Opposing risk management theories: the context of large-scale projects

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Abstract: The normal accidents and high reliability organisations theories are widely known as presenting the intellectual discourse between two opposing schools of thought for risk management of complex systems as the first is tagged as pessimistic while the latter is labelled as optimistic. Due to high level of complexity and riskiness that is associated with large-scale project, discussing these two theories in this context is of high relevance. The context of developing countries was selected as investments in these countries are generally risky due to the high level of instability. This research showed that NAT and HRO are complementary rather than contradictory in such context.

Keywords: large-scale projects; normal accidents; high reliability organisations (HRO); developing countries; risky projects; risk management; development projects.

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1 Introduction

During the last two decades, the development sector was booming worldwide, especially within developing countries that are rich in natural resources. This boom increased pressure on governments to develop large-scale urban projects that can contain the newly emerging developments (Sagalyn, 2007). The purpose of these projects is to divide large land areas into smaller parcels that meet demand requirements while providing necessary

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infrastructure for these parcels. In order to secure success of urban development projects, it is essential to mitigate or reduce the impact of its risks, especially that its processes usually entail a large number of unforeseen risks (Kyvelou and Karaiskou, 2006).

The definition of a 'large-scale project' differs from one reference to another. Some references consider the cost to be the indicator of the project's scale (Verveniotis, 2008). Other references define large-scale projects as the projects that have a social, economic and ecological impact on its context (Alastair et al., 2005). For the purpose of this paper, the later definition will be adopted as the relevance of the development cost varies upon the economic status of the country and the time, during which the project was executed as time is related to inflation.

Despite the fact that development process extends till the end of construction, the main work is conducted prior to construction. This is the period, during which the investment framework is defined and the most critical decisions are taken, and hence holds the highest level of risk. Partnership is established, consultants are appointed, funds are raised and approvals on studies are obtained prior to beginning of construction. Any wrong decision at this phase will have a ripple effect that might endanger the whole project. In addition, this is the period, during which the project manager have the highest level of control over the project as margin of change during later periods will be very limited. Therefore, this period is the main focus of this paper.

The intellectual discourse on normal accidents theory (NAT) and high reliability organisations (HRO) theory has been widely discussed in the context of complex technological systems, the failure of which could lead to major accidents. In the first theory, it is acknowledged that due to complexity of such systems, accidents are considered to be 'normal', whereas in the latter theory, it is assumed that risks could be overcame through focusing on reliability in the organisation. In this paper, this discourse shall be brought to the context of large-scale development project that are known to be highly complex and risky in order to understand how these theories could inform the risk management approach to be followed for these projects. Moreover, this paper builds on previous research work of the author (Baydoun, 2011a, 2011b), in which risk categories of large-scale development projects were identified along with mitigation actions for different risks. The correlation between these risk categories along with the application of NAT and HRO was studied in this paper.

2 Research methodology

This research is a qualitative case study research as it does not require control over behavioural events (Royce and Bruce, 1999; Yin, 2009). Furthermore, it falls under the category of exploratory case study research as its aim is to 'explore' risk management practices in order to 'enlighten' project managers of this type of projects. Multiple case studies were used in order to formulate a 'cross-case' research conclusion.

Literature was reviewed in order to map comparative analysis between NAT and HRO and identify risks of large-scale projects. This review revealed a literature gap in respect to risk management approach to be followed for large-scale development projects. The list of these risks was used as a framework to develop a guide for interviews with managers and assistant managers of selected projects and allowed for a consistent research methodology that enforced the research reliability (Yin, 2009). The purpose of interviews was to identify the followed risk management approach along with risks that

were faced. Collected information were analysed to identify patterns, based on which recommendations for the approach to be followed for risk management of large-scale projects in light of NAT and HRO theories, were formulated. Data were analysed till saturation of different investigation issues. This technique is called theoretical saturation and is convenient for research of complex business environments. Results of interviews were complemented by personal observations and progress reports of selected projects.

The case studies were selected based on the largeness of scale, international recognition and coverage of a wide spectrum of development phases. The following are the selected case studies: Al Shamiyah project in Makkah, Saudi Arabia (a 1,400,000 m^2 project with a construction cost of around two billion USD); Aktau New City project in Aktau, Kazakhstan (a 5,000,000 m^2 project); Jabal Omar project in Makkah, Saudi Arabia (a 1,000,000 m^2 project and the first real estate project to be listed in the Saudi Stock Exchange market); Medini Development project in South Johor, Malaysia (a one and a half billion USD investment); Bandar Jissah project (a 2,000,000 m^2 project); and Al Dariyah project (a 600,000 m^2 project with a construction cost of around six hundred million USD).

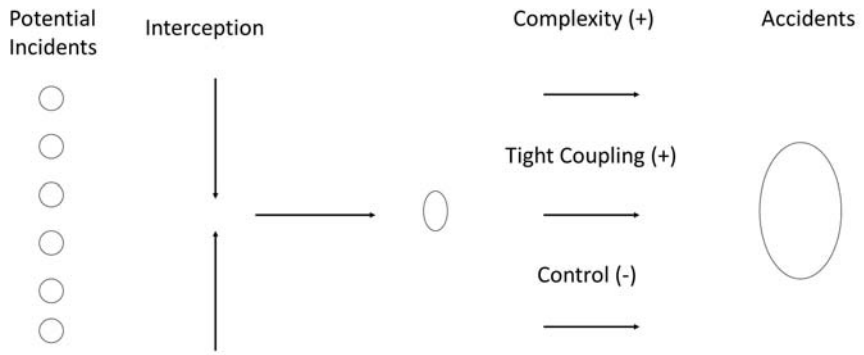
3 Literature review

In this section, literature on NAT, HRO and risks of large-scale projects will be illustrated in order to have a better understanding of the theoretical underpinning for these two theories along with the types of risk that are faced in the projects under discussion. This will help in bringing the intellectual discourse between these theories to the context of large-scale projects.

3.1 Normal accident theory

The NAT was established by Perrow (1984). The focus of this theory is on risks within complex projects that are characterised by a high level of risk. He distinguished between ‘incidents’ that he defines as failure in a sub-element of the system and ‘accidents’ that he defines as major failures in the system (Figure 1). As per NAT, accidents in these complex systems are unavoidable due to its inherent nature, and therefore, accidents are considered as ‘normal’ in this context. These systems have two major characteristics: interactive complexity and tight coupling. Interactive complexity is mostly found in systems where two distinct failures could intermingle in an unexpected manner to cause a major failure in the system. As complex systems usually have a number of unforeseen risks that could interact jointly, these systems are exposed to normal accidents. A tightly coupled system contains elements that have swift and major influences on each other. If the attributes of one component has limited sway on another component, or if the interaction is slow on the scale of the human thinking, tight coupling is not considered as one of the characteristics of the system. This characteristic is usually magnified by the intervention of the end-used that might not have necessary knowledge to properly identify the problem. Perrow (1984) developed his theory from analysis of complex technologies like nuclear power plants and petrochemical plants. As per NAT, incidents shall be foreseen and controls shall be provided within the system to enclose their spread.

Figure 1 Perrow's normal accident theory model



Source: Lally (2005)

3.2 High reliability organisations theory

Researchers of HRO investigated organisations, which were able to successfully handle potential failures. The HRO theory is based on the following critical factors (LaPorte and Consolini, 1991; Sagan, 1993; Klein et al., 1995):

- reliability as a main target for the organisation
- high redundancy in human resources and systems
- promotion of high reliability culture through adoption of decentralised operations
- knowledge development through sophisticated trial and error processes.

Risk mitigation in the context of HRO is focused on effective and intense communications in order to reduce the probability of extended evolution of unforeseen risks.

Despite the fact that NAT and HRO are contradictory in the way risk is approached, these theories are in agreement on the characteristics of risky systems.

3.3 Risks of large-scale projects

As no references were found on risks related to the whole process of development management, literature focusing on the construction part of development was mainly investigated. Other complementary aspects of the relevant literature, namely, sustainability and private-public partnership, were investigated in order to prepare a comprehensive list of risks that are related to the type of projects under discussion. Sustainability was investigated since it is the most comprehensive theme of urban planning nowadays. It discusses mainly the impact of urban projects on their social, economic and ecological environments. Furthermore, as most large-scale development projects usually take place in some kind of partnership between the private and the public sectors, the literature relating to this type of partnership was also investigated.

The identified list was organised along the three identified risk levels that were found to be applicable to the context of large-scale development projects, namely, project

environment, external environment and institutional arrangement. However, little was found on how to mitigate these risks.

Risks at the project environment level include market, financial, technological, management, technical and operational risks (Datta and Mukherjee, 2001; Dey, 2009; Gil, 2009; Perera et al., 2009; Siebert, 1987). Market risks basically relay to large margin of error associated with projecting cost and revenue over long periods, which is usually the case in large-scale, long term projects (Dey, 2009). Financial risks essentially relate to high level of capital loss or gain due to high level of uncertainty associated with the type of projects under discussion. The size of loss or gain will be proportionate to the size of invested capital (Dey, 2009; Gil, 2009; Perera et al., 2009). Technological risks principally convey to use of new technologies that might be neither fully tested nor available, like using new construction materials or techniques or using a new transportation system (Datta and Mukherjee, 2001; Dey, 2009; Siebert, 1987). Management risks are related to managing the large number of parties involved (public agencies, consultants, contractors, operators, local communities and end-users) and their interdependence for the success of the project (Datta and Mukherjee, 2001; Perera et al., 2009). Technical risks mainly relay to level of information provided in the preliminaries bill, tentative drawings and scope change (Dey, 2009; Perera et al., 2009; Siebert, 1987). Finally, operational risks are related to functionality of the project, like satisfaction of end-users, proper accessibility and durability of finishing (Dey, 2009).

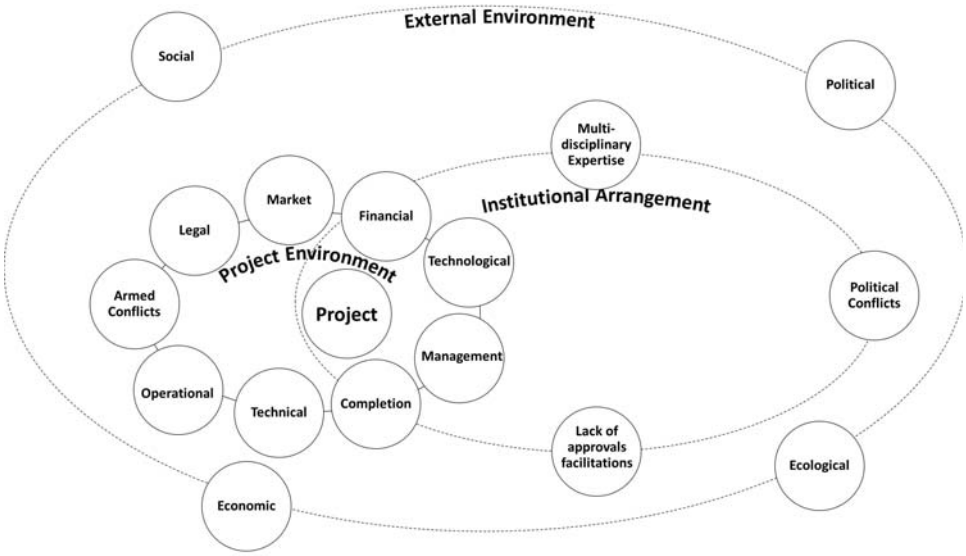
At the level of the external environment, the risks are political, social, environmental and economic risks (Datta and Mukherjee, 2001; Dey, 2009; Gil, 2009; Lehtonen, 2004; Perera et al., 2009; Siebert, 1987; Senge et al., 2007). Political risks are primarily related to political stability that might affect the development right over the project. Social risks basically convey to acceptance of local communities of the project, which might heavily impact the project especially if local communities have tendency towards violent reactions against projects that do not meet their expectations (Siebert, 1987; Lehtonen, 2004; Senge et al., 2007; Senge and Carstedt, 2001). Environmental risks primarily relay to the level of environmental regulations that might lead to substantial increase or decrease in project cost (Dey, 2009; Siebert, 1987; Lehtonen, 2004; Senge et al., 2007; Senge and Carstedt, 2001). Economic risks are related to unexpected changes in economic indicators and assumptions that might affect the project cost like changes in wages, taxes or inflation (Datta and Mukherjee, 2001; Dey, 2009; Perera et al., 2009; Lehtonen, 2004; Senge et al., 2007; Senge and Carstedt, 2001).

Risks at the institutional arrangement level include opposition of interest, multidisciplinary nature of projects under discussion, political conflicts, lack of approvals facilitation and over optimism. Opposition of interest between the private sector and the public sector is caused by the fact that private sector is always looking for short term benefits to maximise return on investment, while the public sector looks for long term benefits like achieving sustainability (Koppenjan and Enserink, 2009). Large-scale projects are multidisciplinary and require diversified expertise to cover its aspects, which might not be available in the public sector. Despite such expertise being usually provided by the private sector, the public sector still needs to have a fair understanding of these disciplines to structure the deal properly (Sagalyn, 2007). Political conflicts are present in contexts where conflicting political parties have decision making power. Such conflicts can lead to either project delay or suspension (Sagalyn, 2007). Lack of approvals is mainly found where bureaucracy has a long history: public authorities who do not benefit

directly from the project do not facilitate approvals (Vanmarrewijk et al., 2008). Over optimism is caused by over sighted announcements of the public parties that are involved in the project, in terms of time and budget. This might endanger the project, especially in terms of public acceptance in case of delays.

Through analysis of case studies in previous work of the author, risk categories that are applicable to the context of large-scale development projects were identified. The details of these risks were illustrated in earlier work of the author (Baydoun, 2011a), and a summary of risk categories is illustrated in Figure 2.

Figure 2 Relation between different environments that can impact the project along with their set of risks



Source: Baydoun (2011a)

Though NAT and HRO are promoted as contradictory in the way they preach addressing risk, these theories are in agreement on the characteristics of risky systems in terms of interactive complexity and tight coupling. These characteristics apply to large-scale development projects that are highly complex and entail a variety of tightly coupled risks.

4 Integral complexity and tight coupling of large-scale projects

Large-scale development projects are highly complex due to their high level of uniqueness and the number of stakeholders and disciplines that are involved in the formulation process of these projects. For the management of these development projects, a highly sophisticated development management approach needs to be followed along the following four work streams: technical, financial, marketing and legal.

The technical work stream includes architectural design, urban design, engineering studies, infrastructure study, value engineering, technical validation, hydro-geological studies, traffic impact assessment, pedestrian modelling, environmental studies, costing studies and way finding studies. The aim of this track is come up with a project that is

valid from different technical angles. For this purpose, these studies need to be managed simultaneously to make sure that each study meets the highest professional standards, and that these studies are synchronised and fold within a single entity defining the technical dimension of the project. Hence, this management process is highly challenging and involves a high level of risk. As an example of risks related to this work stream, improving the level of service of the road network can be mentioned. Such improvement requires widening roads in order to provide additional lanes. This modification might endanger both the master plan and the feasibility study. From the master plan perspective, this will increase the area allocated for the road network, and hence, decrease the parcels area. In this case, the master planner will have less land area to fit the allowable built up area of the project. His design will be changed as he will either need to reduce the project's built up area, which is usually not acceptable financially or increasing height, which might be conflicting with maximum allowable height or with the proposed massing. From a financial perspective, such modification will increase the cost and area of unsellable components on the expense of sellable ones. This might endanger the expected rate of return. However, when thinking outside the box, providing a more relaxed development might allow charging higher rates, which can have a positive impact on the expected financial return. Therefore, a balance needs to be achieved between requirements of different parties. The requirements of this balance are not a 'blue print' solution that can be adopted in different projects. Traffic load, suggested uses, character of area and market supply and demand are all factors that play a role in defining this balance. Hence, solutions are to be proposed on case by case basis.

The financial work stream includes market, feasibility, corporate finance, business strategy and cost control studies. The ultimate goal of this track is to come up with a full fledge financial plan. This financial plan needs to include a project program that is aligned with the market demand, the expected rate of return, required equity contribution, required debt and all documents that are necessary for fund raising. An example of risks that might emerge when managing studies of this work stream is decreasing the construction cost in order to enhance the project's profitability. This might require compromising on the specifications of master plan design. The master planer usually follows a project program that targets a specific market trench; hence, such compromise might shift the design to a lower class than the initial one. As a result, the revenue prices that were initially claimed cannot be achieved anymore. Therefore, a sensible compromise needs to be achieved between design specifications and the assumptions of the feasibility study.

The marketing work stream includes market positioning, branding and project identity. The aim of this track is to come up with a full fledge communication plan for the project. One of the challenges of this work stream is implementing the project branding on the master plan. As design is a subjective field that involves creative egocentric personnel, imposing on the master planner a specific theme that is suggested by the marketing consultant is a challenging task, especially when dealing with a reputable international consultant. This will require ego management for marketing and master plan consultants in order to achieve a common point that serves best the project.

The legal work stream includes preparing different contracts with different consultants, typical purchase agreements, operators' contracts, contractors' contracts and due diligence. The aim of this track is to prepare all legal documents that are necessary for the realisation of the project. One of the challenges within this work stream is

formulating a contract between the developer and a consultant. The development Managers usually want to achieve the best terms of agreement for the developer. Also, they want to have the best consultants on board in order to ensure following the highest possible standards in the studies. Achieving both objectives is very challenging as high calibre consultants have a preset form of contracts that have little margin of modifications. This leads sometimes to a dead end between the consultant and the developer who might not accept particular legal terms imposed by the consultant. In similar cases, the development manager uses its strategic relation with international consultants and its trustworthiness in the eyes of the developer in order to find a common ground that is acceptable for both parties. This is an additional case, in which risk management cannot follow a preset risk plan.

The four aforementioned tracks need to be managed in parallel, in order to make sure that all studies are synchronised and fold within a solid and coherent investment opportunity. Therefore, large-scale projects are 'interactively complex' as this process entails a number of unforeseen risks that could interact to cause a major failure in the project as illustrated in the aforementioned examples. In addition, a failure in one of the trades could have a major impact on the whole project, and therefore, studies of these projects are tightly coupled. Furthermore, the investment opportunity needs to meet the expectations of different stakeholders (investors, financing agencies, public authorities, local communities and operators). The management of the extensive list of studies that covers a wide spectrum of specialties along with the expectations of different stakeholders increase the level of uncertainty in these projects and magnifies the 'tight coupling' effect.

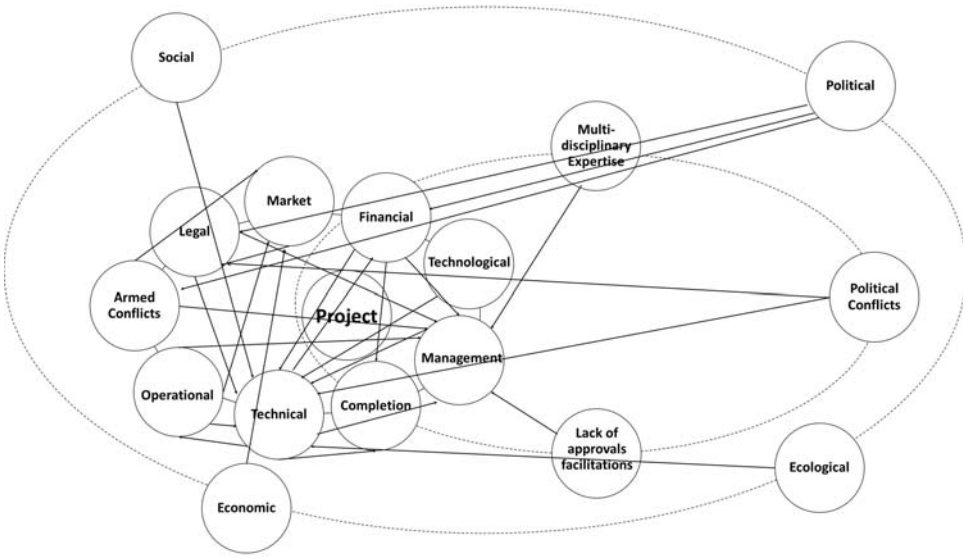
5 Applicability of normal accidents and high reliability theories in large-scale projects

In this section, the applicability of normal accidents and high reliability theories in large-scale projects will be discussed. These two theories were found to be complementary rather than contradictory as per the results below.

The three environments of risk are found to be interrelated. Initially, the project is directly affected by risks related to its environment. Simultaneously, it is affected by risks related to the institutional arrangement of the project that defines the role of different stakeholders involved in the project. At a macro level, risks related to the external environment that contains both environments, has its own set of risks that might impact the project. The relation between different environments along with their risks is illustrated in Figure 3.

As the different risk environments are interrelated, a cause and effect relationship between different risk categories was observed. In the following, the impact of each risk category on other categories will be discussed, starting from the external environment till the project environment while passing through the institutional arrangement as macro risk categories are in the higher level of the chain of cause and effect. Despite the fact that most of risk categories are indirectly related, for each risk category, only its direct impact on other categories will be identified. Indirect links that are related to link between two risk categories through a third one are illustrated when discussing the impact of the third category on the second one.

Figure 3 Cause and effect relationship between different risks categories



5.1 Risk categories of external environment

At the level of external environment, the following are the risks along with its ripple effect:

1 *Political risks:* political changes at the national level might lead to armed conflicts, legal risks or financial risks. Sometimes political conflicts between different parties or with other countries might lead to armed conflicts, which are one of the risk categories of project environment. Furthermore, such conflicts might lead to legal risks as any of kind of legal facilitation or exception that are provided for the sake of the project might be threatened if political cover was drawn down. In addition to that, political conflicts might lead to financial risks as investors will be reluctant to invest in a country that has an unstable political environment.

2 *Social risks:* if local community does not accept the project, technical risks will emerge. In this case, additional studies might be necessary to better explain the project. Otherwise, technical studies need to be modified to secure acceptance of local community.

3 *Economic risks:* any changes in economic indicators that are vital to the project might lead to changes in market dynamics and hence cause market risks. For example, changes in oil prices in a country that is highly dependent on oil production might lead to decreasing public expenditures. This could to lead to closure of many companies, which can cause a reduction in demand on office spaces.

4 *Environmental risks:* if it was proved that the project will have a negative environmental impact, this will require changes in the technical studies in order to avoid such impact. Hence, environmental risks can cause technical risks.

5.2 Risk categories of institutional arrangement

At the level of institutional arrangement, the following are the risks along with its ripple effect:

1 *Multidisciplinary expertise:* in case of unavailability of required expertise for large scale development projects in public authorities, this might lead to management risks as balance between technical and financial dimensions of the project might be threatened.

2 *Political conflicts:* conflicts between different authorities or within the same authority might lead to either legal risks or technical risks. Such conflict might lead to reconsideration of legal facilitations that are provided for the project, i.e., working permits. Furthermore, such conflicts might lead to changes in approvals requirements of technical studies.

3 *Lack of approvals facilitation:* if the public authorities were unable to guarantee facilitation of necessary approvals, this might lead to management risks as the project might be delayed beyond the projected time frame.

4 *Dependency on governmental support:* in case of delay of an essential support from the government side, this might lead to management risks as the project might be delayed beyond the projected time frame.

5 *Influential competitors:* in case an influential competitor was able to hold the project, similarly to the previous two points, this might lead to management risks as the project might be delayed beyond the projected time frame.

5.3 Risk categories of project environment

At the level of project environment, the following are the risks along with its ripple effect:

1 *Market risks:* any negative changes in market assumptions related to either cost or revenue side of the project, might lead to financial risks as the size of required financing will be affected by market changes.

2 *Financial risks:* risks related to project financing might lead to either technical risks or completion risks. In case required financing was not fully provided, this will require revisiting the technical studies to match the design with the size of provided financing. Furthermore, if necessary financing was not provided, this might lead to completion risks as the project cannot be completed without necessary financing.

3 *Technological risks:* technological risks might lead to technical risks as limitations related to use of certain technologies might require revisiting the technical studies to consider other technologies.

4 *Management risks:* managerial risks might lead to either technical or financial risks. In case of delays in the project, this will have an impact on both categories of risk. From one side, such delays might increase the size of required financing. From another side, technical studies might be squeezed in order to accommodate for such delays. If balance between financial and technical studies was found to be at risk,

this will have an implication on both tracks as a compromise between the two needs to be identified.

5 *Completion risks:* any of the listed risks can directly or indirectly imply not completing the project. Hence, such risk is usually caused by other risk categories and do not cause risks by itself.

6 *Technical risks:* technical risks might lead to financial or/and operational risks. If the provided studies propose a project that exceeds the initial financing budget, this will lead to financial risks. Furthermore, if proposed project do not meet the operational requirements, this will lead to operational risks.

7 *Operational risks:* as operation is the last step in the in the sequence of project steps, this risk category is usually caused by other risk categories and do not cause risks by itself.

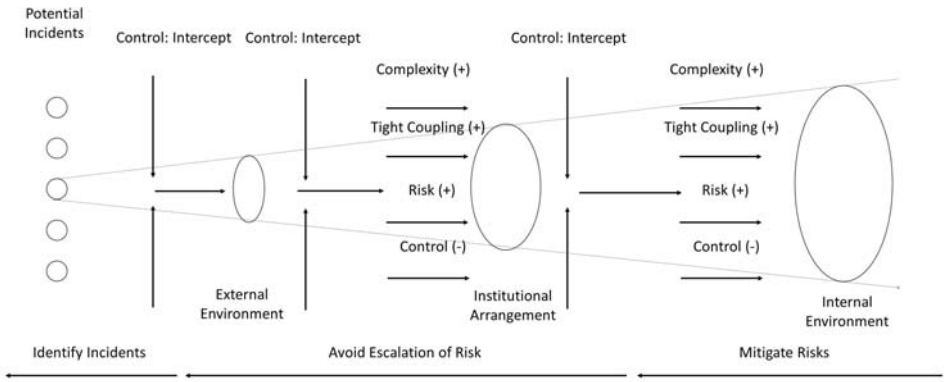
8 *Armed conflicts:* armed conflicts can either lead to market risks or management risks. In case of armed conflicts, market dynamics can change, which might lead to changes in market assumptions. Furthermore, armed conflicts can cause management risks as it can cause delays in the project timeframe.

9 *Legal risks:* legal risks can cause either technical or financial risks depending on the nature of the legal risk that is emerging.

As illustrated in the section above, risks have a cascading effect from the external environment to the institutional arrangement to the project environment. Risks at the levels of external environment and institutional arrangement are the types of risk, over which the project manager has little control compared to the level of project environment. Reactive approach can be adopted for risks that fall under this category similarly to risks of project level; nevertheless, actions to be adopted are usually intended to contain the impact of these risks and not necessarily to mitigate it as the root cause of the risk does not fall within the control zone of the project owners. This approach is in line with NAT principles that focus on foreseeing incidents and providing controls within the system to enclose their spread. Nevertheless, this necessitates adding an extension to NAT model in order account for required intervention when risk is moving from one level to another. This extension includes two additional loops in order to tackle risk at its initiation environment and deal with its ripple effect in the environment(s) to follow (Figure 4). As much as the risk is cascading form one level to another, the level of risk in the project increases, which reduces the level of control over it. Moreover, containment of risk implications on these levels could be informed by proper communication between different team members in order to benefit from the team's collective experience and experiences in previous projects, which is line with the HRO theory. Furthermore, risk management could be better informed by allowing each team member to freely express his opinion in search for innovative solutions for problems that might not be faced in earlier projects. In addition, principles of HRO that promotes continuous evolvement and sharing of knowledge related to the system could help in reducing the probability of extended evolution of unforeseen risks. When moving to the level of the project environment, risks will be more manageable, and this can allow for full mitigation of risks, especially when adopting the HRO principles. Risks at this level are correlated as a

risk might initiate another one as illustrated in Figure 4, and therefore, the project manager needs to be careful when suggesting proper mitigation actions.

Figure 4 Proposed extension for NAT model



6 Conclusions

Based on the above, it can be concluded that large-scale projects are 'interactively complex' as its processes entail a number of unforeseen risks that could interact to cause a large failure in the project. In addition, a failure in one of the trades could have a major impact on the whole project, and therefore, studies of these projects are tightly coupled. The analysis of case studies showed that HRO and NAT are complementary in the context of large-scale development projects. At the levels of external environment and institutional arrangement, adopted actions are usually intended to contain the impact of risk and not necessarily to mitigate it as the root cause of the risk does not fall within the control zone of the project owners. This approach is in line with NAT principles that focus on foreseeing incidents and providing controls within the system to enclose their spread. In addition, an extension for this theory was proposed in order to account for cascading nature of risks in the context of projects under discussion. Moreover, HRO allows for continuously promoting evolvement and sharing of knowledge related to the project in order to reduce the probability of extended evolution of unforeseen risks. These findings shall help managers of the type of projects under discussion to have a better theoretical understanding for the nature of risk and the consequent approach to be followed. This is particularly important due to limited number of publications that focus on risk management in the context of development projects. The developed map for risk of these projects can be used by project managers to identify the environment, under which faced risk falls, for them to select the most convenient approach for risk mitigation. This entails continuous application of the HRO concept and usage of NAT when risks related to institutional arrangement or external environment emerge. This paper shall be considered as a trigger for further development of risk management theories within the context of large-scale development projects, more so since current literature does not highly account for this particular topic.

Like any research work, this article has its limitations. As this is a case study research, its results are based on the analyses of a limited number of case studies. When

analysing different case studies, the results might vary. Furthermore, although different sources of data were used, namely, interviews, observations and progress reports, interviews were used as the main source of data, notwithstanding that the interviewed managers had to rely on their memory while addressing questions. It is quite possible that some events might have fallen from memory and, hence, were not included in the collected data.

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