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SYSTEM DYNAMIC MODELING OF RISK MANAGEMENT IN CONSTRUCTION PROJECTS: A SYSTEMATIC LITERATURE REVIEW

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Review paper

Abstract. *This literature review discusses risk management research with System Dynamic modeling. Literature is reviewed by summarizing the research that has been done and examining research findings, research relationships, and research problems that require further research. The risk management paper with System Dynamic modeling (2000-2020) is reviewed by dividing risk into 3 groups, namely: internal risk, external risk, and project risk. Each group is further divided into technical risks and non-technical risks. The results of the study stated that risk management with System Dynamic modeling has not been widely used as evidenced by research (2000-2020); there are only 25 papers that match the keywords and can be written reviews. Ten internal risk papers include: project members, location risk, document risk & information. External risk papers are only found in 2 papers that discuss: weather risk and social risk, while the project risks are found in 13 papers discussing: cost risk, time risk, work quality risk, and construction risk.*

Keywords: *System Dynamic, Risk, Construction.*

1. Introduction

In research related to risk management, many approaches can be done, one of which is to use System Dynamic, Fuzzy Logic, or other methods. The System Dynamics approach is a simulation method in solving real problems to describe the relationship between variables in a complex system (Maryani et al., 2015). The System Dynamic (SD) can be used as a basis for simulating the effects of various risks on the project schedule to explore optimal measures to prevent prior risks (J. Wang & Yuan, 2016). System Dynamic (SD) can use dynamics and feedback to understand the structure and characteristics of a complex system so that it can help decision making (Yang & Yeh,

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2014). System Dynamic can also be combined with other analytical methods such as Fuzzy; an integrated fuzzy-SD model can be applied to all BOT projects to determine the concession period (Khanzadi et al., 2012). The use of System Dynamics in construction projects has a good track record and has been used for a long time. In (Boateng et al., 2012), the SD method has been used extensively over the past 35 years on complex projects and has proven the track record of project management performance in the project life cycle. This review aims to examine risk management research using System Dynamic modeling to determine what can be accomplished using System Dynamic and to see Research GAP for further research.

2. Methodology

This review is based on a summary of the literature obtained online from trusted sources that discuss Risk Management using System Dynamic modeling, which is then reviewed and synthesized to provide the latest information. In research (Zavadskas et al., 2010), Risk was divided into 3 parts, namely: Internal Risk, External Risk, and Project Risk. Risk allocation structure is shown in Figure 1.

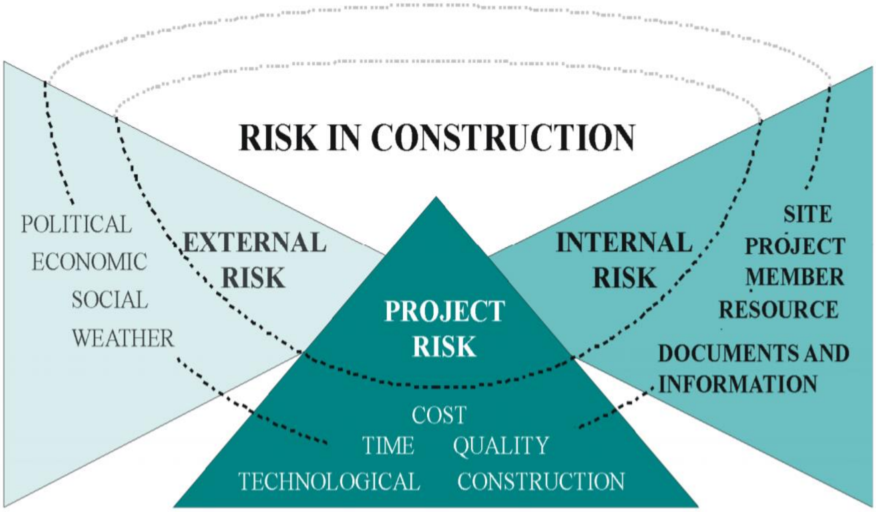


Figure 1. Risk allocation structure (Zavadskas et al. 2010)

Internal risks (intrinsic criteria): (1) Resource risk; (2) Project member risk; (3) Stakeholders Risks; (4) Designer Risk; (5) Contractor Risk; (6) SubContractor Risk; (7) Supplier Risk; (8) Team Risk; (9) Construction site risk; and (10) Documents and information risk. External risks (environmental criteria): (1) Political risk; (2) Economic risk; (3) Social risk; (4) Weather risk. Project risks (construction process criteria): (1) Time risk; (2) Cost risk; (3) Work quality; (4) Construction risk; and (5) Technological risk. The study method is shown in Figure 2.

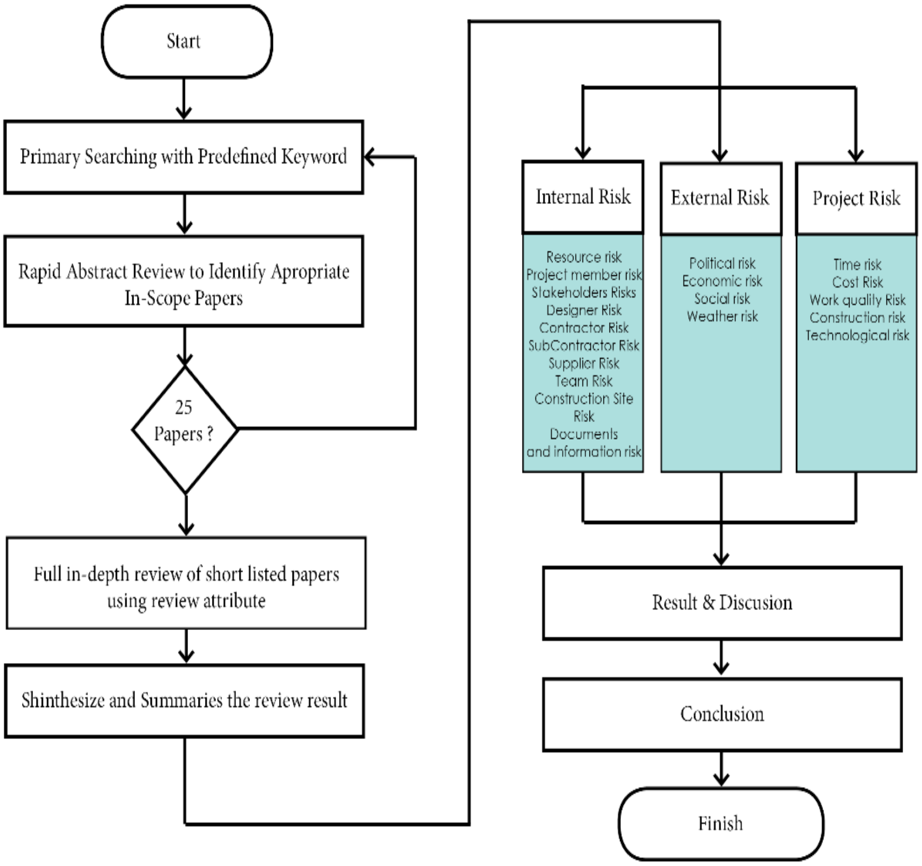


Figure 2. Study Framework: A Systematic Literature Review

3. Results

3.1. Summary of Results

The summary of the paper review related to risk management with System Dynamics modeling is shown in Table 1 (1.1-1.4).

Table 1.1. Summary of Results, Risk Groups & Risk Criteria Based on (Zavadskas et al. 2010)

No.	Paper	Risk Group	Criteria (Risk)	Summary of Results
1.	(Love et al., 2002)	Project	Work Quality	Variation, rework, or both have a significant impact on the level of progress of the project, caused by: (1) Purchaser Changes; (2) Design Freezing; (3) Information management; (4) Building regulations; (5) Consultant fees; (6) Communication; (7) Coordination and integration of the project team; and (8) Training and skills development.
2.	(Nasirzadeh et al., 2008)	Project	Cost	Because of the more obvious negative side effects of the modified labor/equipment policy (MLEP), The quality is better than the overtime workforce policy (OTP) which experiences increased cost overruns.
3.	(Nasirzadeh et al., 2008)	Project	Cost	A large negative impact on project objectives in terms of cost overruns and project delays can be caused by machine breakdowns. The following alternative response scenarios for that risk: (1) use of overtime policy; (2) modification in labor/equipment policy; (3) use of subcontractors; (4) schedule changes.
4.	(Yi & Xiao, 2008)	Project	Cost	Project risks and costs by building a System Dynamics model are influenced by the allocation of stimulating costs between elements and elements between departments.
5.	(Han et al., 2010)	Internal	Construction Site	The relationship between the main indicators, safety culture, and organizational safety conditions and sensitivity analysis based on observing behavior towards the safety climate does not have a significant effect on the safety climate.
6.	(Mohamed & Chinda, 2011)	Internal	Construction Site	An organization with ad-hoc safety implementation (starting from the basic level of maturity of safety culture) must primarily focus on improving leadership attributes, in the context of safety, for rapid and successful progress to a higher level of maturity in the future.
7.	(Boateng et al., 2012)	External	Weather	Four weather conditions that have an impact on the project: (1) Snowfall; (2) High temperature; (3) Rainfall; and (4) Wind.
8.	(Khanzadi et al., 2012)	Project	Time	The proposed integrated fuzzy-SD model can be applied to all Built Operate Transfer (BOT) projects to determine the concession period.
9.	(Shin et al., 2014)	Internal	Team	Examine Three safety enhancement policies: (1) Provide incentives to workers, offer as early as possible for their safe behavior to be most effective; (2) Sharing accident information among workers; and (3) Helping workers experience accidents when sharing accident information.

Table 1.2. Summary of Results, Risk Groups & Risk Criteria Based on (Zavadskas et al. 2010)

No.	Paper	Risk Group	Criteria (Risk)	Summary of Results
10.	(Y. Xu et al., 2012)	Project	Cost	Finally, the price of public private partnership (PPP) highway project concessions can be determined by the following formula: Finalprice = Basicprice* $(1+ \lambda_1 - PRS_1 \frac{\lambda_2 - \lambda_1}{PRS_2 - PRS_1}$ Where: Final Price = Basic Price + Adjustment price Final price = $(1 + \lambda)$ Basic Price $PRS_i = W_{ij} \times (R_{ij} - R_{oj})$ $\sum_{j=1}^{n} W_{ij} = 1$ where, PRS_i is the overall risk similarity between a reference case *i* and a target case; W_{ij} is the weighting of each risk factor; R_{ij} denotes the reference case *i*'s risk factor *j*, R_{oj} denotes the target case *n*'s risk factor *j*; $\sum_{j=1}^{n} W_{ij}$ denotes the summation of weighting of all risk factors.
11.	(Nasirzadeh et al., 2014)	Project	Cost	The optimal percentage of risk allocation is set at 46%. If the client accepts 46% of the risk consequences, the project costs will be minimized.
12.	(Yang & Yeh, 2014)	External	Politic-al	7 steps to solve environmental risk management problems systematically and efficiently. (Step 1) Verification of Stakeholders With Related Problems; (Step 2) Determine Important Issues Between Two Stakeholders; (Step 3) Draw the Important Causal Feedback Loop Diagram for Reference the Indicated Problem to the System Template; (Step 4) Building a Stock Flow System Dynamics Model Referring to the Causal Feedback Loop Diagram; (Step 5) Building a Framework Including a System Dynamics Model for Stakeholder Negotiations on related issues; (Step 6) Repeat Steps 2–5 until all Stakeholders are Involved; and (Step 7) List of Environmental Risks.
13.	(Jiang et al., 2015)	Internal	Team	A System dynamics model for the causation of unsafe behaviors (SD-CUB) produce correct behavior patterns. that is: (1) safety and production can support each other; (2) management conditions on the supervisory level are effective on the improvement of workers' safety awareness; (3) preventive actions are more effective than reactive actions on the enhancement of safety performance.

Table 1.3. Summary of Results, Risk Groups & Risk Criteria Based on (Zavadskas et al, 2010)

No.	Paper	Risk Group	Criteria (Risk)	Summary of Results
14.	(Cunbin et al., 2015)	Internal	Team	The SD model of the transmission of risk elements that simulate the scope and depth of projects affected by human risk elements, we can illustrate as follows: (1) The theory of transmitting risk elements is introduced into the process that how human risk impacts construction and transfer projects, can carry out quantitative analysis at procedures and levels; (2) Schedules will temporarily disrupt elements of human risk; (3) If risks occur late, the right expansion saves more costs, while increasing the number of personnel cannot be completed on schedule; (4) Staff and general staff ratios will be considered. During the increase in technical staff, if it does not reduce construction speed, it will rework more, and form more waste; (5) When the proportion of key staff and general staff is more than standard, the workload of key staff is not saturated, while the risk of general staff increases.
15.	(Maryani et al., 2015)	Internal	Construction Site	The contractor must pay attention to the Components that make up K3 costs, namely: (1) Direct costs; (2) Indirect costs; (3) Training costs; (4) Consumption and non-consumables; (5) OSH equipment and inventory costs; (6) Prize and penalty fees; (7) Prevention costs; (8) Insurance fee; and (9) Costs outside of insurance coverage.
16.	(Boateng et al., 2016)	Project	Construction	Launched the Analytical Network Process (ANP) and System Dynamic (SD), (Integrated SD-ANP), to model the ease of design and construction of megaproject projects, SD-ANP model. The new framework is a superior solution for completing dynamics during design and construction megaprojects.
17.	(Nasir Bedewi Siraj, 2016)	Project	Construction	This paper develops FSD (Fuzzy System Dynamic) work commitments that will address many issues related to financial management by using higher funds that focus on risk issues, complex interactions between various risk factors, and dynamic effects.
18.	(Wang & Yuan, 2016)	Project	Time	There are six main risks, which are very important in influencing infrastructure project schedules, which include: (1) change request by the client; (2) project payment delays; (3) pressure due to tight project schedules; (4) site investigation information is not accurate; (5) loss of skilled labor, and (6) bad contractor management.
19.	(L. Xu et al., 2017)	Project	Documents and information	The Public-private partnership (PPP). This is a form of collaboration between one or more public and private sectors, which is long-term in nature. Based on the project's risk allocation mechanism, the risk factors system is summarized, divided into three sub-systems, including cooperation effectiveness sub-system, cooperation environment sub-system, and construction and operation sub-system.

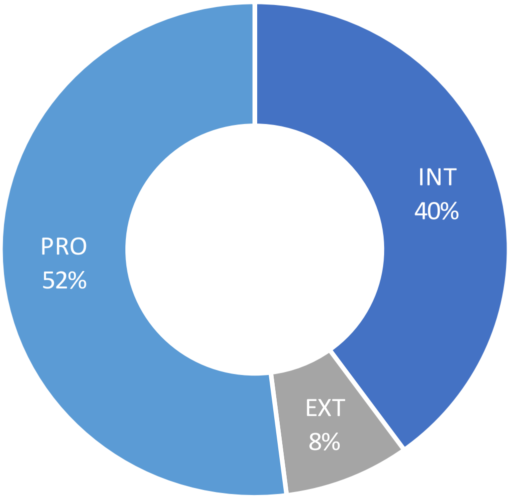
Table 1.4. Summary of Results, Risk Groups & Risk Criteria Based on (Zavadskas et al. 2010)

No.	Paper	Risk Group	Criteria (Risk)	Summary of Results
20.	(Mohammadi et al., 2018)	Internal	Construction Site	Four archetypes are developed to address the identified safety problems during the data collection process, including (1) Delay in design; (2) Number of subcontractors; (3) Project cost and safety; and (4) Supervisors and safety.
21.	(Ullah et al., 2018)	Project	Time	This study proves 59 CSF that affects CP. The results of a survey of 26 industry experts and 30 academics determined that Net Present Value (NPV), Project income (PI), Revenue stream (RS), Severity Involved Risks (SIR), Market situation (MS), and Investment Size (IS) were the most complicated aspects, with a minimum of 8% usage by MS and IS, and a maximum of 29% generated by NPV.
22.	(X. Xu et al., 2018)	Project	Time	The hybrid dynamic model developed was applied in the bridge engineering project to analyze the impact of the four risks selected on schedule. The results are as follows: (1) the degree of influence of risk on performance schedules varies across the project timeline; (2) the effect of risk may have a different rating when the risk occurs at different stages; (3) the effect of multiple risks on a schedule may be more significant than the simple amount of each risk.
23.	(Mohammadi & Tavakolan, 2019)	Internal	Construction Site	The simulation model presented in this paper can be used to: (1) identify changes in safety performance results during project time; (2) evaluate the effect of various factors on the results of safety performance; (3) make new policies or corrective actions to respond to changes in the project correctly.
24.	(Nasir & Hadikusumo, 2019)	Project	Documents and information	That Owner & Contractor relationships could be managed with integrated contract management activities both before and during the construction stage. The preconstruction stage has more potential to influence contractual relationships than the construction stage. The best result was found when all of the previously mentioned policies (preconstruction stage policies, and construction stage policies) were implemented together.
25.	(Mortazavi et al., 2020)	Project	Construction	Ten Diagrams are selected and analyzed, The Results are: (1) 10-Fold Increase in Lack of Budget Coefficient; (2) 10-Fold Increase in the Coefficient of Delays in the Project Implementation; (3) 10-Fold Increase in Claim Coefficient; (4) 10-Fold Increase in the Incomplete Design Coefficient; (5) 10-Fold Increase in the Coefficient of Employing Poor-Quality Second-Class Contractors; (6) 10-Fold Increase in the Coefficient of Low Labor Productivity; and (7) 10-Fold Increase in the Coefficient of Employing Unskilled Labor.

3.2. Risk Group

Based on Table 1 (Sections 1-3) of the Resume Review Paper, it can be concluded that: papers discussing Internal Risk include 10 Papers (40%), 2 papers (8%) discuss

External Risks, and 13 papers (52%) discuss Project Risks. The results of the grouping appear in Figure 3.



Internal Risk	INT	10	40%
External Risk	EXT	2	8%
Project Risk	PRO	13	52%

Figure 3. Risk Group Count

3.3. Risk Criteria

Based on Table 1 (Sections 1-4) in the discussion Continue Review paper, it can be concluded that the Risk Criteria discussed are as shown in Table 2. The grouping results are then sorted by the number of papers discussing the most Risk Criteria, as well as in Table 3. Furthermore, the discussion of the papers according to Risk criteria will be discussed in more detail.

Table 2. The Most Researched Risk Criteria

Risk Group	Risk Criteria	Count
Internal Risk	Construction site risk	5
Project Risk	Cost risk	5
Project Risk	Time risk	4
Internal Risk	Team risk	3
Project Risk	Construction risk	3
Internal Risk	Documents and information risk	2
Exsternal Risk	Political risk	1
Exsternal Risk	Weather risk	1
Project Risk	Work quality	1

Table 3. Risk Criteria Count

Risk	Count	Percentage
Internal Risk	10	40%
Resource Risk	0	0%
Project member risk	0	0%
Stakeholder Risk	0	0%
Designer Risk	0	0%
Contractor Risk	0	0%
Sub Contractor Risk	0	0%
Supplier Risk	0	0%
Team Risk	3	12%
Construction site risk	5	20%
Documents and information risk	2	8%
Exsternal Risk	2	8%
Political Risk	1	4%
Economical Risk	0	0%
Social Risk	0	0%
Weather Risk	1	4%
Project Risk	13	52%
Time risk	4	16%
Costruction risk	5	20%
Work quality	1	4%
Construction risk	3	12%
Technological Risk	0	0%
Total	25	100%

4. Discussion

4.1. Internal Risk, Team Risk

Team risk refers to problems associated with project team members, which can increase uncertainty about project outcomes, such as team member turnover, staff improvement, inadequate knowledge among team members, collaboration, motivation, and team communication problems (Zavadskas et al., 2010). The results show that, during the specified period (2000-2020), there were 3 papers that discussed the Internal Risk for Team Risk Criteria. Construction accidents are caused by unsafe actions (e.g. Behavior or activities of someone who deviates from the safe procedure that is normally accepted) and/or unsafe conditions (for example, hazard or unsafe physical environment). Relatively little is known about eliminating unsafe construction workers' actions. Three safety improvement policies are examined: (1) Providing incentives to workers to make their safe behavior most effective if offered as early as possible, (2) Sharing accident information among workers can help reduce accident incidents, and (3) Helping workers feel an accident when sharing accident information because they assess the risk an accident is based on how likely it is to occur. Difficulties experienced by people in changing their habits and interests related to safety and safety in construction companies. This will be effective for sharing audiovisual accident information (Shin et al., 2014). Unsafe construction workers getting the direct cause of construction accidents, but the causes are not well understood (Jiang et al., 2015). This study discusses the modeling of System Dynamics to understand the systematic construction of unsafe construction. The SD-CUB model was developed to facilitate understanding of how the system optimizes. The SD-CUB model produces correct behavior patterns. The test model also implies that: (1) safety and production can truly support each other; (2) management conditions at the supervisory level are effective in increasing employee safety awareness; (3) preventive measures are more effective than reactive measures to improve safety performance. The characteristics of human resources are complex and flexible, predicting and controlling risks resulting from human resources is more difficult than other risk factors (Cunbin et al., 2015). In the research, the aim is to achieve effective construction objectives, then develop an SD Model to transmit elements of human resources during the construction project. The SD model of the transmission of risk elements that simulate the scope and depth of projects affected by human risk elements, we can illustrate as follows: (1) The theory of transmission of risk elements is incorporated into the process that how human risk impacts on construction and transfer projects, can carry out quantitative analysis at procedures and levels, (2) Schedules will disrupt while human elements of risk occur, (3) If risks occur late, the right expansion saves more costs, while increasing the number of personnel cannot be completed on schedule, (4) Staff and general staff ratios will be considered. During the improvement of technical staff, if it does not reduce the speed of construction, it will process more, and form more waste, and (5) When general staff risks occur, the proportion of key staff and general staff is more than standard, the workload of the main staff is not saturated, while general staff increased.

4.2. Internal Risk, Construction Site Risk

It means that construction site risk is workplace accident exposure that is inherent like the work and is considered best by contractors and their insurance and safety advisors (Zavadskas et al., 2010). The results show that, during the specified period (2000-2020), there were 5 papers that discussed the Internal Risk for Site Construction Risk Criteria. Strong safety culture in companies and the influence of superior Main indicators for safety culture: (1) Worker's behavior; (2) Employee perception; (3) Schedule of delays; (4) Participation of the Safety Committee management; (5) Meetings; (6) Toolbox talks; (7) Safety education; (8) Inspection of superiors; (9) Worker involvement; (10) Inspections at work; (11) Danger; (12) Competence; and (13) Safety training. By integrating all concepts into the System Dynamics model, it is activated to analyze the feasibility of using key indicators previously understood, factors related to safety culture, and improving them on organizational safety. The relationship between the main indicators, safety culture, and organizational safety conditions and sensitivity analysis based on observing behavior towards the safety climate does not have a significant effect on the safety climate (Han et al., 2010). The construction of safety culture and the interaction between five key construction safety culture enablers, as well as the potential of each enabler on the organization's safety objectives during a certain period (Mohamed & Chinda, 2011). The following are 5 Key Enablers in a Construction Project: (1) Leadership; (2) Policies and Strategies; (3) People; (4) Partnerships and Resources; (5) Process. Organizations with ad-hoc safety implementation (starting from the basic level of safety culture maturity) must primarily focus on improving leadership attributes, in the context of safety, for rapid and successful progress to a higher level of maturity in the future.

Work accidents can be caused by members of the supply chain, i.e. parties involved in development projects, from management to workers, work environment, and work pressure related to targets, costs, quality, and time. Accidents will have an impact on costs, especially K3 costs (Maryani et al., 2015). The components that makeup OHS costs that require contractor attention are: (1) direct costs; (2) indirect costs; (3) training costs; (4) consumption and non-consumables; (5) Cost of OSH equipment and supplies; (6) prize and penalty fees; (7) prevention costs; (8) insurance costs; (9) costs outside the insurance coverage.

Repeated behavioral patterns in work safety management continuously have four archetypes identified, namely: (1) design delays; (2) number of subcontractors; (3) project costs and security; and (4) supervisors and safety. Each archetype is discussed at different stages of dynamic complexity, behavior over time, and the point of leverage to show how to deal with archetypes (Mohammadi et al., 2018). In construction projects caused by system failures, not just because of a single factor such as an unsafe problem or condition (Mohammadi & Tavakolan, 2019). Therefore, the construction of safety must be investigated using a systematic view that can think of the complex nature of reporting. Construction projects are also often canceled from the schedule issued and decided from the pressure caused by contract or client deadlines. Therefore, good project managers are needed for dynamic change. The simulation results in this paper can be used to: (1) identify changes in safety performance results during project time; (2) evaluate the effect of various factors on the results of safety performance; (3) make new policies or corrective actions to respond to changes in projects correctly.

4.3. Internal Risk, Documentation & Information Risk

Document and information risk assumptions include: contradictions in documents; pretermission; law and communication. Changing order negotiations and pending dispute resolution are significant risks during project construction. Communication is very important throughout all construction periods and after completing construction work (Zavadskas et al., 2010). The results showed that, during the specified period (2000-2020), there were 2 papers that discussed the Internal Risk for Documentation & Information Risk Criteria. The Public-private partnership (PPP) is a form of collaboration between one or more public and private sectors, which is long-term in nature. Based on the project's risk allocation mechanism, the risk factors system is summarized, divided into three sub-systems, including cooperation effectiveness sub-system, cooperation environment sub-system, and construction and operation sub-system. By setting the System Dynamics model, it can be concluded that government efficiency and contract document conflicts are key elements. In conclusion, the conflict of contract documents and the efficiency of the project company must be strictly controlled in this project (L. Xu et al., 2017). Another paper has examined the Contract Documents Between Owners and Contractors in a Construction project as a facilitating and integrated way to facilitate owner-contractor (O/C) relations in construction projects. This paper focuses more on discussing Policy in Pre-Construction Phase Policy, Construction Phase Policy & Combined Policy. Police Simulation in Pre-Construction Stage: (1) Standard value; (2) Procedure for selecting the right contractor; (3) Proactive contracting process; (4) Contractor involvement in design; (5) Quality of the written clause; (6) Abnormal low bids. Police Simulation in Construction: (7) Bureaucracy and politics deadline; (8) Late payment progress; (9) Efficient reporting; (10) Adequate scheduling system; (11) Adjustments to adequate and fair compensation. Police Simulation in Combined Police: (12) Policy 2 + 3 + 4 + 5 + 6; (13) Policies 7 + 8 + 9 + 10 + 11; and (14) 12 + 13 Policy. The Study Results state: The hostile nature of the O/C relationship has been a matter of concern and can lead to poor relationships in the construction contract, which causes a bad relationship in the contract. This study reveals that the development of the O/C relationships can be better understood if it regulates management approval for a combination of several improvements and balances. O / relationship can be managed with good contract management activities before and during construction. The pre-construction stage has a greater potential to influence contractual relations than the construction stage. The best results are found when all the policies mentioned earlier (pre-construction stage policies, and construction phase policies) are implemented together (Nasir & Hadikusumo, 2019).

4.4. External Risk, Political Risk

Political risk is a change in government laws regarding the legislative system, regulations, and policies as well as inappropriate administrative systems, etc. (Zavadskas et al., 2010). The results show that, during the specified period (2000-2020), there was only 1 paper that discussed the External Risk for Political Risk Criteria Environmental risks arise from external forces that can easily place a project outside management's control. To avoid the influence of external forces, it is necessary to understand the problems between the project and external stakeholders. Seven processes are proposed using the SD Model to solve environmental risk management problems in a systematic and efficient manner. In the case study, there are seven steps to solve the problem of environmental risk management systematically, and efficiently. Step 1: Kernel Stakeholder Verification with the relevant Problem; Step 2: Determine Meaningful Issues Between Two Stakeholders; Step 3: Draw the Feedback Loop Diagram Cause of Cause for Reference Problems Indicated for System Archetypes; Step 4: Build a Dynamics Model of the Stock-Flow System by Referring to the Causal Feedback Loop Diagram; Step 5: Build a Frame Including a System Dynamics Model for Negotiations among Stakeholders for the Problem Indicated; Step 6: Repeat Steps 2–5 Until All Stakeholders Are Involved; Step 7: Make a List of Environmental Risks. This process allows project managers to reduce the negative impact of project threats (Yang & Yeh, 2014).

4.5. External Risk, Weather Risk

In connection with a very abnormal problem, the contractor is risking because it affects the construction method that can be agreed by the contractor (Zavadskas et al., 2010). The results show that, during the specified period (2000-2020), there was only 1 paper that discussed the External Risk for Weather Risk Criteria. The effect of critical weather conditions (CWC) and addressing their direct impact on construction activities is very important for contractors, clients, and affected communities (P Boateng et al., 2012). The reason is that SD is used to model delays and cause cost overruns for the results of weather phenomena. Four weather conditions that impact the project: (1) Snow falling; (2) High temperature; (3) Rainfall; (4) Wind.

4.6. Project Risk, Time Risk

Time risk can be determined by assessing construction delays, technology, and for all jobs (Zavadskas et al., 2010). The results show that, during the specified period (2000-2020), there were 4 papers that discussed the Project Risks for Time Risk Criteria. The Project BOT Financing using System Dynamic modeling is integrated with Fuzzy. It chooses the integrated fuzzy-SD model that can be applied to all BOT projects to determine the concession period (Khanzadi et al., 2012). Effects of Risk Schedule Delay are generated. There are six main risks (Wang & Yuan, 2016) which are very important in influencing infrastructure project schedules, which include: (1) changes in demand by clients; (2) project payment delays; (3) pressure from tight project schedules; (4) the information from the site investigation is inaccurate; (5) loss of skilled labor, (6) poor contractor management. Another paper has examined the planning scheduling problems in infrastructure project management. This study is a research modeling, System Dynamic (SD) and discrete event simulation (DES). The results are as follows: (1) the degree of influence of risk on the performance schedule varies across the project schedule; (2) risk effects can have different ratings when risks occur at different stages; (3) the effect of various risks on a schedule may be more significant than the simple amount of each risk. SD-DES modeling that can be used easily compares models for real reflection, performs various sensitivity and analysis analyzes and determines the results of more effective comparisons (X. Xu et al., 2018). The System Dynamic (SD) approach to provide deep understanding of the critical success factors (CSF) that determine the project concession period (CP) and model it for local use. This study proves 59 CSF that affects CP. The survey results from 26 industry experts and 30 academics determined that Present Value (NPV), Project income (PI), Revenue stream (RS), Severity Involved Risks (SIR), Market situation (MS), and Investment Size (IS) is the most complicated aspect, with a minimum use of 8% by MS and IS, and a maximum of 29% generated by NPV (Ullah et al., 2018).

4.7. Project Risk, Cost Risk

Cost risk is the opportunity cost of the product that goes up because it ignores management (Zavadskas et al., 2010). The results show that, during the specified period (2000-2020), there were 5 papers that discussed Project Risks for Cost Risk Criteria. Overtime employment policies result in more significant swelling costs and poor quality compared to modification of labor/equipment policies (MLEP) due to their more prominent negative side effects (Nasirzadeh et al., 2008). This time, they discussed the risk of engine damage that can cause a large negative impact on project objectives in terms of cost overruns and project delays (Nasirzadeh et al., 2008). The following alternative response scenarios for this risk: (1) use of overtime policy; (2) modification in labor/equipment policy; (3) use of subcontractors; and (4) schedule changes. Another paper analyzed the optimal percentage of risk allocation determined at 46% (Nasirzadeh et al., 2014). The output of the model shows that if the client receives 46% of the risk consequences, the project costs (client costs) will be minimized.

The price of highway project concessions, as a result, the price of PPP highway project concessions can be determined by the following formula (Y. Xu et al., 2012):

$$\text{Final price} = \text{Basic price}^* \left(1+ \lambda_1 - \text{PRS}_1 \frac{\lambda_2 - \lambda_1}{\text{PRS}_2 - \text{PRS}_1}\right) \tag{1}$$

Where:

Final Price = Basic Price + Adjustment price

Final price = (1 +λ) Basic Price

$\text{PRS}_i = W_{ij} \times (R_{ij} - R_{oj})$

$\sum_{j=1}^{n} W_{ij} = 1$

where, PRS_i is the overall risk similarity between reference case i and a target case;

W_{ij} is the weighting of each risk factor;

R_{ij} denotes the reference case i's risk factor j, R_{oj} denotes the target case n's risk factor j;

$\sum_{j=1}^{n} W_{ij}$ denotes the summation of weighting of all risk factors.

The Stimulation of cost allocation between elements and elements between departments influence project risk and costs by building a System Dynamics model (Yi & Xiao, 2008). Allocation ratio is shown in Table 4. From the output results, when the allocation ratio is 0.6: 0.3: 0.1, cost savings reach the maximum of 2707 (2704) and the risk reaches the minimum of 0.28 (0.27). When the probability of the project risk occurrence is 0.27 or 0.28, it is in the supportability scope.

Table 4. Allocation ratio (Yi & Xiao, 2008)

	Allocation ratio		
Bonus: environment cost: training cost	0.6: 0.3: 0.1	0.45: 0.35: 0.2	0.3: 0.4: 0.3
Risk	0.28 (0.27)	0.30 (0.29)	0.32 (0.31)
Saved cost	2707 (2704)	2622 (2619)	2521 (2518)
Time (week)	10.5 (10.75)	10.5 (10.75)	10.5 (10.75)

4.8. Project Risk, Work Quality Risk

Construction delays and additional costs for contractors are due to the quality of the work that is damaged and easily creates disputes regarding deflection obligations. (Zavadskas et al., 2010). The results show that, during the specified period (2000-2020), there was only 1 paper that discussed the Project Risks for Work Quality Risk Criteria. Matters that have a significant impact on the level of project progress that can cause variation, rework, or both (Love et al., 2002), namely: (1) Buyer Changes; (2)

Freezing of Design; (3) Information management; (4) Building regulations; (5) Consultant fees; (6) Communication; (7) Coordination and integration of the project team; (8) Training and skills development.

4.9. Project Risk, Construction Risk

Construction risk refers to the Risks involved in construction delays, changes in work, and construction technology (Zavadskas et al., 2010). The results show that, during the specified period (2000-2020), there were 3 papers that discussed the Project Risks for Construction Risk Criteria. The 10 diagrams selected and analyzed to identify and assess risks, and to develop predictive models for feedback behavior and to illustrate the effects of risks to each other in bridge construction projects (Mortazavi et al., 2020), The results are: (1) 10-Fold Increase in Lack of Budget Coefficient; (2) 10-Fold Increase in the Coefficient of Delays in the Project Implementation; (3) 10-Fold Increase in Claim Coefficient; (4) 10-Fold Increase in the Incomplete Design Coefficient; (5) 10-Fold Increase in the Coefficient of Employing Poor-Quality Second-Class Contractors; (6) 10-Fold Increase in the Coefficient of Low Labor Productivity; and (7) 10-Fold Increase in the Coefficient of Employing Unskilled Labor. The Analytical Network Process and System Dynamic, (Integrated SD-ANP) are used to model the ease of design and construction of megaproject (Prince Boateng et al., 2016). The new framework is a superior solution for completing dynamics during design and construction megaprojects. Another paper develops FSD (Fuzzy System Dynamic) work commitments that will address many issues related to financial management using higher funds that focus on risk issues, complex interactions between various risk factors, and effects dynamic (Nasir Bedewi Siraj, 2016).

5. System dynamic Software

Out of 25 Papers Regarding Risk Management with System Dynamic modeling, 12 papers used VENSIM software while the other 13 papers do not explain the use of System Dynamic Software. Recent research (Mortazavi et al., 2020) also uses VENSIM Software for System Dynamic Modeling.

6. Future Research

Some of the papers reviewed mostly did not inform future research, only (Boateng et al., 2016) that proposed future research would look at risks such as Social, Technology, Economics, Ecology, and Politics (STEEP) in construction projects. This research was later published in 2016 by the same author. In Table 3, there are many risks that have not been studied with System Dynamic, and this can be used as a research gap for further research. The Research gap for the Internal risk group: Resource risk; Project member risk; Stakeholder risk; Designer risk; Contractor risk; Sub Contractor risk; and Supplier risk. The Research gap for the External risk group: Economical risk; and Social risk. The research gap for the Project risk group: technological risk.

7. Conclusion

The results of the study stated that risk management with System Dynamic modeling has not been widely used as evidenced by research (2000-2020); there are only 25 papers that match the keywords and can be written reviews. Ten Internal risk papers include: project members, location risk, document risk & information. External risk papers are only found in 2 papers that discuss: weather risk and social risk, while the project risks are found in 13 papers discussing: cost risk, time risk, work quality risk, and construction risk. The most widely used software is VENSIM.

The Internal Risk group: System Dynamic Modeling helps systematically understand unsafe behavior structures that result in correct behavior patterns; Dynamic Modeling System is also able to simulate the scope and depth of projects affected by human risk elements; using the System Dynamic on the main indicators of safety culture allows to analyze the appropriateness of the use of key indicators and factors related to safety culture, and improve organizational safety; Work accidents can be caused by parties involved in a development project, from management to workers, work environment, and work pressure related to targets, costs, quality and time. Accidents will have an impact on costs, especially K3 costs; in the PPP Project, the use of System Dynamics can conclude that government efficiency and contract document conflicts are key elements; in the contact relationship between Owner and contractor (O/ C), Dynamic Systems are used for Police Simulation at Pre-Construction Stage.

The External Risk Group: The problem between the project and external stakeholders must be understood to avoid the influence of external forces. Dynamic systems can be used for studies that allow project managers to systematically and efficiently reduce the negative impacts of project threats; Meanwhile, to deal with weather risk, SD is used to model delay and cause cost overruns due to weather phenomena.

The Project Risk group: Time-related System Dynamic Modeling can be integrated with Fuzzy which can be used in all BOT Financing Projects to determine the concession period; Dynamic systems can also be integrated with Discrete Event Simulation (DES) to be able to compare real reflection models, perform various models and sensitivity testing and determine the results of a more effective comparison; Regarding costs, the Dynamic Systems Project can support policies relating to overtime, additional employees or additional equipment; in Job Quality Risk using a dynamic system capable of identifying project progress and rework or both; Construction Risk uses a dynamic system to identify and assess risk, and to develop predictive models for feedback behavior and to describe the effects of risk; Dynamic Systems can also be integrated with Network Process Analytics (ANP) to model the ease of megaproject design and construction; In addition, Fuzzy System Dynamic Integration is able to solve many problems related to financial management using higher funds which focus on risk issues, complex interactions between various risk factors, and dynamic effects.

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