FUNDAMENTAL RISK ASSESSMENT IN EXAMPLE OF TRANSSHIPMENT SYSTEM

M. Zajac

•
Wroclaw University of Technology, Wroclaw, Poland
Mateusz.Zajac@pwr.wroc.pl

D. Valis
•

University of Defense, Brno, Czech Republic

David.Valis@unob.cz

ABSTRACT

The paper represents discussion about risk assessment for transhipment system in reduces data condition. As a particular example transhipment system is presented. Article can be treated as first estimation. Future work and objectives are characterized in the end.

1 INTRODUCTION

Container transport is permanently growing way of goods transportation. Even during the time of global crisis, transportation in these load units still increase (in Poland more than 5%). Translocation of goods is part of logistics chain, where one of important factor is reliability. The reliability model of combined transport was presented during conference of ESREL. There were calculations of transitions between reliability and maintenance states in that paper. However the problem of reliability can be also considered from risk assessment point of view. Researches proved that one of important link in this chain is transshipment. The article shows fundamental risk assessment of transshipment system as container terminal in reduced data conditions.

2. RISK ASSESSMENT – INITIAL SET

The paper was prepared according to [3]. In general "risk is something that may badly affects your system". In particular example risk is meant as decrease of transshipment ability on terminal caused by adverse circumstances; in result the system is not able to serve all arriving containers. It was assumed that bad transshipment conditions are affected by crane's break downs. Naturally, stops can be introduced by i.e. some atmospheric reasons, some bad managing decisions, etc., but according to assumptions, that all bad what may happen is caused by break downs.
Risk assessment is in our case based onto finding three factors – risk contributors:

- probability of occurrence - v_{oi},
- impact V_i,
- probability of "discover ability" v_d ,

and all the factors must be given for *i-th*-element of the system.
When prepare standard risk assessment, character (or just some information) of break down must be known. Not only information that machine is broken, but also time of failure, time of repair, probability of occurrence, etc. Than for each machine we can prepare data like in table1.

Table 1. Desired data for machine

No.	Broken element	Probability of occurrence	Time of repair	Probability of "discovery"
1	element 1	p_1	t_1	p_{d1}
2	element 2	p_2	t_2	p_{d2}
..	…	…	…	…
n		p_n	t_n	p_{dn}

In our case we don't have all information about. We have just information given in table 2.
Value of impact can be characterized by scale number according to intervals defined by number of not transshipped containers. For determination of the probability of occurrence of the failure mode, besides published information regarding the failure rate, it is very important to consider the operational profile (environmental, mechanical, and/or electrical stresses applied) of each component that contribute to its probability of occurrence. This is because the component failure rates, and consequently failure rate of the failure mode under consideration, in most cases increase proportionally with the increase of applied stresses with the power law relationship or exponentially. Probability of occurrence of the failure modes for the design can be estimated from [3]:

- data from the component life testing,
- available databases of failure rates,
- field failure data,
- failure data for similar items or for the component class.

Discover ability likelihood can be also defined by scale according to intervals. The proposal represented by a scale is presented in table 2. The scale was determined according to the perspective of the entrepreneurs and the technicians who are responsible for corrective maintenance.

Table 2. Discover ability scale

Discover ability	Character	Value
Minor	chance to discovered a failure manifestation before every new motion	1
Major	chance to discovered a failure manifestation before a fault is not sure at all	2
Critical	chance to discover a failure manifestation is hard	3
Catastrophic	chance to discover a failure manifestation. is impossible	4

One of the methods of quantitative determination of criticality is the Risk Priority Number, RPN [3]. Risk is here evaluated by a subjective measure of the severity of the effect and an estimate of the expected probability of its occurrence for a predetermined time period assumed for analysis. In some cases where these measures are not available, it may become necessary to refer to a simpler form of a non-numeric FMEA.
Risk priority number (RPN) can be obtain by following formula

$$RPN_i = v_{oi} \cdot V_i \cdot v_d \tag{1}$$

where:
value of probability of occurrence - v_{oi},

value of impact V_i,
value of likelihood of discover ability v_d,

Obtained values are compared to scale, that describe the priority of the event affecting the system/element of the system. The problem is to find adequate thresholds of risk level. The acceptance of RPN may be linked with hurt understood as looses of money. Normally there is threshold of permissive looses. Its contributory factors are:
money not earn because of decrease of container transshipment number,
penalty coursed by breach of delivery contract,

- cost of repairs,
- other reasons.

Thresholds can be assigned from technical point of view. Mechanical systems are designed and prepared to run with load of 80%. Greater usage (even 100%) is naturally possible, but makes, those elements of machines (systems) wear faster than average. I.e. on container terminals transshipment machines are prepared to handle 42 tons, but heavy loaded container weight 32 tones. Typical container crane (rail crane) can pick up 40 tons – 32 tons – it means 80% of total handle capacity.
Transshipment ability is given according to formula [1]:

$$W = \frac{\beta \cdot T}{t_c}, \qquad (2)$$

where:
T – time in a day, when terminal is open [min],
t_c – time of one cycle of transshipment [min],
β – work time efficiency rate.

Work efficiency rate gives information in how many percent of period of time, the machine is really loaded (at work). This number is usually presented as a work efficiency rate with values from 0 to 1. In practice β factor is in interval (0.6 – 0.8).

3. THE CASE

3.1. System introduction

The system consists of 4 cranes on container terminal. Terminal is open 12h a day. Transshipment abilities of each machine calculated according to formula (2) are presented in table 3. If provider can make about 184 movements per day, and there is access of 150 containers, than system can make 34 movements more that is required. Decrease of transshipment ability on 20% means, that system can not operate 37 containers. According to terminal owner it was assumed that minor impact, acceptable by terminal management, is decrease of transshipment ability on 45 containers.

Table 3. Cranes transshipment abilities

	Crane 1	Crane 2	Crane 3	Crane 4
t_c [min]	9	9	12	15
T 12h/day [min]	720	720	720	720
β	0.64	0.71	0.73	0.72
Trans-shipment ability [cont.]	51.2 = 51	56.8 = 56	43.8 = 43	34.56 = 34

That number was consistently use to assumed numbers as a scale of impact. The scale of impact is presented in table 4.

Table 4. Scale of impact

Type of impact	Number of not transshipped containers	Value
Minor	0-45	1
Major	46-90	2
Critical	91-135	3
Catastrophic	136-	4

One of the problems in particular example is assessing discover ability likelihood. According to formula (1), to calculate risk priory number, value of ability likelihood must be known. This factor also can be given from scale, which describes if each failure could be discovered before affect the system. There is no information about it in the case. Research materials don't include information about detecting probable failures. Consequently, the factor must be assumed.
Discover ability scale can be also found on 4 level's, where value of 1 mean easy recognize coming failure, and value of 4 absolutely inability of coming failure discover. The mean value of four level scale is 2.5. This value was taken to each calculation as discover likelihood.

Scale of impact has influence on thresholds of RPN acceptance. Thresholds are assumes:

1. operational ability lowered not more that 20% (transshipment ability greater that 147 containers),
2. operational ability lowered on 21 – 40 % (transshipment ability between 109 - 146 containers),
3. operational ability lowered on 41 – 60 % (transshipment ability between 108 - 72 containers),
4. operational ability lowered more than 61 % (transshipment ability less than 72 containers),.

Naturally it can calculate "how much costs 1%". Total operational ability is 184 containers/day, so 1% is 1.84. When one transshipment costs 24EUR (typical price for one transshipment), than 1% is 1.84x24EUR = 44.16EUR. Than thresholds from the financial point of view are:

1. total looses less than 20x44.16EUR = 883.2 ~ 883EUR,
2. total looses between 883 – 1760EUR,
3. total looses between 1760 – 2650EUR,
4. more than 2650 EUR.

Due to following calculations container terminal management estimated, that acceptable conditions are result of:

- probability of crane's failure 0.04,
- discover likelihood value of 2.5,
- money looses less than 883 EUR – decrease of transshipment ability less than 20%, consequently impact value of 1.

It makes, that acceptable level of RPN is 0.1.
As completely unacceptable RPN follows from

- probability of failure more than 0.1
- discover ability value of 2.5,
- impact value of 4.

Than unacceptable RPN is 1 or more.
According to presented assumption, taking into account system's conditions values of RPN can be calculated due to formula (1).
Table 5 shows numbers of RPN when only one machine breaks down.
As it can be seen the highest RPN value is prescribed to machine 3, where simple break down makes value of 0.2. Rest of machines makes RPN on half lower. Even if focus on the slowest machine – the 4th and the most efficient – the 2nd, both of them obtain RPN on level 0.1, whitch is still acceptable.
The simplest scenario is when only one machine breaks down. Examples of various break downs should be taken into account.

Table 5. RPN values when one crane is broken down

	Crane 1	Crane 2	Crane 3	Crane 4
Machine trans-shipment ability	51	56	43	34
Trans-shipment ability of system	133	128	141	150
Value of impact	2	2	2	1
Failure probability	0.02	0.02	0.04	0.04
RPN	0.1	0.1	0.2	0.1

3.2. Scenarios

All machines may break down one after another or at the same time. It was assumed that reparation of machines 1 and 2 last exactly 3 days, machines 3 and 4 – 2 days.
When there is assumption about time of repair than the total looses are result from combination of break downs and total time of reparation of each machine. But each day the risk will be different, because transhipment ability is different for each machine. So also sequence of break downs is important.

When two machines break down, there are 30 combinations of system delays. When three, then the number of reparation scenarios is 208.

In adverse situation 4 machines can stop one by one, and total time of reparation is 7 days or all machines stop at the same time. First situation is presented in table 6.

In case of the longest disturbs RPN value changes in following days. The highest value fall due to fifth day of disturbs. RPN value is 0.45, against 0.1 on 1st, 2nd and 7th day. Total looses caused by decrease of transshipment is almost 5700 EUR. It is important to point, that although four machines break down, RPN value during 4 days is on acceptable level. RPN is far from unacceptable value.

Other scenario is presented in table 7. Four machines break down day after another. The lowest transshipment ability is on 3rd day, only 34 containers. The highest impact value is also on 3rd day – 3 in scale. In this case RPN achieves higher value – 0.6. Total looses are 7320 EUR.

There is another scenario of break downs presented in table 8. In this example two faster cranes break down at the same time. In third day of reparation another crane stops. In this case value of impact is 3and lasts also 3 days. The greatest RPN is 0.6. Total looses are 7320 EUR.

Table 6. Model of the longest disturbs of system

Crane 1	51	51	51				
Crane 2			56	56	56		
Crane 3					43	43	
Crane 4						34	34
Day of reperation	1	2	3	4	5	6	7
Decrese of trans-shipment	51	51	107	56	99	77	34
Impact value	2	2	3	2	3	2	1
p-ty 1st	0.02	0.02	0.02	0	0	0	0
p-ty 2nd	0	0	0.02	0.02	0.02	0	0
p-ty 3rd	0	0	0	0	0.04	0.04	0
p-ty 4th	0	0	0	0	0	0.04	0.04
RPN	0.1	0.1	0.3	0.1	0.45	0.4	0.1
Looses [EUR]*	408	408	1752	528	1560	1032	0
total looses [EUR]*	408	816	2568	3096	4656	5688	5688

* - 24 EUR is assumed cost of one transshipment

Table 7. Scenario of 5 days of disturbs – first variant

Machine 1	51	51	51		
Machine 2		56	56	56	
Machine 3			43	43	
Machine 4				34	34
Day of reperation	1	2	3	4	5
Decrese of trans-shipment	51	107	150	133	34
Impact value	2	2	3	3	1
p-ty 1st	0.02	0.02	0.02	0	0
p-ty 2nd	0	0.02	0.02	0.02	0.02
p-ty 3rd	0	0	0.04	0.04	0.04
p-ty 4th	0	0	0	0.04	0.04
RPN	0.1	0.2	0.6	0.75	0.25
Looses [EUR]*	408	1752	2784	2376	0
total looses [EUR]*	408	2160	4944	7320	7320

* - 24 EUR is assumed cost of one transshipment

There is more difficult situation presented in table 9. Four machines are broken at the same time. In this case RPN is the biggest in compare to scenarios presented before – the lowest 0.8, the greatest 1.2. The screnario presents situation, when RPN crosses value of acceptance.During time of

disturbs ipact value achieves the highest number of 4. Calculated looses in two days are greater than in total time of disturbs in scenario from table 6. Total money loose is almost 9000 EUR.
Only the most harmful scenarios were presented in the paper. According presented basic calculations it can be seen, that failure of all machines in assumed conditions may occur different impact and brings various money looses. When all operating machines break down and time of disturbs is shorter and RPN and money looses are greater. In fact break down of all machines is hardly probable. Path of machine's break downs is presented in figure 1.

Table 8. Scenario of 5 days of disturbs – second variant

Machine 1	51	51	51		
Machine 2	56	56	56		
Machine 3			43	43	
Machine 4				34	34
Day of reperation	1	2	3	4	5
Decrese of trans-shipment	107	107	150	77	34
Impact value	3	3	3	2	1
p-ty 1st	0.02	0.02	0.02	0	0
p-ty 2nd	0.02	0.02	0.02	0.02	0.02
p-ty 3rd	0	0	0.04	0.04	0.04
p-ty 4th	0	0	0	0.04	0.04
RPN	0.3	0.3	0.6	0.5	0.25
Looses [EUR]*	1752	1752	2784	1032	0
total looses [EUR]*	1752	3504	6288	7320	7320

Probability that two machines break down at the same time is 0.0104. Probability of break down of three machines at the same time is 0.000576, so probability of damage of four machines at the same time can be practically overlooked.

4. CONCLUSIONS AND FUTURE WORK

In particular example of system the analysis shown that keeping long duration of disturbs makes risk priory number and consequences lower. In case of 7 days of disturbs the maximum RPN is 0.45, when disturbs last only 3 day, RPN 1.2. Lower impact is possible when less number of transshipment machines break down at the same time. According to this, financial consequences are also not so harmful. When all machines are out of order looses are on level of 8000 EUR, if they break down one after another looses are reduced on even 40%.
This article shows initial risk assessment in reduced data condition. Lack of data made, that the authors couldn't prepare full risk assessment. There is also no links to risk management, no indications to avoid risk situations in article. It can be said, that presented assessment is founded on boundary assumptions. A future objective is to clarify and define possible break downs of machines. The classification will be prepared for each machine.

Table 9. Variant of total break down of system

Machine 1	51	51	51
Machine 2	56	56	56
Machine 3		43	43
Machine 4	34	34	
Day of reperation	1	2	3
Decrese of transshipment	141	184	150
Impact value	4	4	4
p-ty 1st	0.02	0.02	0.02
p-ty 2nd	0.02	0.02	0.02
p-ty 3rd	0	0.04	0.04
p-ty 4th	0.04	0.04	0
RPN	0.8	1.2	0.8
Looses [EUR]*	2568	3600	2784
total looses [EUR]*	2568	6168	8952

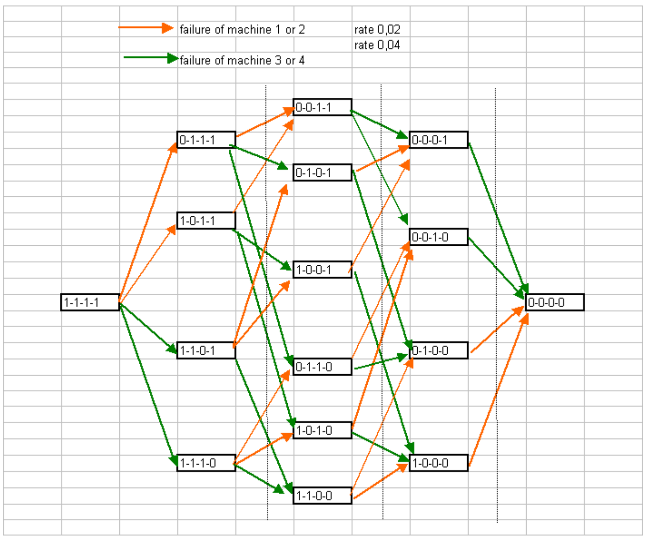

Figure 1. Paths of break downs

Other objective is to asses consequences and impact of disturbs. These recognize requires time of data collection and researches carried on real system. Cutting-edge result is to qualify failures, impact and occurrences probabilities and their function distributions. It should be taken into account, that machines working on terminal are exposing on processes like aging and different types of forces, conditions, ect. It is very important to recognize failure mechanisms, to solve one of the most important weaknesses of the article – lacks of information about value of likelihood of discovers ability. Future work is connected with detailing characteristics of both discover abilities in response to failures and description, more precise classification of failures which may occur. This goal enables to precise the approaches for discover ability and consequences of possible failure.

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