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An Innovative Risk Matrix Model for Warehousing Productivity Performance

Rudiah Md Hanafiah [1,*], Nur Hazwani Karim [1], Noorul Shaiful Fitri Abdul Rahman [2], Saharuddin Abdul Hamid [1] and Ahmed Maher Mohammed [3]

[1] Faculty of Maritime Studies, University Malaysia Terengganu, Kuala Terengganu 21030, Terengganu, Malaysia; hazwani@umt.edu.my (N.H.K.); sdin@umt.edu.my (S.A.H.)
[2] Faculty of Business, Higher Colleges of Technology, Abu Dhabi 25035, United Arab Emirates; nsfitri2107@gmail.com
[3] Faculty of Transport and Logistics, Muscat University, Muscat 113, Oman; amm.alhamdany@gmail.com
* Correspondence: rudiah@umt.edu.my

Abstract: In today's era of industrial economics, warehousing is a complex process with many moving parts and is required to contribute productively to the success of supply chain management. Therefore, risk management in warehouses is a crucial point of contention to ensure sustainability with global supply chain processes to accommodate good productivity performance. Therefore, this study aims to analyse risks factors that affect warehouse productivity performance towards a systematic identification of critical factors that managers should target to sustain and grow warehouse productivity. This study utilised a traditional risk matrix framework, integrating it with the Borda method and Analytical Hierarchy Process (AHP) technique to produce an innovative risk matrix model. The results indicate that from the constructed ten warehouse operation risk categories and 32 risk factors, seven risk categories, namely operational, human, market, resource, financial, security and regulatory, including 13 risk factors were prioritised as the most critical risks impacting warehouse productivity performance. The developed risks analysis model guides warehouse managers in targeting critical risks factors that have a higher influence on warehouse productivity performance. This would be extremely helpful for companies with limited resources but seek productivity improvement and risks mitigation. Considering the increasing interest in sustainable development goals (economic, environmental, and social), arguably, this work support managers in boosting these goals within their organisation. This study is expected to benefit warehouse managers in understanding how to manage risk, handle unexpected disruptions, and improve performance in ever-changing uncertain business environments. It often has a profound effect on the productivity level of an organisation. This study proposes an innovative risks analysis model that aims to analyse risks, frame them, and rate them according to their importance, particularly for warehousing productivity performance.

Keywords: warehouse service operations; warehouse productivity; risk analysis; risk matrix; productivity strategy; supply chain risk

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1. Introduction

Warehouse management is an essential component of the supply chain. The rapid progression of globalisation has driven companies to search for new approaches to improve their performance by producing products at a much lower cost, timelier and with superior quality. As such, performance nowadays needs to be perceived considering productivity, cost, quality, flexibility, scheduling, safety, social performance, environmental performance, and product life cycle (plan, development, activity operation destruction/recycling) [1]. Therefore, warehouse management aims to increase productivity and accuracy, reduce, and control the cost of inventory and shipping, while providing good customer service [2].

At the point where supply chain operations include the utilisation of warehouses, it is critical to consider the potential risks. Risk managers must reduce the probability of incidents and events from occurring and reduce the severity and impact on the business when they do occur as the warehouse will be vulnerable to huge losses that can seriously affect the performance of the organisation. These risks might also lead to serious injuries in the labour force. For instance, EUROSTAT [3] reported that 62% of all work-related injuries—in the European Union—came from the warehousing and transportation sectors in 2007. Similarly, the warehousing processes were the root cause for around 40% of the reported sicknesses cases in the United States in 2014.

Risks often occur due to unforeseen circumstances or events that are unplanned. Therefore, risk management for efficient, if not uninterrupted, warehouse operations is important to ensure the security and sustainability of the business and global supply chain. Wieland and Marcus Wallenburg [4] mentioned that supply chain risk management (SCRM) is one of the fastest-growing areas in logistics research based on continual risk assessments to reduce the level of vulnerability to the business and to ensure SCRM processes and standard operating procedures (SOPs) are effective. SCRM can be defined as the management of risk through identifying potential sources of risk and implementing appropriate coordination activities to avoid or contain supply chain vulnerabilities [5,6]. Uncertainty about the future often results in risks and unforeseen events occurring.

In the context of warehousing, Lynch and Cross [7] argued that risk management could directly impact the performance of a business, both in the short and long term that helps managers treat and mitigate the risk as a priority in a systematic manner. Warehouse productivity is one of the key aspects where management measure and monitor their warehouse operations [8,9]. Eventually, Karim et al. [10] define productivity performance as incorporating main inputs, namely labour, equipment, space, and information system, within the work area to represent the movement and storage output performance. Moreover, research conducted by Abdul Rahman et al. [11] indicate that the weight values of the main criteria which led by the criterion "Space (0.4005)" at the top ranking, followed by Information System (0.2445), Labor (0.2065) and Equipment (0.1484). From the theoretical perspective, supply chain management (including warehousing) positively affect productivity [12].

While numerous studies have focused on supply chain risks, only a few have addressed warehouse risk and its influence on supply chain performance [13]. Therefore, to address this issue, this study investigates warehouse productivity performance and risk management as components of the overall supply chain. From a static point of view, the research question is: What are the risks within the warehouse operation, and how does this affect the entire warehouse productivity performance? By embracing risk management and warehouse productive performance into an innovative risk analysis model, productive performance can be maximised, and critical risks can be minimised. Thus, this study aims to contribute to the body of knowledge in the field of warehouse risk management by addressing warehouse operational risks that affect productivity performance. To this end, this study introduces an innovative risk matrix model, which integrates the traditional risk matrix with the Borda method and Analytical Hierarchy Process (AHP). This helps warehouse managers in identifying important risk factors that are most critical for warehouse productivity performance.

2. Literature Review

2.1. Risk Assessment and Its Applications

A risk assessment is utilised to examine the level of risk related to each threat or peril. The objective of a risk assessment is to demonstrate which zone and activities in the value chain are most susceptible to certain hazards or threats [14]. James [15] mentioned that a risk assessment is a cycle, that uses an approach for assessing hazards, as characterised by the likelihood and recurrence of an event of a perilous function, exposure of people and property to the hazard, and consequences of that exposure. Hazards are defined by Rout and Sikdar [16] as the possibility of unfavourable outcomes and the associated loss of a selected choice plan because of various vulnerabilities in the decision-making process.

ISO 31000:2018 defines risk as to the influence of uncertainty on objectives, addressing the combination of 'consequences' and 'likelihood'. This definition is also backed by White [17], who states that the concept of likelihood is important to risk assessment, as is the use of a statistical database. As a result, the risk matrix technique is used in this study to examine and evaluate the discovered hazards.

In the supply chain context, managing risks has gained a growing interest by practitioners as a response to the massive disruptions supply chains experienced (e.g., pandemic, protests, floods, etc.) and thus several pieces of research conducted [18–22]. Supply chains might experience poor performance due to poor risk management approaches [23,24]. This would negatively impact productivity performance, forecasting, business reputation and continuity and customer satisfaction, in addition to management issues among firms' stakeholders [25]. Therefore, managers are forced to incorporate robust risk management in their supply chains to tackle risks consequences [26,27]. However, supply chains consist of several echelons in which the warehousing seizes a crucial role in being close to the marketplace with a direct influence on customer satisfaction and business reputation. However, the literature revealed scarce research directed to this echelon that this research aims to target.

2.2. Warehouse Operation Risk Categories

For the most part, supply chain risk can vary from both internal and external classifications [28,29]. This will create warehouse resource risk. Internal risk alludes to risk factors that started from sources identified with the association's activity that are doubtlessly controllable by the organisation [28,30]. Also, network risk, security risk and organisational risk are assembled as internal risk [31–34]. External risk, on the other hand, refers to external risks to the organisation that may have a negative impact, such as natural risk (for example, natural catastrophes) and man-made risks (for example war, terrorism, political, market change) [29,32,33,35]. Meanwhile, Karim et al. [36] prioritised risks regarding warehousing productivity performance, namely labour related (safety and foreign workers-miscommunication), poor technology and poor layout design that affect the warehousing productivity performance.

Risks can be partitioned into several groups, as indicated by the effects on the activity of the organisation and its current environment [37]. Ho et al. [35] grouped supply chain factors into two classifications, macro-risk factors (ecological risk) and micro-risk factors (supply risk, demand risk, transportation risk, information risk, manufacturing risk, financial risk). Risk management of warehousing, as suggested by Lam et al. [38], features important risk sources through conceptualising with modern specialists, which fall into nine classifications, namely, physical environment risk, operational risk, human risk, market risk, resource risk, managerial risk, financial risk, security risk and regulatory risk. Additionally, the most current techniques used to manage risk in warehouses fail to consider the risk level associated with the characterisation of stock-keeping units (SKU) [39]. Since SKU is one of the significant components in distribution centre activity, this study includes inventory management as a source of risk accordingly. Presently, Abdul Rahman et al. [40] has highlighted the human aspect in the occurrence and severity of musculoskeletal injuries that maybe happen among the warehouse workers can affect the company's productivity, product quality, and overall competitiveness. Zheng et al. [41] analysed in cold logistics system, which warehousing links recorded the minor sensitivity affecting the regular activity; however, must be maintained in the best practise of temperature and humidity, adequate storage, and hygienic conditions.

In terms of collecting literature on warehouse operation risk, the search for publications was linked with the theme of this research. The keywords "warehouse operation risk", "warehouse risk", "warehouse risk management" and "supply chain risk management" were chosen. Table 1 summarises the classification of warehouse operations risk factors from the selected publications, which fall into external and internal risk categories, highlighting the breadth of the study in the warehousing industry.

Table 1. Classification of Warehouse Operation Risk.

Author(s)	External Risk			Internal Risk						
	PER	**MarR**	**RegR**	**OR**	**HR**	**FR**	**IR**	**ResR**	**SR**	**MagR**
[13]	√	√	√	√	√		√	√		
[38]	√	√	√	√	√	√		√	√	√
[39]							√			
[40]				√	√					
[41]	√	√		√	√		√	√		
[42]				√	√			√		
[43]		√								
[44]				√	√	√			√	
[45]				√	√		√			

PER = Physical Environment Risk, MarR = Market Risk, RegR = Regulatory Risk, OR = Operational Risk, HR = Human Risk, FR = Financial Risk, IR = Inventory Risk, ResR = Resource Risk, SR = Security Risk, MagR = Managerial Risk.

2.3. Risks Assessment Methods

Due to the complexity of supply chain networks and associated processes downstream and upstream the chain, a robust risk basement is a crucial need. Risk assessment should include methods and supporting tools that analyse, categorise, and assess risks in which managers can control efficiently [46]. The literature showed the superiority of the mathematical-based deterministic methods in embracing both qualitative, quantitative perspectives. The risks assessment would normally include tangible and intangible data that needs subjective evaluation that experts suffer from normally. Saaty [47] developed the Analytic Hierarchy Process (AHP) method, as aid efficient tool in handling such decision-making problems. To this end, AHP handles the evaluation of intangible criteria via user-friendly comparisons among them. Decision-makers can give their opinions using a clear linguistic scale. Also, AHP's ability to aggregate multiple opinions regarding the evaluation of tangible and intangible criteria represents a great advantage. Furthermore, the AHP method presents the decision-making problem in a systematic way including all input data parameters. This enables managers to have a clear overview regarding the decision problem.

Thus, Wallenius et al. [48] and Rashidi et al. [49] proved that AHP is the most usable multi-criteria decision-making method via their review studies. In the supply chain context, it has been commonly employed to handle evaluation and analysis of supply chain performance assessment [19,50–52]. Also, it has been widely applied to study supply chain risk management [28,53–56]. In addition to the AHP method, this aims to employ the Borda method to identify the critical risks factors after being weighted by the AHP. This will group risks from the most to least critical based on multiple evaluation criteria. The Borda method uses probability and severity rank as independent scores to provide further ordering to avoid conflicts. This method has proved its ability in ranking and prioritising alternatives in several research studies [57–60]. However, to the best of the authors' knowledge, this is the first study that merges the Borda method along with AHP and risks matrix in the warehousing sector.

3. Construction of the Innovative Risk Matrix Model for the Warehouse Productivity Performance Risk Assessment

3.1. Risk Matrix Model

An innovative risk matrix method was used to analyse the management of warehouse productivity performance by identifying the risk factors which exist in warehousing operations. The conventional risk matrix was composed of the impact of severity and the probability of occurrence. However, in this paper, the reformed risk matrix was developed according to the features of warehousing productivity performance. The innovative risk matrix model with the conventional risk matrix severity and the probability of consequences in establishing the risk rating scales group is used in this study. The sequence values are then used to calculate the weight values by using the AHP method and procedures [61]. The analysis process is divided into five steps, which are as follows:

- Object to Analyse: Identifies the risk category and risk factor used to evaluate the impact and severity of the risk towards warehouse performance productivity.
- Impact: The occurrence of undesirable consequences falls into five categories and is addressed using a scale ranging from one to five, used in this study. The illustrative definition is to recognise the risk category level related to warehouse operations from a productivity perspective, as shown in Table 2. Level one denotes having no impact or incurring no losses because of an incident on productive performance, whereas level five denotes having the greatest impact, resulting in a performance failure or fatalities (people).

Table 2. Risk Matrix Impact Assessment.

Impact Category	Scale	Description
Negligible (N)	1	Risk had almost no effect on the warehousing productivity performance.
Minor (Mi)	2	Risk had slightly affected but could meet the objectives.
Moderate (Mo)	3	Moderate risk affected the warehousing productivity, but part of the objectives can be achieved.
Serious (S)	4	Serious risk led to a significant decrease in warehousing productivity.
Critical (C)	5	Critical risk directly affects the poor performance of warehousing productivity.

Source: Authors' illustrative.

- Probability: Probability or frequency of occurrence is divided into five categories, as shown in Table 3. The range of probability or frequency is presented as a percentage in which an illustrative interpretation is used to evaluate the likelihood of occurrence, of the risk factors, under each risk category.

Table 3. Probability of Occurrence.

Probability Category	Range	Interpretation
Unlikely (A)	0–10%	Very Unlikely to Occur
Seldom (B)	11–40%	Unlikely to Occur
Occasional (C)	41–60%	May Occur About Half of the Time
Likely (D)	61–90%	Likely to Occur
Frequent (E)	91–100%	Very Likely to Occur

Source: Authors' illustrative based on Garvey and Lansdowne [62] and Parra et al. [63].

- Risk Rating Scale: Table 4 illustrates 5 × 5 matrix cells with irregularly shaped risk zones. The matrix comprises a square divided into several boxes, with each box representing a different underlying estimation of risk [64]. The main reason for using a risk matrix is to access and prioritise a list of risks at the same level. The use of blue, green, yellow, orange, and red colours reflects the categorisation of the risk into negligible, low, medium, high, and extreme, respectively.

Table 4. Risk Rating Scale.

Critical	Medium	High	High	Extreme	Extreme
Serious	Medium	Medium	High	High	Extreme
Moderate	Low	Medium	Medium	High	Extreme
Minor	Low	Low	Medium	High	Extreme
Negligible	Negligible	Low	Medium	High	Extreme
Origin	0.00–0.10	0.10–0.04	0.04–0.60	0.60–0.90	0.90–1.00

Source: Peace [65].

- Analysis and Results: The final step is to verify the most critical risks according to the results obtained from the risk rating scale, Borda rank and AHP ranking.

3.2. Borda Order Value Method

The Borda Voting method is one of the decision-making tools Ref [66] to rank an item from the most to least critical based on multiple evaluation criteria [42,67]. This study implemented the Borda method in applying the risk matrix as used by Engert and Lansdowne [68] with the following procedures:

For example, in the risk matrix, let N be the total number of risks and the index i represents a particular risk. Then, let k denote the evaluation criteria, which are the impact assessment (severity, probability), where k = 2. Let b_i be the Borda index for risk i, and then the Borda value is expressed as follows:

$$b_i = (N - k_s) + (N - k_p) \quad (1)$$

Next, calculate k_s as a representation of the rank position of the severity of occurrence, as shown in Equation (2). Let s be the total number of severity of occurrences. Hence, in total, there are s = 5 possible assessments, which are Critical, Serious, Moderate, Minor and Negligible. Let C_s be the s^{th} possible impact assessment which is assumed to be ordered as C_s which has a higher impact than C_{s+1}. Let M_s be the number of risks having C_s as the impact rating. Let k_s be the rank position for all risks that are given the s^{th} possible impact, as given below.

$$k_s = \frac{1}{2}\,(2C_s + 1 + M_s) \quad (2)$$

Next, calculate k_p as a representation of the rank position of probability, as shown in Equation (3). Let p be the total number of possible probability assessments. There are five default probability ranges, so p = 5. Let B_p be the p^{th} possible impact assessment which is assumed to be ordered as B_p which has a higher impact than B_{p+1}. Let N_p be the number of risks having B_p as the impact rating. Let k_p be the rank position for all risks that are given the s^{th} possible impact.

$$k_p = \frac{1}{2}\,(2B_p + 1 + N_p) \quad (3)$$

In particular, the risk with a higher Borda Count is the most critical risk and so on. The final step is to rank the risks by referring to their Borda Counts. The Borda Ranks for a given risk is represented as the number of other risks that are more critical. As an example, the total number of N is 5; the risk's Borda Count is 3. Then, the Borda Rank is 2, which means that two other risks are more critical than risk. A Borda rank of 0 signifies that the respective event is the most critical risk. In contrast, another Borda rank of 1 indicates that one other risk is more critical than the respective event as the format integer (0–N) must be applied.

3.3. Analytical Hierarchy Process (AHP)

3.3.1. Building a Judgement Matrix

The b_i is the ordering value used as the corresponding elements in the judgement Matrix A (Figure A1) [42,61,69]. Concerning Saaty's scales, as shown in Table 5, the pairwise comparison is formed by pairwise comparison of the n number of risk factors, and the matrix elements of the quantised values are the importance of the elements i and j. The calculated judgement of the comparison on pair (A_i, A_j) is renowned as a_{ij} in Matrix A (Figure A1), as addressed in Equation (4).

$$A = \mathrm{a_{ij}} = \begin{bmatrix} 1 & a_{12} & \ldots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \ldots & a_{2n} \\ \ldots & \ldots & 1 & \ldots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \ldots & 1 \end{bmatrix} \quad (4)$$

Table 5. Linguistic Terms and the Corresponding Triangular Fuzzy Number.

Saaty's Scale	Definition
1	Equally important (E. Imp)
3	Weakly important (W. Imp)
5	Fairly important (F. Imp)
7	Strongly important (S. Imp)
9	Absolutely important (A. Imp)
2, 4, 6, 8	The intermittent values between two adjacent scales

Source: Saaty [47].

3.3.2. Calculating the Weight Value and Checking Consistency Ratio

A weight value w_k can be calculated using Equation (5) as follows:

$$w_k = \frac{1}{n}\sum_{j=1}^{n}\left(\frac{a_{kj}}{\sum_{i=1}^{n} a_{ij}}\right)(k = 1, 2, 3, \ldots, 4) \quad (5)$$

To ensure a reasonable conclusion of the AHP, consistency ratio (CR) checking to the judgement matrix is computed, applying Equations (6) and (7) is compulsory as follows:

$$\mathrm{CR} = \frac{\left(\frac{\lambda max - n}{n-1}\right)}{RI} \quad (6)$$

$$\lambda max = \frac{\left(\frac{\sum_{k=1}^{n} w_i a_{jk}}{w_i}\right)}{n} \quad (7)$$

Besides, suppose the dimensions or items constitute more than 15 risk factors. In that case, the extension of the random index (RI) can be dominated, as illustrated in Table 6, and as proposed by Alonso and Lamata [70] can be computed.

Finally, by calculating CR $\leq$ 0.1, the consistency of the judgement matrix and risk factors sort results can be accepted. In contrast, the judgement matrix and risk factors sort result cannot be accepted if CR $\geq$ 0.1 [69].

Table 6. Table of the λmax and Random Index for Dimensions Greater than 15.

n	16	17	18	19	20	21	22	23
λmax	39.9676	42.7375	45.5074	48.2774	51.0473	53.8172	56.5872	59.3571
RI	1.5978	1.6086	1.6181	1.6265	1.6341	1.6409	1.6470	1.6526
n	24	25	26	27	28	29	30	31
λmax	62.1270	64.8969	67.6669	70.4368	73.2067	75.9767	78.7466	81.5165
RI	1.6577	1.6624	1.6667	1.6706	1.6743	1.6777	1.6809	1.6839
n	32	33	34	35	36	37	38	39
λmax	84.2864	87.0564	89.8263	92.5962	95.3662	98.1361	100.9060	103.6759
RI	1.6867	1.6893	1.6917	1.6940	1.6962	1.6982	1.7002	1.7020

Source: Alonso and Lamata [70].

4. Application of the Risk Matrix Model

In this study, the most critical warehouse operation risks affecting the poor warehouse productivity performance by utilising the innovative risk matrix model are assessed (Figure 1). The study began with risk identification in which information was gathered from the experts to determine the risk impact and the probability of consequences. As the original risk matrix comprises 25 cells and sporadically shaped zones, this technique restricted the intended goal. Risk ties prevent risks from being ranked unambiguously Ref. [71] from the principle of a risk matrix for prioritising risks and constructing risk mitigation actions [72].

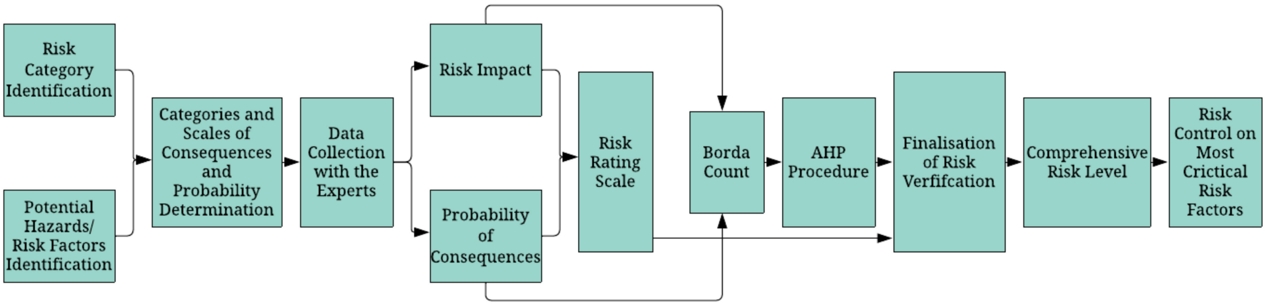

Figure 1. Procedure of Warehouse Productivity Performance Risk Assessment.

Subsequently, this study employed a methodology based on the Borda count by utilising the probability and severity rank as independent scores to provide further ordering; in any case, several combinations lead to equal Borda counts. At that point, the AHP method is employed using the Borda sequence values according to Saaty's scales to construct the judgement matrix followed by the weight values assessments.

4.1. Establish the Architecture of Warehouse Operation Risk Set

First, the need for identification of a prime risk category, risk factors, appearances and how to define the specific risks must be mitigated with the highest priority. To address and tackle the risk that leads to poor warehouse productivity performance, a literature survey was used to identify and determine the risk categories and risk factors that occurred in warehouse operations. Then, the risk set is established, as shown in Table 7, which contains three grades of the risk sets as (1) subject of risk; (2) risk category (C1–C10) and (3) risk factor (F1–F32).

Table 7. The Architecture of Warehouse Operation Risk Set.

Subject	Risk Category	Risk Factor
Risk Factors for Warehouse Operation	Physical Environment Risk (C1) *The physical environment such as natural disasters would affect warehouse operations resulting in the interruption of service, damage to cargo and warehouse facilities*	F1: Natural Disaster: *Flood, Earthquake, Windstorm*
		F2: Epidemic, Disease
		F3: Fire
		F4: Temperature
	Operational Risk (C2) *This results from the breakdown of internal procedures, systems, and people when the factors directly affect the process of internal warehouse operations*	F5: Information System Shutdown: *Warehouse Management System, RFID*
		F6: Unexpected order change

Table 7. *Cont.*

Subject	Risk Category	Risk Factor
	Human Risk (C3) *Warehouse labour/staff with insufficient knowledge to carry out the logistics services*	F7: Manual Handling Injuries
		F8: Lack of skills and knowledge
		F9: Ignorance and negligence
		F10: Wrong estimation or judgement resulting in poor planning of the warehouse operations
	Market Risk (C4) *The company may suffer a loss due to the warehouse's market situation and customer preference*	F11: Market Change
		F12: Loss of key customers
	Resource Risk (C5) *The warehouse may suffer a loss due to the unavailability of resources*	F13: Utility Failure
		F14: Machinery and equipment breakdown
		F15: Storage space utilisation resulting in limited space in accommodating inbound quantities
		F16: Ageing of facilities, equipment, and machinery
	Managerial Risk (C6) *Refers to poor managerial skills of senior management and insufficient conceptual skills to solve the problems and complex situations related to the warehouse*	F17: Change in future business development direction
		F18: Culture gap
		F19: Miscommunication
	Financial Risk (C7) *Refers to the cash flow problem of a warehouse.*	F20: Non-filling the warehouse
		F21: Delay in customer payment
		F22: Poor financial planning
	Security Risk (C8) *Security concerns such as anti-theft facilities and security of the IT system are important to protect the customers' goods, especially high-value goods and ensure the safety of confidential customer information.*	F23: Criminal Activities (e.g., stolen cargoes)
		F24: Information security
	Regulatory Risk (C9) *An unfavourable change in regulations and policy would bring pressure and risk when the warehouse tries to fit in with the new environment.*	F25: War, Civil Disobedience
		F26: Import and Export Regulations
	Inventory Risk (C10) *Dealing with the security risk classification of Stock Keeping Units (SKU) located in the warehouse.*	F27: Damage to the product
		F28: Damage to stuff
		F29: Property Damage
		F30: Terrorism
		F31: Material Smuggling
		F32: Human Smuggling

4.2. Data Collection and Processing

By using the risk set (refer to Table 7), survey interviews using face-to-face mode were conducted with 12 carefully selected industrial experts who are involved directly and indirectly in the warehousing operations department. Here, the expert sampling method in the sampling strategy was used where specific setting persons are selected circumspectly to provide sufficient information [73]. Also, to locate and find experts who are accessible and willing to participate in the expert judgement area of this study was limited due to the busy schedule and timetable of most potential respondents. As such, a minimum of three experts was recommended in some areas of limitation of expertise [74]. Accordingly, this study covered 12 organisations that classified themselves as logistics service providers (LSP), including warehousing and storage services, thereby representing players in the logistics service provider industry in Malaysia. It was also necessary given the context of this study to understand the characteristics of the respondents throughout the assessment and research findings. The experts graded each risk category's impact on poor warehouse productivity performance and each risk factor's probability of occurrence in the form of questionnaires. Table 8 presents the list of 12 experts who participated in the risk assessment of this study, including their designation, years of experience and the expert's warehouse services.

Table 8. List of industrial experts.

Name	Designation/Position	Years of Experience	Warehouse Services (*)
Expert 1	Warehouse Manager	10 years	D; C; CD
Expert 2	Warehouse Operation Manager	20 years	I; D
Expert 3	Warehouse Manager	10 years	D; CD
Expert 4	Warehouse Assistant Manager	3 years	D; C; CD
Expert 5	Senior Manager	10 years	I; D; R; C; E; CD
Expert 6	Warehouse Executive	23 years	I; D
Expert 7	Director of Business and Development	19 years	D; E
Expert 8	Branch Manager	20 years	D
Expert 9	Warehouse Manager	16 years	D; C
Expert 10	Warehouse Manager	12 years	D; R; E; CD
Expert 11	Operation Manager	10 years	D
Expert 12	Head of Warehouse	15 years	CD; T

* I—Industry/Factory Warehouse; D—Distribution Centre; R—Reverse Logistics; C—Control-temperature Warehouse; E—E-commerce; CD—Cross-docking; T—Transhipment.

4.3. Risk Matrix Assessment

The average value, according to the questionnaire, was calculated and graded against the risk rating scale for each risk factor, as shown in Figure 2. Based on the risk matrix assessment zoning map, the warehouse productivity performance risks are distributed in two risk rating groups which are medium and high. Most of the risks amounted to 25 risks in total and were categorised as high-risk levels. The other eight risks have a medium level of risk rating.

4.3.1. Borda Count Assessment

By determining the number of scales for the impact of risk category and probability source of risks, the number assigned was used in the Borda count calculation procedures. Table 9 shows the values of impact and probability of the risk sets. By using Equations (2) and (3) the r_s and r_p are calculated as follows:

$$k_s = \frac{1}{2}(2(0) + 1 + 32) = 16.5$$

$$k_p = \frac{1}{2}(2(0 + 13) + 1 + 11) = 19$$

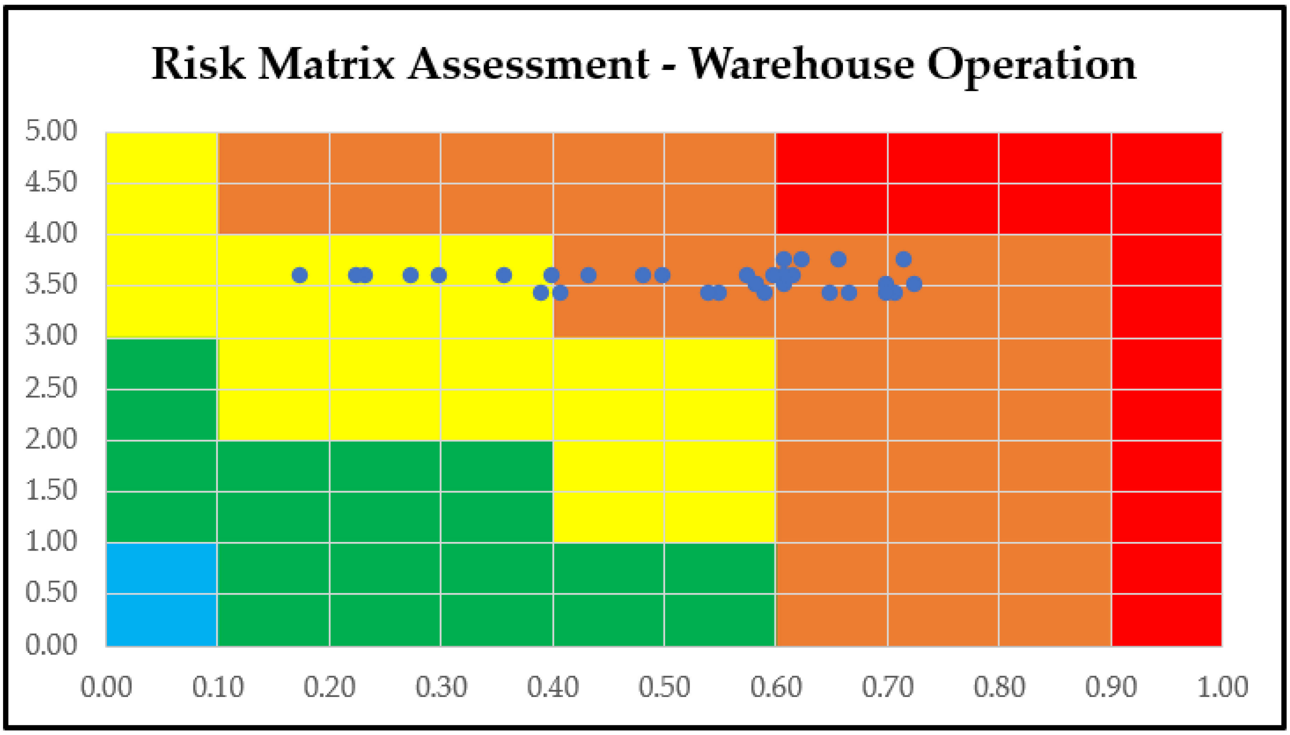

Figure 2. Risk Matrix Assessment of Warehouse Operation.

Table 9. Values of Impact (M_s and k_s) and Probability Range (N_p and k_p).

Severity	Impact	M_s	k_s	Probability	Probability Range	N_p	k_p
4–5	Critical	0	N/A	5	91–100%	0	0
3–4	Serious	0	N/A	4	61–90%	13	7
2–3	Moderate	32	16.5	3	41–60%	11	19
1–2	Minor	0	N/A	2	11–40%	8	15.5
0–1	Negligible	0	N/A	1	0–10%	0	N/A

Accordingly, an innovative risk matrix model in warehousing productivity performance is established, as shown in Table 10.

Table 10. An Innovative Risk Matrix Model in Warehousing Productivity Performance.

Risk Category	Risk Factor	Impact		Probability		Risk Rating Scale	r_s	r_p	Borda Count Value b_i	Borda Rank
		Category	Scale	Category	Scale					
C1	F1	Moderate	3.58	Seldom	0.23	Medium	16.50	15.5	32	13
	F2	Moderate	3.58	Seldom	0.30	Medium	16.50	15.5	32	13
	F3	Moderate	3.58	Occasional	0.43	High	16.50	19	29	21
	F4	Moderate	3.58	Seldom	0.36	Medium	16.50	15.5	32	13
C2	F5	Moderate	3.50	Likely	0.61	High	16.50	7	41	0
	F6	Moderate	3.50	Likely	0.70	High	16.50	7	41	0
C3	F7	Moderate	3.42	Occasional	0.41	High	16.50	19	29	21
	F8	Moderate	3.42	Occasional	0.55	High	16.50	19	29	21
	F9	Moderate	3.42	Likely	0.67	High	16.50	7	41	0
	F10	Moderate	3.42	Likely	0.65	High	16.50	7	41	0
C4	F11	Moderate	3.42	Likely	0.71	High	16.50	7	41	0
	F12	Moderate	3.42	Likely	0.70	High	16.50	7	41	0

Table 10. *Cont.*

Risk Category	Risk Factor	Impact		Probability		Risk Rating Scale	r_s	r_p	Borda Count Value b_i	Borda Rank
		Category	Scale	Category	Scale					
C5	F13	Moderate	3.75	Likely	0.61	High	16.50	7	41	0
	F14	Moderate	3.75	Likely	0.66	High	16.50	7	41	0
	F15	Moderate	3.75	Likely	0.72	High	16.50	7	41	0
	F16	Moderate	3.75	Likely	0.63	High	16.50	7	41	0
C6	F17	Moderate	3.42	Occasional	0.54	High	16.50	19	29	21
	F18	Moderate	3.42	Seldom	0.39	Medium	16.50	15.5	32	13
	F19	Moderate	3.42	Occasional	0.59	High	16.50	19	29	21
C7	F20	Moderate	3.50	Occasional	0.58	High	16.50	19	29	21
	F21	Moderate	3.50	Likely	0.73	High	16.50	7	41	0
	F22	Moderate	3.50	Occasional	0.58	High	16.50	19	29	21
C8	F23	Moderate	3.58	Occasional	0.58	High	16.50	19	29	21
	F24	Moderate	3.58	Likely	0.62	High	16.50	7	41	0
C9	F25	Moderate	3.58	Seldom	0.23	Medium	16.50	15.5	32	13
	F26	Moderate	3.58	Likely	0.61	High	16.50	7	41	0
C10	F27	Moderate	3.58	Occasional	0.60	High	16.50	19	29	21
	F28	Moderate	3.58	Occasional	0.50	High	16.50	19	29	21
	F29	Moderate	3.58	Occasional	0.48	High	16.50	19	29	21
	F30	Moderate	3.58	Seldom	0.18	Medium	16.50	15.5	32	13
	F31	Moderate	3.58	Seldom	0.40	Medium	16.50	15.5	32	13
	F32	Moderate	3.58	Seldom	0.28	Medium	16.50	15.5	32	13

4.3.2. AHP Methods Procedures

According to the Borda rank and based on the AHP procedures, judgement Matrix A (Figure A1) of warehouse operation risks is established. To comply with the AHP procedure pairwise comparison, if the difference between the values exceeds nine when the judgement matrix is developed, it should be revised as nine according to Saaty's scale (Table 5) [75]. For example, Borda rank of Risk 5 versus Risk 7 has different values of 22. However, the value is regarded as nine since the biggest scale value in AHP is 9. Meanwhile, if the difference is between decreasing numbers, the pairwise comparison should be presented as reciprocal values. For instance, Borda Ranking Risk 1 versus Risk 5 has a different value of 14, but the value is reciprocal to 1/9 as Risk 1, which has a bigger value than Risk 5.

According to the judgement in Matrix A (Figure A1) above, the AHP method procedures were then followed to calculate the weight of each risk factor, and the result is presented in Table 11. A further step was to check the consistency ratio on the judgement Matrix A (Figure A1) by denoting the λmax following with the consistency index (CI) and RI as follows:

$$\lambda max = 34.05 \tag{8}$$

$$\text{CI} = \frac{(34.05 - 32)}{(32 - 1)} = 0.07 \tag{9}$$

Based on Table 6, the RI for 32 risk factors is 1.6867. As a result, the CR is calculated as 0.04, which is less than 0.1. Hence, the judgement matrix is acceptable, which also means the weight value of each risk is reasonable. At this step, the result of the risk set using the conventional risk matrix, Borda method and AHP method is presented on the highest risk ranking. Table 12 presents the final 13 most critical risks for warehousing productivity performance. Consequently, an innovative risk matrix model assisted in reducing the risk ties in the risk rating scales.

Table 11. Weight Value of Warehouse Operation Risk.

Risk Category	Risk Factor	Weight Value	Rank
C1	F1	0.0236	2
	F2	0.0236	2
	F3	0.0053	6
	F4	0.0236	2
C2	F5	0.0633	1
	F6	0.0633	1
C3	F7	0.0053	6
	F8	0.0051	7
	F9	0.0633	1
	F10	0.0633	1
C4	F11	0.0633	1
	F12	0.0633	1
C5	F13	0.0633	1
	F14	0.0633	1
	F15	0.0633	1
	F16	0.0633	1
C6	F17	0.0049	8
	F18	0.0187	3
	F19	0.0047	9
C7	F20	0.0046	10
	F21	0.0633	1
	F22	0.0044	11
C8	F23	0.0042	12
	F24	0.0633	1
C9	F25	0.0126	4
	F26	0.0633	1
C10	F27	0.0041	13
	F28	0.0039	14
	F29	0.0037	15
	F30	0.0083	5
	F31	0.0083	5
	F32	0.0083	5
TOTAL	1.000		

Table 12. Verification of Risk Matrix results with Borda and AHP.

Risk Category	Risk Factor	Risk Matrix	Borda Count	AHP
C1	F1			
	F2			
	F3	✓		
	F4			
C2	F5	✓	✓	✓
	F6	✓	✓	✓
C3	F7	✓		
	F8	✓		
	F9	✓	✓	✓
	F10	✓	✓	✓
C4	F11	✓	✓	✓
	F12	✓	✓	✓
C5	F13	✓	✓	✓
	F14	✓	✓	✓
	F15	✓	✓	✓
	F16	✓	✓	✓
C6	F17	✓		
	F18			
	F19	✓		
C7	F20	✓		
	F21	✓	✓	✓
	F22	✓		
C8	F23	✓		
	F24	✓	✓	✓
C9	F25			
	F26	✓	✓	✓
C10	F27	✓		
	F28	✓		
	F29	✓		
	F30			
	F31			
	F32			

5. Discussion

A warehouse risk assessment is extremely important since it infers that the demand for warehousing is growing by a vast number and competition for safe, reliable, and efficient services. This implies that a warehousing risk assessment is fundamental, if not significant, to organisations since it assists in creating awareness of potential hazards, prioritising them and constructing control measures in addition to mitigating actions. Controlling and reducing warehousing hazards will help the organisation from incurring any financial loss while continuing to deliver quality services to its customers. Alongside the aim to either eliminate the risk or reduce the probability and impact of the risks that trigger the failure of warehousing productivity performance, this study proposed an action plan as part of the control options among the verified 7 risk categories and 13 risks. Table 13 shows the critical risks that attribute to the failure of warehousing productivity performance with suggested risk control options.

Table 13. Critical Risks with Risk Control Options.

Risk Category	Risk Factor	Risk Control (Action Plan)
C2	F5	• Installation of a second network that could accommodate and function in the event of a failure of the primary network. • Construct a special procedure to deal in the case of network failure. • Develop a warehouse storage space reservation hub system.
	F6	• Inventory planner to create a demand forecast for the warehouse operation's teams to be prepared for any high demand season. • Construct a special procedure to deal with unexpected order changes.
C3	F9	• Reduce manual touch by transitioning human manual work to automated material handling equipment. • Daily assembly before the working hour to reduce negligence and ignorance; human's need to be reminded, supervised, and trained as people do not work at a consistent rate. • Develop a labour incentive application (which is to guide individual achievement by daily activities achieved). • To conduct consistent training for new or veteran employees.
	F10	• Employing a Warehouse Management System (WMS) in which labour works and functions as what the system instructs.
C4	F11	• Need to adapt to changing trends proactively.
	F12	• Review the operational process by identifying factors that will improve people and processes.
C5	F13	• Installation of Warehouse Rooftop Solar System Power to integrate with traditional electricity supply.
	F14	• Construct a proper preventive maintenance programme. • Develop an effective troubleshooting system.
	F15	• Integration of transporter information through Innovative Notice Shipment (ASN) with warehouse operations to reduce congested goods in the staging space area. • Deploying an innovative Warehouse Management System (WMS) to plan for the overall process of the operations for efficiency and efficient flow of warehouse operations as artificial intelligence (AI) is applied.
	F16	• To reliability, conduct life cycle cost analysis to identify the reliability of machinery for a given performance and cost implication of the entire life span of the machine.
C7	F21	• Remind clients about financial transactions using automated systems.
C8	F24	• Access the security system and intervene if necessary. • Improve the security system by the integration of existing CCTV and mobile applications for 24-hour supervision.
C9	F26	• Develop a system that can integrate between the government and industrial players through electronic transactions.

From the analysis that had been conducted in this study, resources risk carries the most significant number of risk factors, including utility failure, machinery and equipment breakdown, storage space utilisation, and aging of facilities, equipment and machinery. As such, the warehouse operation depends highly on machinery and equipment to operate during inbound and outbound processes. Therefore, failure and delay in resources can result in poor warehouse productivity performance, impacting the output performance of put-away and picking productivity. Also, it is witnessed that the other primary warehouse resource is under human risk includes two risk factors: ignorance and negligence, and wrong estimation or judgment, affecting the operation decision and unseen cost to the organisation. Significantly, the research analysis reflects the definition of productivity on how well the resources have been used to perform an activity. Thus, the suggested action plan has introduced some new ideas for risk prevention which can intervene either in the short-term or long-term project since the cost and time need to be calculated precisely before the organisations can take any action.

6. Conclusions

This study has addressed the achievement of the objective established for this study to assess warehouse operation risk affecting productivity performance. Even though this study will contribute to an exceedingly small portion of the supply chain pool of literature in this field, this study has highlighted some key features. From the perspective of this study, it creates awareness for warehouse managers on the critical risks that influence and can severely disrupt warehousing operations and productivity. Furthermore, based on the comprehensive literature review, including field practices, subsequently, this study makes several contributions to the existing body of knowledge in this field, first, by proposing a new approach to mitigating warehouse productivity risks generated from warehouse operational risks involving 10 risk categories and 32 risk factors, cumulatively. This study presented the 13 most critical risk factors under 7 risk categories that require further attention in securing optimal warehouse productivity performance. In addition, this study also contributed by proposing a mitigation action plan on the critical risks to sustain from incurring financial and productivity losses due to unforeseen risks. Second, from the first methodological approach incorporating the traditional risk matrix, factual data and high-risk ties, this study integrates this approach with the Borda method and AHP method to lessen the risk ties. These three methods and the decision-making process underpinning this method is specific and integrated with other methods to increase the objectivity of the assessment results. As technically proven in this study, each stage verifies the methods used in this study as the results from the risk matrix alone present 24 risk factors with high-risk ties. Following the Borda method, it presents 13 risk factors which are then verified with the AHP procedures and validated with the CR less than 0.1, showing 13 most critical risks.

6.1. Research Implication

With the increasing competitiveness among global supply chains, one of the main targets is to elevate the productivity of warehousing performance that has a huge impact on customer service by being located close to the marketplace downstream the chain. One the same time, risk management is a continuous serious issue for managers in the industry due to its impacts on business performance and continuity. This work aims to analyse risks factors that affect warehouse productivity performance towards a systematic identification of critical factors that managers should target to sustain and grow warehouse productivity. Theoretically, it presents an innovative risks analysis model that aims to analyse risks, frame them, and rate them according to their importance. This approach could be used by any scholar to analyse and rank risks on other stages of the supply chain network. For instance, this approach could be applied to transportation risks analysis and its performance, allowing to identify bottlenecks and decide informed and reliable decisions to minimise consequences and increase supply chain stability and service quality.

6.2. Practical Implication

From a managerial perspective, the developed risks analysis model can guide warehouse managers in targeting critical risks factors that have a higher influence on warehouse productivity performance. This would be extremely helpful for companies with limited resources but seek productivity improvement and risks mitigation. Senior managers can use the results to identify risks that should get the most consideration and resources. This study also gives insights to the practitioners' understanding of the significance of productivity risk to plan, optimise, utilise, and execute the human factor, equipment, space, and inventory within the operation to maximise overall customer satisfaction with their services. It can be argued that the implementation of this work would have an influence not only on the warehouse productivity performance but also the competitive advantages of the entire supply chain. Considering the increasing interest in the sustainable development goals (economic, environmental, and social), arguably, this work support managers in boosting these goals within their organization, mainly economic and social as it maximises productivity performance and minimises possibilities of injuries among workforces.

6.3. Limitation and Future Research Directions

Accordingly, there is no doubt that the performance of the warehouse directly ensures the security of supply chain processes. This study limits the results to warehousing services that include industry/factory warehousing, distribution centres, reverse logistics, control-temperature warehousing, e-commerce, cross-docking, and transhipment as per the experts' risk evaluation. In the future, the method employed in this study could be employed in other forms and kinds of risk assessments in other jurisdictions and industries. As this study focuses on warehouse productivity performance and risk assessment, future research should look to broaden the investigation to incorporate other risk assessment perspectives such as human injuries, fire, epidemics (such as the Coronavirus (COVID-19) pandemic), custom regulation, halal regulation, equipment monitoring, work instruction, staff turnover, and in Industry 4.0 situations. Furthermore, this work poses the possibility of some incidents and researchers might take this forward by using simulation modelling to optimise warehouse performance according to each incident scenario and its severity. Also, this may include the incorporation of the Value Stream Mapping theory to depict and compare various scenarios.

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Appendix A

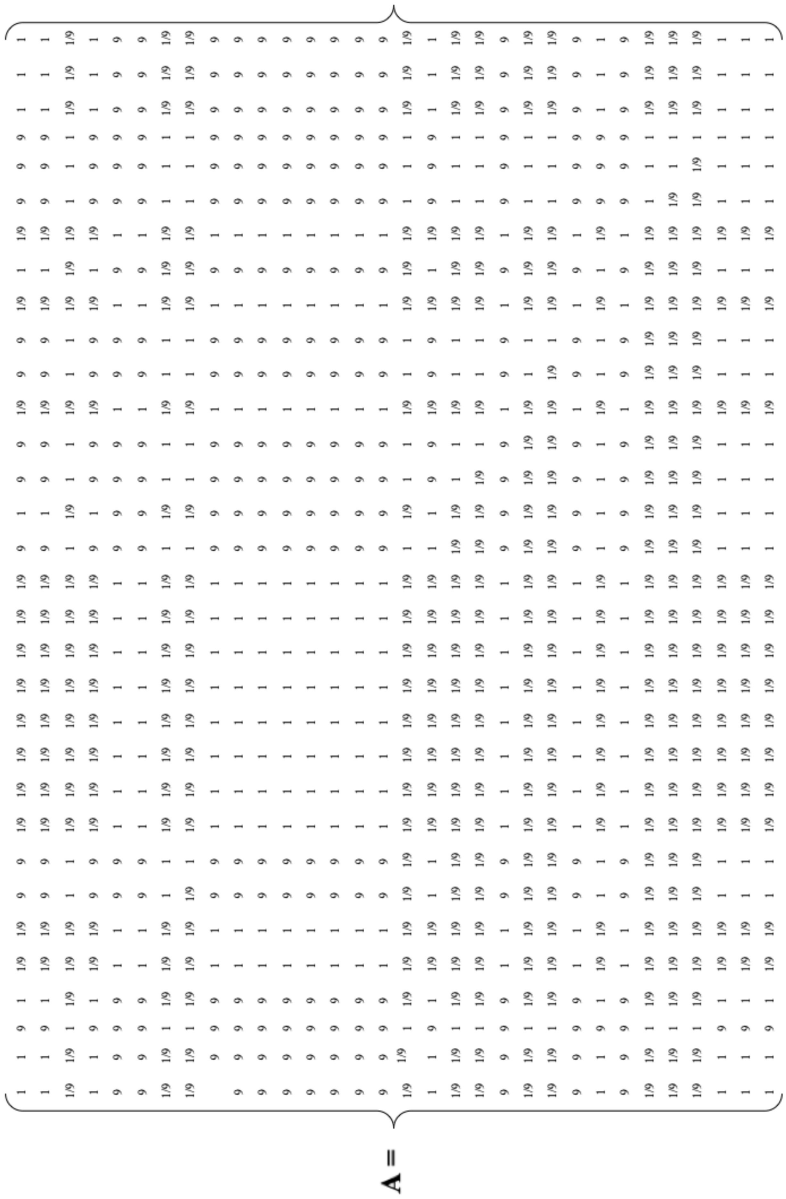

Figure A1. Matrix A.

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