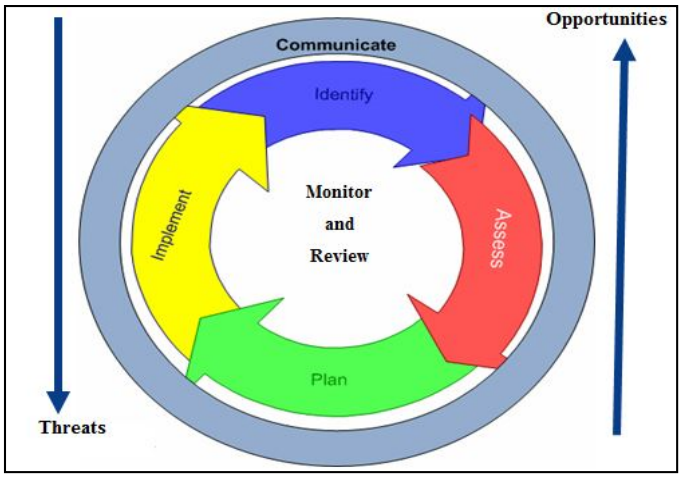

Fig. 6. The risk management process.

Fifth: In order to make sure that all risks are under control, the life cycle of the risk management process has to be completed through the continuous monitor of the outcomes of the actions taken and reviewing the results every time.

For each countermeasure we need to make sure that it works as planned, reduced the overall exposure to risk, improved efficiency, continued to be cost effective, and the level of residual risk is acceptable and being adhered to [6].

Furthermore, contingency planning refers to the fact that it is very important to provide sufficient resources and time for risk management activities, and to establish an agreed upon bases for evaluating risks.

IV. Project Risks Identification

With all those possible risks out there, where on earth do we start? If we tried to identify every potential risk to our business we could make it a full time job, and for most of us this simply is not an option. Therefore, we need to focus our efforts. We need to concentrate on the risks to the most important parts of our business. These are likely to vary from business to business [6]. For this particular Wi-Fi network project the following risks have been included:

a) **Risks Related to Project Management:** completion on time, the big challenge; production lead time; activities synchronization; hardware delivery; lack of specific resources; visa for expats.
b) **Owner Side Risks:** letter of credit delay; supervisory team; MW frequency license; customs clearance; site acquisition and contracting; site access; electric power availability and connections; work permits.
c) **Financial Risks:** project early start and advance payment; increased cost; exchange rate; underestimated budget; political unrest; instable banking operations; high competition; customer not able to pay.

d) **Strategic Risks:** new challenge for Ericsson Libya; chance to win or lose the second phase of the same project; university of Tripoli tender; other Wi-Fi tenders.
e) **Technical Risks:** connectivity and line-of-sight survey problems; underestimated or overestimated quantities; DC tower was not included; synchronization among different activities; unexpected interference problems; disconnection during remote integration; reduced performance; unsatisfactory bandwidth; power failure on Wi-Fi controller as there is no redundancy in the system power.
f) **On-Site Operative Risks:** working at height; security issues; site neighborhood resistance; disruption caused by local community activists; weather conditions; less working hours in the month of Ramadan; rework of completed tasks.
g) **Technological Risks:** reduced coverage and more sites needed; unsatisfactory services and/or products.

V. Project Risk Analysis

As the risks become clearer and better articulated, it is helpful to rate and rank them according to their relative likelihood and impact. In this way, it is eventually becomes possible to decide which risks most deserve the scare resources available to the project and who should be held accountable for mitigating them [7].

A. Qualitative analysis:

This is a subjective analysis of all possible risks that produces a risk ranking, usually, in the order of high, medium, low, or on an ordinal scale. Rankings are made by agreement between the project team, sponsors and key stakeholders [5]. In this project, the ranking was insignificant, minor, moderate, major and catastrophic.

B. Quantitative Analysis:

This is a numerical analysis of the probability (P) and impact (I) of the risk on the project [5]. Determine overall project risk (risk exposure), identify risks requiring the most attention, determine cost and schedule reserves, and create realistic and achievable cost, schedule, or scope targets [5].

Risk Score Value (Rating) = P × I

VI. Risk Register

One method that organizations can use to manage their risk information is to make use of what is called a risk register, also known as a risk log. The risk register serves as a central repository for the organization's risk information and allows for the information that results from the risk management process to be suitably sorted, standardized, and merged for relevance to the appropriate level of management. Its key function is to provide management, the board, and key stakeholders with significant information on the main risks faced by the organization. The risk register also gives the organization's risk management stakeholders a clear view of the current status of each risk, at any point in time [8].

The project risk register is where most of project risk information is kept. It is one document for the whole risk management process in the project that will be constantly updated with information as identify risks, and the later risk management processes are completed. On the other hand, the risk register becomes part of the project documents and is included in historical records that will be used for future projects. Table 1 show the preliminary risk register of the project, where previously mentioned potential risks are presented with their likelihood of occurrence, impact, rating, and the responsible person or team.

TABLE I. The Initial Risk Register of the Project

Category	Code	Risks	Inherent Assessment			Responsible
			Likelihood	Impact	Rating	
1- Project Management Risks	1.1	Completion on Time (The Big Challenge)	4	5	20	PM
	1.2	Production Lead Time	4	4	16	PM & KAM
	1.3	Activities synchronization	3	4	12	PM & TC
	1.4	HW delivery Timing	4	4	16	PM
	1.5	Lack of Specific Resources	3	4	12	PM & H. OPS
	1.6	Visa	3	4	12	PM
2- Owner Side Risks	2.1	Letter of credit delay	4	4	16	PM & KAM
	2.2	Supervisory Team	4	2	8	PM & TC
	2.3	MW Frequency license	5	2	10	TC
	2.4	Customs Clearance delay	3	1	3	H. OPS
	2.5	Site acquisition & contracting	5	2	10	TC
	2.6	Site access	3	3	9	TC
	2.7	Electrical power connections	2	2	4	TC
	2.8	Work permits	2	4	8	PM
3- Financial Risks	3.1	Increased Cost	2	4	8	PM & KAM
	3.2	Exchange rate	2	4	8	PM & KAM
	3.3	Underestimated project budget	3	3	9	KAM
	3.4	Political Unrest	3	4	12	PM & KAM
	3.5	Instable Banking Operations	3	4	12	PM & KAM
	3.6	High Competition	3	3	9	PM & KAM
	3.7	Customer not Able to pay	4	5	20	PM & KAM
4- Strategic Risks	4.1	New Challenge Ericsson Libya	3	5	15	PM
	4.2	**Second Phase chance**	3	5	15	PM
	4.3	**University of Tripoli tender**	3	4	12	PM
	4.4	Other WI-FI Tenders	3	3	9	PM
5- Technical Issues	5.1	Connectivity and LOS problems	3	4	12	TC
	5.2	Under / Overestimated Quantities	2	4	8	PM & TC
	5.3	**Data Center Tower not included**	4	2	8	PM & TC
	5.4	Nodes synchronization	3	5	15	TC
	5.5	Disconnection during remote integration	4	5	20	TC & PM
	5.7	Reduced performance	2	4	8	TC & PM
	5.8	Unsatisfactory Bandwidth	3	4	12	TC & PM
	5.9	**Power failure on Wi-Fi controller**	4	5	20	TC & PM
6- On Site Operative Risks	6.1	Working at Height	2	5	10	PM
	6.2	Security issues	4	5	20	PM
	6.3	Site Neighborhood Resistance	4	3	12	PM
	6.4	Disruption by local community activists	4	4	16	PM
	6.5	Weather conditions	2	2	4	PM
	6.6	Less Working Hours (Ramadan)	3	3	9	PM
	6.7	Electrical power interruptions	4	5	20	PM
	6.8	Rework	3	4	12	PM
7- Technological Risks	7.1	Reduced coverage, more sites needed	3	5	15	TC & PM
	7.2	Unsatisfactory Service / Products	2	5	10	TC & PM

VII. Risk Matrix

The risk matrix helps us to rate the significance of our identified risks based on the likelihood of the risk materializing and the impact if it does [6]. There are various sizes and types of risk matrix, depending on the rating scale chosen. The simplest form uses a 3×3 grid, but you could use a 4×4, a 5×5 or a 6×6 grid, depending on how complicated or simple you want to make things [6]. In reality, it does not really matter. Because when we look at likelihood and impact, we are really trying to determine the most significant risks, in other words, the ones that are most likely to happen and the ones with the most serious consequences [6]. For the purpose of this project 5×5 matrix is used as shown in Figure 7. It can be helpful to color code the squares in the matrix green, amber and red, to indicate the seriousness and priority for action for any given risk, and to carry this color coding through to our risk register [6].

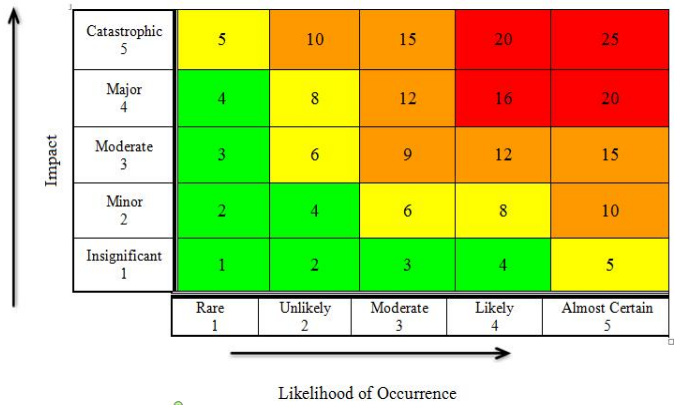

Fig. 7. The risk matrix of the project

VIII. The Response Strategies

Risk response is the process of developing strategic options, and determining actions, to enhance opportunities and reduce threats to the project's objectives.

A. *Strategies for negative risks or threats*

Avoidance: Risk prevention, changing the plan to eliminate a risk by avoiding the cause/source of risk, protect project from impact of risk. Examples: change the supplier/engineer, do it ourselves (do not subcontract), reduce scope to avoid high risk deliverables, adopt a familiar technology or product [5].

Mitigation: Seek to reduce the impact or probability of the risk event to an acceptable threshold. Be proactive, take early actions to reduce impact and/or probability and don't wait until the risk hits your project. Examples: staging, more testing, prototype, redundancy planning, more qualified resources [5].

Transfer: Shift responsibility of risk consequence to another party, does not eliminate risk, most effective in dealing with financial exposure. Examples: buy/subcontract, move liabilities, selecting type of procurement contracts, fixed Price, insurance, warranties [5].

B. *Strategies for positive risks or opportunities*

- Exploit: Ensure opportunity is realized [5].
- Enhance: Increase the probability and impact of the opportunity. Example: Adding more resources to finish early [5].
- Share: Allocate some or all of ownership to third part able to capture the opportunity, like joint ventures, special purpose companies [5].

C. *Acceptance strategy* (*for both threats and opportunities*)

Active Acceptance: Develop a contingency plan to execute if the risk occurred [5].

Passive Acceptance: Deal with the risks as they occur through workarounds, usually for low ranked risks [5].

For this particular Wi-Fi project, four levels were used to describe the outcome of multiplying likelihood and impact; these levels are ranging from low, moderate, significant, to catastrophic risks. As a result, after we assessed each listed risk in Table 1, selection of risk response strategies was made as shown in Figure 8. The Figure shows the risk rating levels and the associated response strategy planned for each indicated risk. Where, low risks have value ranges from 1 to 4 and referred by green boxes in the table, these are considered as accepted risks. Moderate risks vary from 5 to 8 and denoted as the yellow boxes in the table, and these are considered as manageable risks. Significant risks indicated by orange boxes and have value ranges from 9 to 15. These must be mitigated to an accepted threshold level, even managed or transferred in some cases. The last range contains the catastrophic risks that laying between 16 and 25 denoted by red boxes. Avoidance is the planned strategy with risks of this level. Moreover, there are four potential opportunities marked bold in the risk register (Table 2). These include (a) big chance to win the second phase, (b) university of Tripoli tender, (c) to provide MW tower for the data center, and (d) to include an uninterrupted power supply (UPS) to overcome the power failure on the Wi-Fi controller.

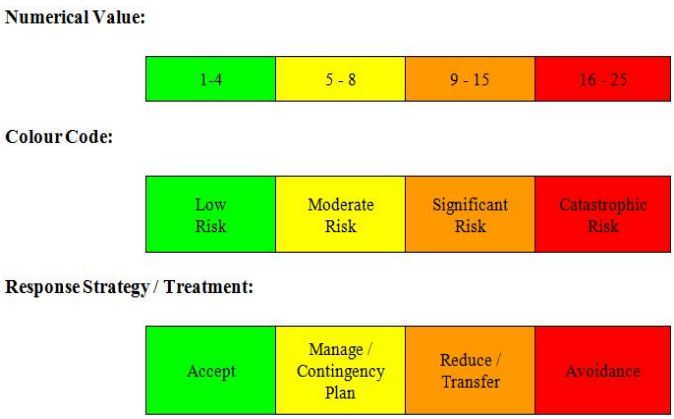

Fig 8. The color coding used in the risk matrix and the response strategies

The distribution of responsibilities on the implementation of the countermeasures and the follow up of the planned actions is summarized in Figure 9. It is recognizable that most of the actions are under the responsibility of the project manager (PM), with 37.2% of the total responsibilities. Followed by 23.3% of the actions shared between the PM and the technical coordinator (TC). Then 18.6% shared between the PM and the key account manager (KAM). Moreover, 2.3% shared between the PM and the head of operations (H. OPS). Thus, the project manager, individually or as a team member, is playing the most important role, and taking the major part of the responsibility on implementing countermeasures and actions follow up.

IX. Results and Observations

The genuine risk register of the project under investigation in this case study is presented in Table 2. In this risk log, the identified risks, the inherent likelihood, impact and score associated with each risk are given. Also, the responsible

person or team, the planned strategy, the action to be taken and the review date of each action are also stated in Table 2.

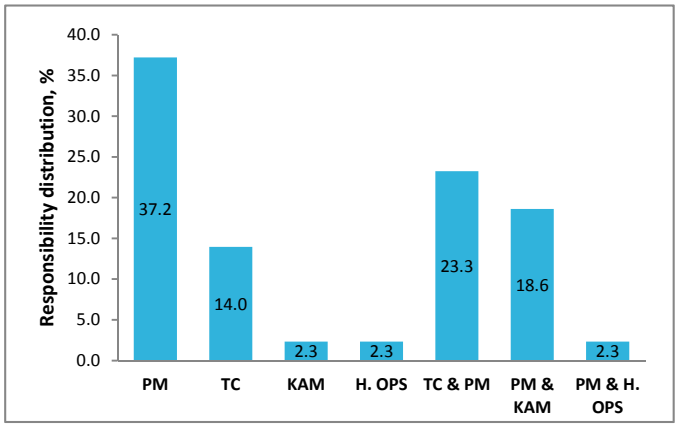

Fig. 9. The distribution of the responsibilities in the risk register.

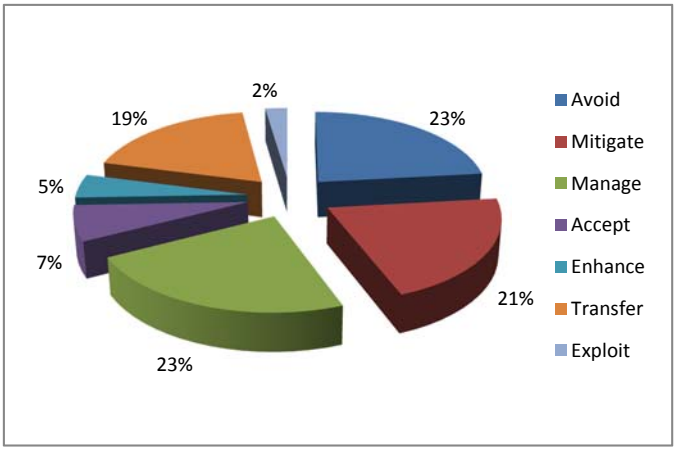

Fig. 10. The usage of strategies in the first cycle of risk management process

The response strategies planned for the first cycle were categorized as 23% of the risks were identified as catastrophic risks, another 23% of the risks were categorized as manageable, 21% of the risks were recommended to be mitigated, and 19% of the risks were nominated to be transferred. In addition, 7% of the recognized risks were classified as acceptable risks.

Besides, for the cases of positive risks and potential opportunities, mentioned earlier and marked bold in the risk register of Table 2. There are 5% usage of enhancement strategy, and 2% of exploitation strategy. Figure 10 shows the usage distribution of these strategies during the first cycle of risk management process in this Wi-Fi project

The inherent risks in percentage as they appear in the genuine risk register of the project before applying planned countermeasures are shown in Figure 11. The figure indicates that 23% of the identified risks are considered as catastrophic risks, and 54% measured as significant risks. Moderate risks were 16%, while only 7% of the identified risks classified as low risks.

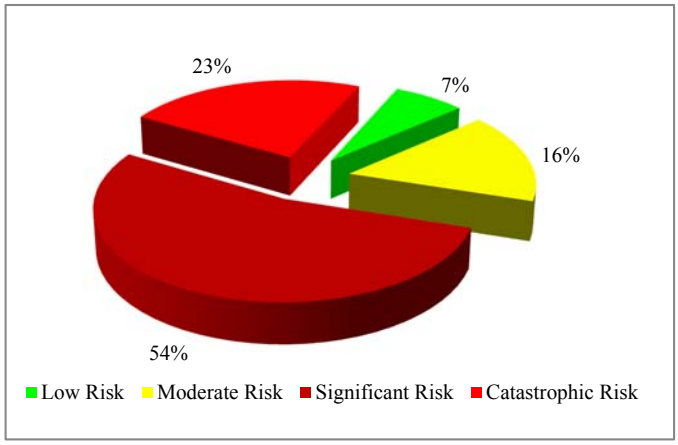

Fig. 11. Project risks before applying countermeasures

After the first monitor and review cycle, the residual assessment presented in Table 2 shows the new risk score and the improvements achieved. These improvements come as a result of applying the planned strategies, actions and countermeasures. This representing the resulted risks rated after completing only one cycle of the planned risk management process.

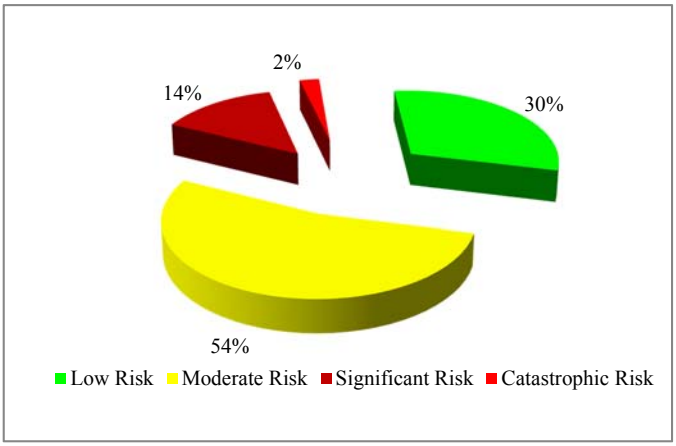

Fig. 12. Project risks after applying countermeasures

The residual risks in percentage as they appear in the genuine risk register of the project after applying the planned countermeasures are shown in Figure 12. The figure shows that there left only 2% of the risks considered as catastrophic, while only 14% are still measured as significant risks. Moderate manageable risks increased to become 54%, and the accepted low risks increased to 30%.

Based on the risk score and rating after applying the countermeasures in the first cycle, Figure 13 gives an idea about the expected usage of these strategies during the second

cycle of the risk management process of the project. The use of avoidance strategy decreased to become only 2%, mitigation 14%. Managing strategy increased to 49% and acceptance strategy increased to 26%. This is in addition to 9% usage of enhancement strategy.

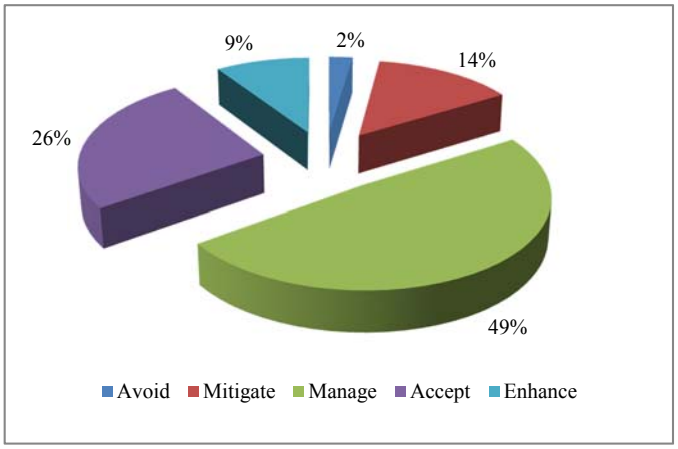

Fig. 13. The expected usage of strategies during the second cycle.

Frequent updating and good follow-up of the items on the project risk register with continuous monitor and review of planned actions and countermeasures and their outcomes significantly minimized the likelihood and impact of the project risks and reduced the area of uncertainty. Figure 12 shows great improvement compared to Figure 11. Results demonstrate that having risk analysis in conception stage with good tracking of responses and countermeasures reduced area of uncertainty associated with business performance. Comparing the two graphs in figures 11 and 12 clearly shows the improvements resulted after taking the proper actions and implementing countermeasures to the associated risks. This decreased catastrophic risks from 23% to 2%. Significant risks decreased from 54% to 14%. This reflected in satisfying key stakeholder expectations.

The greater contribution is directly connected the advance payment which has been received two weeks before receiving the letter of credit (LC). In other words, before the contracted official start of the project, this made it possible to initiate an internal early start for the project and making the order of the material and start manufacturing of the equipment, which means gaining enough time for ordering before the official start of the project. Furthermore, having the LC on time made it easier and minimized most of the financial risks. As a final point, two out of four potential opportunities have been realized. The first is the MW tower for the core site, with all accessories, and the second one is the UPS for the Wi-Fi controller. The project manager agreed with the customer to add these items on top of the contract and consider them as add-on sales. Therefore, they have been included in a separate change order, which increased the total project value.

X. Conclusions and Recommendations

After conducting this study and analyzing the real project data and the associated results obtained, the conclusions can be summarized in the following points:

- The genuine risk register of Wi-Fi network deployment project in Tripoli, Libya (phase one) under investigation in this case study is presented in Table 2.
- Great improvements in terms of finance and timing have been recorded after the first review cycle of the identified risks as a result of applying proper countermeasures and planned response strategies.
- The calculated score of the risks is based on 5×5 risk matrix.
- The major responsibility of implementing countermeasures and actions follow up is mainly related with the project manager.
- The response strategies planned for the first cycle were categorized as 23% of the risks were identified as catastrophic risks, another 23% of the risks were categorized as manageable, 21% of the risks were recommended to be mitigated, and 19% of the risks were nominated to be transferred. In addition, 7% of the recognized risks were classified as acceptable risks.
- Some of identified risks in this Wi-Fi project are positive and potential opportunities. Thus, 5% of the logged risks were used as an entrancement strategy and 2% as exploitation strategy.
- The improvements resulted after taking proper actions and implementing countermeasures to associated risks included:
    - Decreasing of catastrophic risks from 23% to 2%.
    - Decreasing of significant risks from 54% to 14%
    - Increasing of low risks from 7% to 30%
    - Increasing of moderate risks from 16% to 54%

  This reflected in satisfying key stakeholder expectations.
- The greater contribution in gaining the time is directly connected the advance payment received two weeks before the letter of credit
- Two potential opportunities realized and generated add-on sales on top of the contract increased the total project value.

This clearly shows that the risk management plan of this project particular Wi-Fi project is successful and working as planned. According to the results obtained in this case study, it was also proved for project risk management process, in order to save people, money, time, quality, and increase the chance of potential opportunities, it is strongly recommended:

- To start very early with project conception stage and to involve all stakeholders and project team members.
- For continues improvement, continuously track risks, and identify new risks and continuously update the risk register.
- Risk identification, assessment and management process should not stop throughout the project lifecycle

Exploit opportunities and be proactive not reactive.

GLOSSARY

AP	Access Point
ASP	Authorized Services Provider
BNG	Border Network Gateway
DC	Data Center
DNS	Domain Name Server
ES	Early Start of project
FAT	Factory Acceptance Tests
GW	Gateway
H. OPS	Head of Operations
HW	Hardware
I & C	Installation and Commissioning
IGW	Internet Gateway
IP	Internet Protocol
ISP	Internet Service Provider
KAM	Key Account Manager
KPIs	Key Performance Indicators
LC	Letter of Credit
LOS	Line of Sight
MW	Microwaves
NMS	Network Management System
P2P	Point-to-Point
PM	Project Manager
PMP	Point-to-Multipoint
TC	Technical Coordinator
UPS	Uninterrupted Power Supply
Wi-Fi	Wireless Fidelity

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BIOGRAPHY

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TABLE II. PROJECT RISK REGISTER, *L = LIKELIHOOD, I = IMPACT AND RATING = L × I

Category	Code	Risks	Inherent Assessment			Responsible	Strategy	Countermeasures	Review Date	Residual Assessment		
			L*	I*	Rating*					L*	I*	Rating*
1- Project Management Risks	1.1	Completion on Time (The Big Challenge)	4	5	20	PM	Avoid	Project Early Start	27-Mar-2014	3	4	12
	1.2	Production Lead Time	4	4	16	PM & KAM	Avoid	Project Early Start	27-Mar-2014	2	3	6
	1.3	Activities synchronization	3	4	12	PM & TC	Mitigate	Assign one Technical Coordinator	27-Mar-2014	2	3	6
	1.4	HW delivery Timing	4	4	16	PM	Avoid	Air shipment	27-Mar-2014	3	2	6
	1.5	Lack of Specific Resources	3	4	12	PM & H. OPS	Mitigate	E// Global Support & Training Locals	27-Mar-2014	2	2	4
	1.6	Visa	3	4	12	PM	Transfer	Customer Involvement	27-Mar-2014	3	3	9
2- Owner Side Risks	2.1	Letter of credit delay	4	4	16	PM & KAM	Avoid	Advance Payment	13-Mar-2014	2	3	6
	2.2	Supervisory Team	4	2	8	PM & TC	Transfer	Customer Involvement	3-Apr-2014	2	2	4
	2.3	MW Frequency license	5	2	10	TC	Transfer	Customer Involvement	3-Apr-2014	3	2	6
	2.4	Customs Clearance delay	3	1	3	H. OPS	Accept	Customer Involvement	3-Apr-2014	2	1	2
	2.5	Site acquisition & contracting	5	2	10	TC	Transfer	Customer Involvement	3-Apr-2014	3	2	6
	2.6	Site access	3	3	9	TC	Transfer	Customer Involvement	3-Apr-2014	2	3	6
	2.7	Electrical power connections	2	2	4	TC	Accept	Customer Involvement	3-Apr-2014	1	2	2
	2.8	Work permits	2	4	8	PM	Manage	Customer Involvement	3-Apr-2014	2	4	8
3- Financial Risks	3.1	Increased Cost	2	4	8	PM & KAM	Manage	Contingency	24-Mar-2014	2	3	6
	3.2	Exchange rate	2	4	8	PM & KAM	Manage	Contingency	24-Mar-2014	2	3	6
	3.3	Underestimated project budget	3	3	9	KAM	Mitigate	Local resources usage	24-Mar-2014	3	2	6
	3.4	Political Unrest	3	4	12	PM & KAM	Mitigate	Contracted Payment Terms	17-Mar-2014	3	2	6
	3.5	Instable Banking Operations	3	4	12	PM & KAM	Mitigate	LC and Insurance	17-Mar-2014	3	3	9
	3.6	High Competition	3	3	9	PM & KAM	Manage	Speed / Quality	10-Apr-2014	3	2	6
	3.7	Customer not Able to pay	4	5	20	PM & KAM	Avoid	LC & Advance Payment	24-Mar-2014	1	3	3
4- Strategic Risks	4.1	New Challenge Ericsson Libya	3	5	15	PM	Mitigate	Ericsson Global Support	14-Apr-2014	2	4	8
	4.2	**Second Phase chance**	3	5	15	PM	Exploit	Quality / KPIs / Timing	14-Apr-2014	2	4	8
	4.3	**University of Tripoli tender**	3	4	12	PM	Enhance	Quality (Product & Service)	14-Apr-2014	2	3	6
	4.4	Other WI-FI Tenders	3	3	9	PM	Manage	Demonstration / Reputation	14-Apr-2014	2	2	4
5- Technical Issues	5.1	Connectivity and LOS problems	3	4	12	TC	Transfer	ASP / Candidates & ranking	15-Apr-2014	3	2	6
	5.2	Under / Overestimated Quantities	2	4	8	PM & TC	Mange	Contingency	15-Apr-2014	2	2	4
	5.3	**Data Center Tower not included**	4	2	8	PM & TC	Enhance	MW & Tower Separate order placed	15-Apr-2014	4	2	8
	5.4	Nodes synchronization	3	5	15	TC	Mitigate	Integration Plan / Communication	15-Apr-2014	2	5	10
	5.5	Disconnection during remote integration	4	5	20	TC & PM	Avoid	integration locally on site	15-Apr-2014	2	3	6
	5.7	Reduced performance	2	4	8	TC & PM	Manage	Architect to Review and re-design	15-Apr-2014	1	4	4
	5.8	Unsatisfactory Bandwidth	3	4	12	TC & PM	Transfer	Extra Channels / Customer	15-Apr-2014	2	3	6
	5.9	**Power failure on Wi-Fi controller**	4	5	20	TC & PM	Avoid	Include UPSs	15-Apr-2014	1	4	4
6- On Site Operative Risks	6.1	Working at Height	2	5	10	PM	Transfer	Subcontractor & Certification	15-Apr-2014	2	4	8
	6.2	Security issues	4	5	20	PM	Avoid	Parallel activities/more ASP	15-Apr-2014	4	4	16
	6.3	Site Neighborhood Resistance	4	3	12	PM	Manage	Awards/Intensives/Gifts	15-Apr-2014	3	3	9
	6.4	Disruption by local community activists	4	4	16	PM	Avoid	Customer Involvement / AP indoor	15-Apr-2014	3	3	9
	6.5	Weather conditions	2	2	4	PM	Accept	Parallel activities / Planning / ASP	15-Apr-2014	2	2	4
	6.6	Less Working Hours (Ramadan)	3	3	9	PM	Manage	Rescheduling / Planning	15-Apr-2014	2	2	4
	6.7	Electrical power interruptions	4	5	20	PM	Avoid	Onsite generators	15-Apr-2014	2	2	4
	6.8	Rework	3	4	12	PM	Mitigate	Training & Awareness	15-Apr-2014	2	3	6
7- Technological Risks	7.1	Reduced coverage, more sites needed	3	5	15	TC & PM	Mitigate	Conservative assumptions on Design	15-Apr-2014	2	4	8
	7.2	Unsatisfactory Service / Products	2	5	10	TC & PM	Manage	FAT, Testing & Monitoring	15-Apr-2014	1	3	3