



**International
Standard**

ISO 19014-5

**Earth-moving machinery —
Functional safety —**

**Part 5:
Tables of performance levels**

Engins de terrassement — Sécurité fonctionnelle —

Partie 5: Tableaux des niveaux de performance

**First edition
2026-10**

Sample Document

get full document from standards.iteh.ai



COPYRIGHT PROTECTED DOCUMENT

© ISO 2026

All rights reserved.

This ISO publication is protected by copyright and is owned by ISO and/or its licensors.

The content of this ISO publication is provided under licence, not sold. Use is subject to the applicable licence terms issued by ISO, an ISO member body, or an authorized third-party distributor.

Except as required for implementation or expressly permitted by a separate licence, no part of this ISO publication may be reproduced, distributed, modified, used, or made available in any form or by any means – electronic or mechanical, including photocopying, scanning, recording, or posting on internal or external digital platforms.

Any use beyond the scope of the granted rights is prohibited and may result in legal action.

ISO copyright office
CP 401 • CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword	v
Introduction	vi
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 General	3
4.1 General principles	3
4.1.1 Safety requirements	3
4.2 Mapping of functions to a safety control systems (SCS)	3
4.3 Applicability of the listed machine performance levels required (MPL _r) to machines	3
4.4 Truncation	4
4.5 Effects of different technologies on machine control system safety analysis (MCSSA)	4
4.6 Supporting diagrams and data for Tables A.1 to AA.1 on machine performance levels	5
5 Additional machine control system safety analysis (MCSSA) scenario information	5
5.1 Traffic rate on road	5
5.2 Steering while roading	5
5.3 Slow / stop and machine speed	7
5.4 Work cycles	7
5.4.1 Dumper	7
5.4.2 Excavators	8
5.4.3 Wheel loaders	9
5.4.4 Skid steer loaders	10
5.5 Swing / slew of backhoe loaders and excavators	11
5.5.1 <i>H</i> variable for working beside traffic or co-workers	11
5.5.2 <i>P</i> values for swinging into traffic or co-workers	12
5.6 Maximum foreseeable <i>P</i> variables for typical areas on a site	13
5.7 Seat belts	13
5.8 Maintenance tasks	13
5.9 Backhoe arm out and wheeled excavator or backhoe stabilizer down while travelling or roading	13
6 Information for use	14
6.1 Information for use	14
Annex A (normative) Performance level tables for rigid frame dump trucks	15
Annex B (normative) Articulated-frame dumpers equal to or greater than 22 000 kg performance level tables	25
Annex C (normative) Articulated-frame dumpers equal to or less than 22 000 kg performance level tables	30
Annex D (normative) Crawler excavators less than 109 000 kg performance level tables	36
Annex E (normative) Wheeled excavators performance level tables	50
Annex F (normative) Backhoe loaders performance level tables	66
Annex G (normative) Large wheel loaders equal to or greater than 24 000 kg performance level tables	76
Annex H (normative) Medium, small and compact wheel loaders less than 24 000 kg performance level tables	87
Annex I (normative) Wheeled and crawler skid steer loaders performance level tables	95
Annex J (normative) Landfill compactor performance level tables	105
Annex K (normative) Roller performance level tables	110

Annex L (normative) Grader performance level tables	117
Annex M (normative) Crawler dozer performance level tables	128
Annex N (normative) Pipelayer performance level tables	136
Annex O (normative) Crawler loader performance level tables	143
Annex P (normative) Wheeled dozer performance level tables	151
Annex Q (normative) Scraper performance level tables	156
Annex R (normative) Crawler excavators equal to or greater than 109 000 kg performance level tables	162
Annex S (normative) Cable excavator (front shovel) performance level tables	170
Annex T (normative) Cable excavator (dragline) performance level tables	178
Annex U (normative) Compact trencher less than 4 500 kg performance level tables	184
Annex V (normative) Medium trencher greater than or equal to 4 500 kg and less than 18 000 kg performance level tables	200
Annex W (normative) Heavy trencher greater than or equal to 18 000 kg performance level tables	210
Annex X (normative) Telescopic wheel loader performance level tables	222
Annex Y (normative) Compact tool carrier performance level tables	224
Annex Z (normative) Powered attachments performance level tables	232
Annex AA (normative) Miscellaneous functions	236
Bibliography	242

Sample Document

get full document from standards.iteh.ai

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 2, *Safety, ergonomics and general requirements*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 151, *Construction equipment and building material machines - Safety*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This first edition cancels and replaces the first edition (ISO/TS 19014-5:2021), which has been technically revised.

The main changes are as follows:

- revision of machine control system safety analysis (MCSSA) discrepancies in [Annex A](#) through [Annex AA](#);
- addition of alternative control outcomes to all scenarios in [Annex A](#) through [Annex AA](#).

A list of all parts in the ISO 19014 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document addresses systems of all energy types used for functional safety in earth-moving machinery.

The structure of safety standards in the field of machinery is as follows.

Type-A standards (basic standards) give basic concepts, principles for design and general aspects that can be applied to machinery.

Type-B standards (generic safety standards) deal with one or more safety aspects, or one or more types of safeguards that can be used across a wide range of machinery.

- Type-B1 standards on particular safety aspects (e.g. safety distances, surface temperature, noise).
- Type-B2 standards on safeguards (e.g. two-hands controls, interlocking devices, pressure sensitive devices, guards).

Type-C standards (machinery safety standards) deal with detailed safety requirements for a particular machine or group of machines.

This document contains a list of machine performance level requirements (MPL_r) by function and earth-moving machinery type, determined through the process outlined in ISO 19014-1:2026.

This document is a type-C standard as stated in ISO 12100:2010.

This document is of relevance, in particular, for the following stakeholder groups representing market players with regard to machinery safety:

- machine manufacturers (small, medium and large enterprises);
- health and safety bodies (regulators, accident prevention organizations, market surveillance etc.).

Others can be affected by the level of machinery safety achieved in accordance with this document:

- machine users and employers (small, medium and large enterprises);
- machine users and employees (e.g. trade unions, organizations for people with special needs);
- service providers, e. g. for maintenance (small, medium and large enterprises);
- consumers (in case of machinery intended for use by consumers).

The above-mentioned stakeholder groups have been given the possibility to participate in the drafting process of this document.

The machinery concerned and the extent to which hazards or hazardous events are covered are indicated in the Scope of this document.

When requirements of this type-C standard differ from those in type-A or type-B standards, the requirements of this type-C standard take precedence over the requirements of the other standards for machines that have been designed and built according to the requirements of this type-C standard.

Earth-moving machinery — Functional safety —

Part 5: Tables of performance levels

1 Scope

This document specifies machine performance levels required (MPL_r) by common function and type for earth-moving machinery as defined in ISO 6165:2022. These MPL_r can then be mapped or applied to safety control systems (SCS) used to control or that affect the functions defined in [Tables A.1](#) to [AA.1](#).

To cover all the relevant safety requirements for the products in its scope, this document is used in combination with ISO 19014-1:2026, ISO 19014-2:2026, ISO 19014-3:2026, and ISO 19014-4:2026.

This document is not applicable to earth-moving machinery manufactured before the date of its publication.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6165:2022, *Earth-moving machinery — Basic types — Identification and vocabulary*

ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 19014-1:2026, *Earth-moving machinery — Functional safety — Part 1: Methodology to determine safety-related parts of the control system and performance requirements*

ISO 19014-2:2026, *Earth-moving machinery — Functional safety — Part 2: Design and evaluation of hardware and architecture requirements for safety-related parts of the control system*

ISO 19014-3:2026, *Earth-moving machinery — Functional safety — Part 3: Environmental performance and test requirements of electronic and electrical components used in safety-related parts of the control system*

ISO 19014-4:2026, *Earth-moving machinery — Functional safety — Part 4: Design and evaluation of software and data transmission for safety-related parts of the control system*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 6165:2022, ISO 12100:2010, ISO 19014-1:2026, ISO 19014-2:2026, ISO 19014-3:2026, ISO 19014-4:2026 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1 hold still

function that keeps the wheels or crawler tracks stationary, preventing the machine from moving

EXAMPLE An SCS that controls the hold still function is a park brake.

3.2

slow / stop

function which reduces or brings to zero the *machine speed* ([3.4](#))

EXAMPLE An SCS that controls the slow / stop function is a service brake.

3.3

machine speed

function which controls the rate of travel

EXAMPLE An SCS that controls the machine speed function is a throttle control, propel control or gear selection control.

3.4

engine speed

function which controls the rotational speed of the engine

EXAMPLE An SCS that controls the engine speed function is a throttle control.

3.5

machine direction

function which controls the longitudinal direction of the machine travel

EXAMPLE An SCS that controls the machine direction function is a forward, neutral, or reverse selection control.

3.6

steering

function which controls the lateral direction of machine travel

EXAMPLE An SCS that controls the steering function is a steering wheel or joystick.

3.7

swing / slew

function which controls the clockwise or anti-clockwise rotation of the upper structure of an excavator or digging linkage

EXAMPLE An SCS that controls the swing / slew function is a joystick.

3.8

roading

machines moving on a *road* ([3.12](#))

Note 1 to entry: A suitably designed machine and road homologation can be required.

3.9

travelling

machine moving from one point on a worksite to another without going on a *road* ([3.12](#))

EXAMPLE On a haul road, unimproved road or other thoroughfare on a site.

3.10

high wall

mine, quarry or other similar type wall associated with the worksite that a machine is working near

Note 1 to entry: It is considered machine abuse to operate machines near high walls without *berms* ([3.11](#)) in place.

3.11

berm

pile of dirt, rocks or other material intended to prevent a machine from passing into an area it is not intended to be operated in

Note 1 to entry: Some regions use different terms, e.g. bund, windrow.

3.12

road

public traffic area for use by automotive vehicles for travel or transportation

Note 1 to entry: Public traffic area does not include the sites of temporary road works (e.g. for repairs, maintenance, alterations, improvements, installations, or any other works to, above or under the road, including works to road equipment, lighting, barriers, walls etc) or roads not open to the public (e.g. on new housing and industrial developments), or on which public traffic is not permitted.

[SOURCE: ISO 17253:2014, 3.2]

3.13

operator presence system

system fitted to a machine that detects if an operator is positioned in an operator station and automatically takes a control system action based on that determination

4 General

4.1 General principles

4.1.1 Safety requirements

The MPL_r in this document are determined through the machine control system safety analysis (MCSSA) process outlined in ISO 19014-1:2026. A brief explanation of how the levels were derived, and the associated assumptions are contained herein.

The MPL_r provided in this document can be used as an alternative to performing an MCSSA for like machinery per ISO 19014-1:2026 and were derived using that process. The functions, applications and use cases used to determine these levels are based on generic limits of machine application for the machine type. If the MPL_r in this document are used, the MPL_r shall be in accordance with [Annexes A](#) to [AA](#) after following the review outlined in, [4.2](#), [4.3](#), [4.4](#), [4.5](#), [4.6](#), and [6.1](#).

Machinery shall conform to the safety requirements and risk reduction measures of ISO 19014-1:2026, ISO 19014-2:2026, and ISO 19014-4:2026. In addition, the machine shall be designed according to the principles of ISO 12100:2010 for relevant but not significant hazards which are not dealt with by this document.

All exposure calculations in this document are rounded up to the nearest whole number.

4.2 Mapping of functions to a safety control systems (SCS)

The MCSSA supporting these MPL_r were carried out by function rather than system. In practice, there can be several SCS that can fail in a way that is described by the failure type listed for any particular function. All SCS on a machine shall be reviewed to determine if any failure can cause a hazardous outcome associated with a failure type of the functions listed. For example, a brake system can be mapped from a slow / stop or hold still function, as can another system that interferes with the ability of the machine to brake at an appropriate rate to meet the ISO 3450:2011 stopping distance.

Measures beyond SCS can be applied to mitigate hazardous failures (e.g. mechanical lock outs, guards, administrative controls). In such a case, a MCSSA shall be completed to assess the MPL requirements of any residual risk associated with the SCS.

4.3 Applicability of the listed machine performance levels required (MPL_r) to machines

This document does not eliminate the need to do a risk assessment in accordance with ISO 12100:2010 as required by ISO 19014-1:2026.

The MCSSA supporting these MPL_r were carried out considering the limits of the machine type usage across the industry. Unique or limited applications or use cases can result in a different MPL_r for the machine

function. If a machine is specifically designed or modified for an application other than what is considered in in [Tables A.1](#) to [AA.1](#), an MCSSA shall be performed to determine if any functions require a different MPL_r .

While every effort was made to perform the supporting MCSSA in a general sense, there can be times where the assessment does not match a specific machine design; this is particularly relevant to the selection of the controllability factors (AC, AR, AW). The supporting MCSSA assume a common operator control layout around the operator station and no common cause failures. If there is a common cause failure between the SCS mapped to the function being assessed and the MCS or SCS being used for controllability, the MPL_r in the table is not applicable (e.g. two systems sharing a control element or a control unit). Likewise, where the control used to activate the avoidance on a particular design does not align with the AR score in the table, the table is not applicable. For example, a brake is assumed to be on the floor immediately next to a throttle or propel pedal, if the brake is controlled with a lever the AR score changes from an AR3 to an AR2, a size difference within a machine type that results in a change in severity. In this case, the machine designer shall perform a MCSSA according to ISO 19014-1:2026 to consider these facts. If the remaining data used in the assessment are applicable to the machine being assessed, the data can be used in that MCSSA and the non-applicable score changed. It is the responsibility of the machine designer to review and assess whether the scoring used in the MCSSA are applicable to their machine.

4.4 Truncation

Due to the large number of combinations of inputs, the MCSSA supporting [Tables A.1](#) to [AA.1](#) in [Annexes A](#) to [AA](#) are focused on scenarios that clearly dominate the MPL_r (scenario that drives the highest MPL_r for the same function). Where a dominant scenario was not clearly identifiable, multiple scenarios were assessed to find the scenario(s) that led to highest MPL_r . Non-dominant scenarios were truncated from MCSSA. Part of the truncation process included equating scenarios to be the same, no worse, or less than scenarios already assessed; where this is the case, detail is not provided in in [Tables A.1](#) to [AA.1](#) for the sake of legibility.

Only the scenarios that led to the highest MPL_r are included in in [Tables A.1](#) to [AA.1](#) unless a different failure type with a different hazardous outcome existed, in which case the scenarios with the highest MPL_r for all those failure types are included in in [Tables A.1](#) to [AA.1](#). Additional explanation in this space can be found in the function-dominant failure type matrices. When more than one scenario of the same failure type led to the highest MPL_r , all such scenarios have been included.

4.5 Effects of different technologies on machine control system safety analysis (MCSSA)

In most cases, the MPL_r in this document apply regardless of the technology used in the SCS; however, there are times when this is not the case, e.g. mechanical drivetrains versus electric or hydrostatic drivetrains.

When considering an alternative SCS technology (e.g. electric or hydrostatic), the assessments in in [Tables A.1](#) to [AA.1](#) shall be reviewed. Any assumptions or assessments that are invalidated by the introduction of a different technology shall be reassessed according to [4.3](#). Additionally, the functionality of these systems can cause MPL_r to be mapped to different SCS.

NOTE Not all machines were assumed to have mechanical drivetrains; dozers, excavators, skid steer loaders and rollers were assumed to have a hydrostatic drivetrain.

The following are some situations where technology differences can affect MPL_r :

- there are changes in response to machine speed, propel, brake or direction commands (e.g. compared to mechanical drivetrains, some electric and hydrostatic drivetrains apply functions differently);
- retarders have possibly not considered a safety function on a mechanical drive system but can possibly be the primary means of slowing the machine in an electric drive machine;
- controllability assessments can be different due to common components and other common cause failure considerations;
- there are additional safety functions associated with new hazards created by using a different energy type;

- engine speed can become decoupled from other systems (e.g. engine speed no longer has a direct effect on machine speed);
- there are changes in SCS performance due to system stored energy level (e.g. output performance varying due to battery charge).

4.6 Supporting diagrams and data for [Tables A.1](#) to [AA.1](#) on machine performance levels

Scenarios that dominated the MPL_r score in the MCSSA are listed in [Tables A.1](#) to [AA.1](#) and a brief explanation is provided in [Annexes A](#) to [AA](#). Where more detail is deemed necessary, additional diagrams and information are provided in [Clause 5](#).

5 Additional machine control system safety analysis (MCSSA) scenario information

5.1 Traffic rate on road

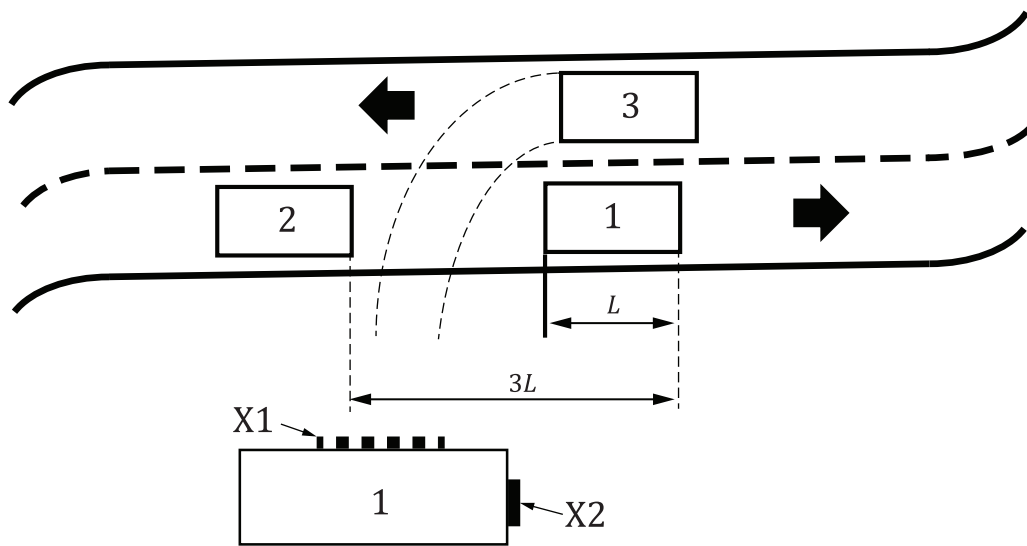
The exposure of bystanders to an uncommanded steering event is largely dictated by the distance between vehicles. Earth-moving machinery cannot be designed to mitigate situations where illegal or unsafe actions are committed by other road users. The MCSSA considered traffic rates with two car lengths distance between cars as the norm (less distance between cars being commonly considered unsafe across the world).

While traffic can momentarily exceed this rate, the P value shall account for the machine lifecycle. Traffic rates with less spacing do not occur continually over the entire machine lifecycle; this makes the traffic rate of one car every three car lengths conservative (see [Figure 1](#)).

NOTE This document refers to "cars", "light vehicles", and "vehicles". "Car" is typically used in the context of a roading use case, "light vehicles" is typically used in the context of mining applications for vehicles that weigh less than 3 500 kg, and "vehicles" is used generically.

5.2 Steering while roading

All failure types for steering create the same hazard, depending on whether the desired path is straight or curved (i.e. uncommanded steering on a straight road has the same hazardous outcome as failure to steer on a curved road), wherein the machine will leave the intended travel lane.

**Key**

X1	zone 1
X2	zone 2
1	vehicle 1
2	vehicle 2
3	machine
L	length

Figure 1 — Steering hazard zone for on road travel

Earth-moving machinery can cause an S3 injury if there is contact between the machine and a vehicle. The proportion of the vehicle that results in an S3 injury is quantified below.

- The passenger cabin of the vehicle (i.e. machine contacts the side of the vehicle); this equates to approximately $\frac{1}{2}$ the car length (see dotted line on vehicle in [Figure 1](#), X1).
- The front of the vehicle (i.e. the vehicle drove straight into the side of machine due to the machine steering in front of the vehicle); this equates to approximately $\frac{1}{2}$ the width of the vehicle (see solid line on vehicle in [Figure 1](#), X2). Contact on the corners of the vehicle is less likely to cause an S3 injury.
- The ratio of length to width varies by vehicle; however, an estimation of an average ratio of 1:3,5 has been used.

When roading there is a risk of contacting a vehicle, a bystander or an object on the other side of the machine; this is less than the traffic rate. A *P* variable of 10 % has been used.

Based on these limiting factors, the H and P variables for machines roading can be shown to be no higher than:

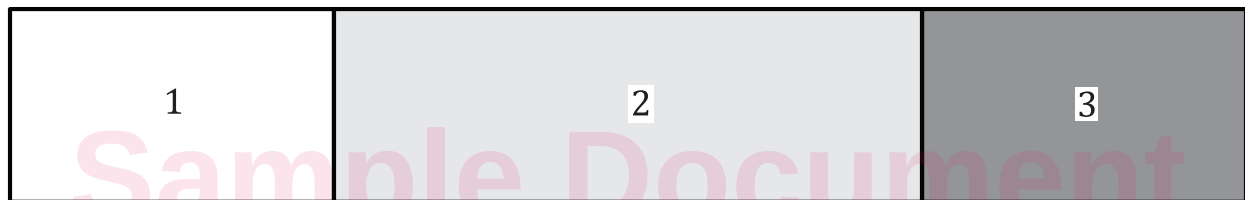
$$H_R P_R + H_L P_L = H_R P_R + H_L \left(T_R \left(\frac{L}{2} + \frac{W}{2} \right) \right) = (50 \% \times 10 \%) + \left(50 \% \left(\frac{1}{3} \left(\frac{1}{2} + \frac{1}{7} \right) \right) \right) = 16 \%$$

where

L	1 car length;
H_R	H variable for right hand uncommanded steering = 50 % (if the machine steers without command, half the failures steer the machine to the left, the other half to the right);
P_R	P variable for the right-hand uncommanded steering = 10 %;
H_L	H variable for left hand uncommanded steering = 50 %;
P_L	P variable for the left-hand uncommanded steering;
T_R	traffic rate per 5,1 = 1 / 3;
W	$L / 3,5$.

5.3 Slow / stop and machine speed

The hazard zone for a brake failure is the area beyond the machine's normal stopping distance. An uncommanded increase in machine speed has a similar hazard zone (see [Figure 2](#)).



Key

- 1 machine
- 2 intended stopping distance
- 3 increased stopping distance

Figure 2 — Slow / stop and machine speed hazard zone

5.4 Work cycles

This section contains descriptions of common work cycles for the various machine types used in the MCSSA evaluations to determine MPL_{r} .

The values used in the percentage breakdown in [Tables 1](#) through [6](#) represent the worst credible scenario for the failure type being assessed as determined in the MCSSA.

[Figures 3](#) through [6](#) represent work cycles as considered in the MCSSA.

5.4.1 Dumper

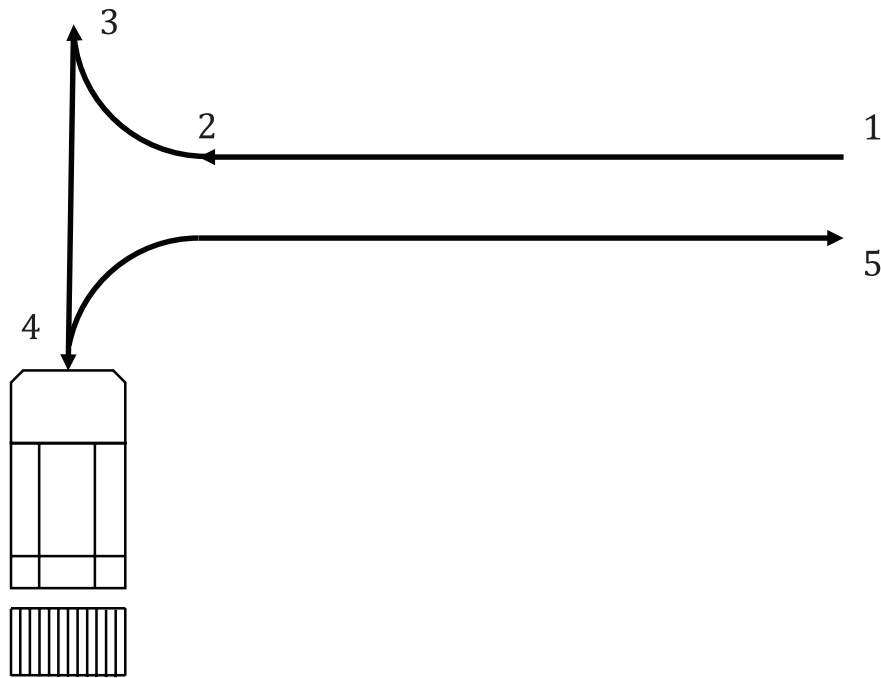


Figure 3 — Truck unloading and queuing cycle

Table 1 — Truck unloading and queuing cycle

Unloading and queuing long cycle ^a		
1 – 2 (slow forward speed, high traffic)		50 %
2 – 3 (slow forward speed, low traffic)		8 %
3 – 4 (slow reverse speed, low traffic)		17 %
Dump		17 %
4 – 5 (medium forward speed, high traffic)		8 %

^a See [Figure 3](#).

5.4.2 Excavators

Table 2 — Excavator object handling work cycle

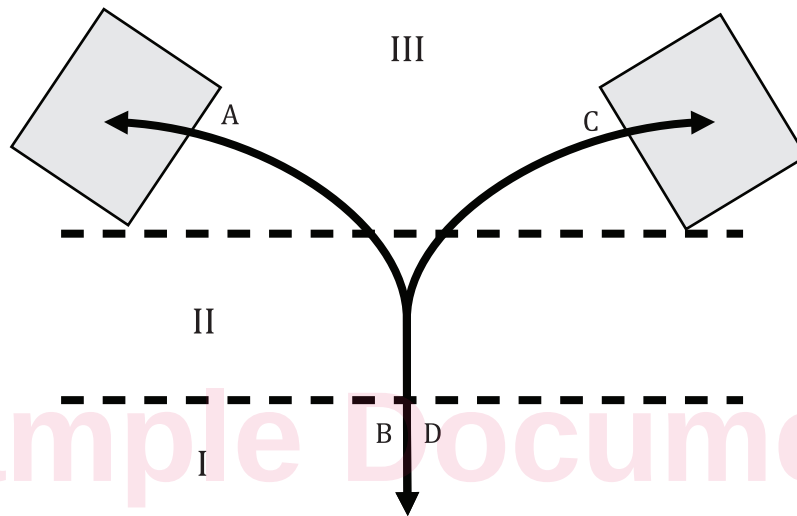
Object handling cycle		
Step	Time (s)	% cycle
① lower / lash	45	21,3 %
② lift	30	14,2 %
③ swing	15	7,1 %
④ lower	60	28,4 %
⑤ unlash	45	21,3 %
⑥ lift	4	1,9 %
⑦ swing	2	0,9 %
⑧ travel	10	4,7 %
total cycle time	211	100,0 %

Table 3 — Excavator trenching work cycle

Trenching use case	
dig (includes some lift)	35 %
swing CCW	25 %
dump	10 %
swing CW	25 %
travel	5 %

5.4.3 Wheel loaders

5.4.3.1 Wheel loader bucket work


Key

A	loading
C	unloading
B and D	travel during cycle
I	zone with offsite traffic $P = 50\%$
II	zone with site traffic $P = 20\%$
III	zone where it is considered machine abuse, between machine and destination $P = 0\%$

Figure 4 — Wheel loader bucket work cycle**Table 4 — Wheel loader bucket work cycle**

Wheel loader bucket work cycle	
Segments A, C	30 %
Segments B, D	20 %