



International Journal of Linguistics & Computing Research

Computational Formulation and mapping of Pāṇini's *Kāraka-Vibhakti* for Machine Translation

Sudhir Kumar Mishra

Pune

sudhirkumarmishra@gmail.com

Abstract—The goal of the paper is to present mapping of Pāṇini's *kāraka* and *vibhakti*, and Computational formulation for implementation of *kāraka* and *vibhakti* for any larger NLP system based on Sanskrit Language. Pāṇini discusses *kāraka* [Aṣṭ 1.4.23- Aṣṭ 1.4.54], *vibhakti* [Aṣṭ 2.3.1- Aṣṭ 2.3.73] and *karmapravacanīya* [Aṣṭ 1.4.82- Aṣṭ 1.4.97] in different chapters of Aṣṭādhyāyī. *Kāra*kas are not compulsory for each *pada* in a sentence, but *vibhaktis* are. Pāṇini mentioned two types of rules as *sāmānya* and *apavāda*. *Sāmānya* rule works in all section of Aṣṭādhyāyī, keeping in mind of *tripādi* and *savāsaptādhyāyī*. *Apavāda* rule works only a specific portion of Aṣṭādhyāyī. There is no any default mapping of *kāraka* and *vibhakti* as we assumed because more than one *vibhaktis* are used in each *kāraka* in specific conditions. This paper describes Pāṇini's *kāraka* and *vibhakti* including *vārtika* for mapping each *kāraka* to all possible *vibhaktis* and logical presentation of every *sūtra* for computing.

Keywords: *aṣṭādhyāyī* = A/ Aṣṭ, *vārtika* = vā, rule no = rle #, condition = con, result = res, formal statement = fs, pseudo code = pc, verbal base = vb, pre-verb = pv, nominal stem = ns.

I. INTRODUCTION

There are six types of *kāra*kas as – *kartā* (Agent), *karma* (accusative, object), *karaṇa* (Instrumental), *saṃpradāna* (dative, Recipient), *apādāna* (Ablative) and *adhikaraṇa* (Locative). Pāṇini links directly the *kāraka* relations to case endings or post nominal suffixes. According to Pāṇini, case endings recur to express such *kāraka* relations as *kartṛ* etc and they are known as *prathamā* (nominative endings) etc. Pāṇini assign six different case endings for expressing the six types of *kāraka* relations. Pāṇini assigns one more type of case ending (which is not a *kāraka*) as *sambandha* (genitive). The Genitive case is not related to the verb, it is in the sense of 'of' or 'possessed of' so this is not *kāraka*. It generally expresses the relation of a noun to another. The genitive must not be constructed with a verb. In these seven types of case endings, there are 21 sup *vibhaktis*.

Pāṇini discusses the entire gamut of *kāraka-vibhakti* relations in three sections of Aṣṭādhyāyī as follows [1]–

- *kāraka sūtra* (Aṣṭ.-1.4.23 to Aṣṭ.-1.4.55)
- *vibhakti sūtra* (Aṣṭ.-2.3.1 to Aṣṭ.-2.3.73)
- *karmapravacanīya* (Aṣṭ.-1.4.82 to Aṣṭ.-1.4.97)

Pāṇini discusses *kāraka* in 33 *kāraka-sūtras* in the following sequence- *apādāna*, *saṃpradāna*, *karaṇa*, *adhikaraṇa*, *karman* and *kartṛ*. *Kāraka* only express by the *vibhaktis* but this is not necessary that every *vibhakti* express to *kāraka*. Pāṇini uses *vibhakti* in two manners as follows–

- assign *kāraka samjñā* then mark it by any *vibhakti*.
- directly use the *vibhakti* in any condition.

Under the *kāra*kas Pāṇini has discussed only those *sūtras* which are marking the *kāraka samjñā*. And in *vibhakti* section, Pāṇini has discussed two types of *sūtra* as follows–

- which are marking *vibhaktis* to any *samjñā* like different *kāraka*, *karmapravacanīya* etc.
- which are assigning directly *vibhaktis* in any specific syntactic or semantic condition.

In the *karmapravacanīya* part, Pāṇini has defined those *sūtras* which are making the *karmapravacanīya samjñā* of *nipāta*. In the above three sections those *sūtras* which are making *kāraka*, *vibhakti* and *karmapravacanīya samjñā*, are

discussed. But in this section only those *sūtras* are discussed which are marking any *vibhakti* to any *kāraka*.

II. FORMULATION AND MAPPING OF *KĀRAKA-VIBHAKTI(S)*

kāraka-vibhakti mapping and formulation of the mapped *sūtras* are as follows in the sequence of the *karṭṛ*, *karman*, *karaṇa*, *sampradāna*, *apādāna* and *adhikaraṇa* *kāraka*. One optional *kāraka sūtra* and its *vibhakti* also discussed at the end of the mapping.

A. FORMULATION AND MAPPING OF *KARṬṚ KĀRAKA* WITH *VIBHAKTI(S)*

Normally *prathamā vibhakti* is used in *karṭṛ kāraka* but Pāṇini did not make directly any rule for this. Pāṇini says only *prathamā* and *ṭṛtīyā vibhaktis* are used in *karṭṛ* and *karaṇa kāraka* (*karṭṛkaraṇayoṣṭṛtīyā* -Aṣṭ.-2.3.18). These rules are coming in the domain of the *anabhihite* (un-expressed). If they are expressed by some other means then *prathamā vibhakti* is used in every *kāraka*. The *prathamā vibhakti* (Shastri Charu Deva, 1991) is employed after a noun expressive of the *karṭṛ*, when the *karṭṛ* is in agreement with the verb. According to Charu Deva Shastri “what is conceived as independent in the accomplishment of the action is also the agent and not only what is actually so, it follows that when the action of the agent is not intended to be conveyed and instead *karaṇa* and others are represented as the agent, the so-called agent, if in agreement with the verb, would take the *prathamā vibhakti*”. [2] Pāṇini assigns *ṭṛtīyā* and *ṣaṣṭhī vibhakti* in *karṭṛ kāraka*. Pāṇini makes *karman samjñā* of *karṭṛ kāraka* also in two *sūtras* as Aṣṭ.-1.4.52-53. Therefore *dviṭīyā vibhakti* is also used in *karṭṛ kāraka*. Pāṇini assigns *ṣaṣṭhī vibhakti* to *karṭṛ kāraka* in following one *sūtra* as-

rle #	A 2.3.68
rule	<i>adhikaraṇavācīnaśca</i>
con	if ns in conjunction with suffix <i>cta</i> -ending word and denotes <i>adhikaraṇa</i>
res	<i>karṭṛ</i> → <i>ṣaṣṭhī</i>
fs	{ <i>ṣaṣṭhī</i> (<i>karṭṛ</i> [<i>adhikaraṇavācī cta</i> <i>pratyayānta</i>]) }
pc	check <i>cta</i> -ending word which denotes <i>adhikaraṇa</i> if true then check <i>karṭṛ</i> assign <i>ṣaṣṭhī</i>

Pāṇini assigns *ṭṛtīyā* and *ṣaṣṭhī vibhakti* to *karṭṛ kāraka* in one *sūtra* as follows-

rle #	A 2.3.71
rule	<i>kṛtyānām kartari vā</i>
con	if ns used in the sense of <i>karṭṛ</i> with construction of words ending in suffix <i>kṛtya</i>
res	<i>karṭṛ</i> → <i>ṭṛtīyā</i> , <i>ṣaṣṭhī</i>
fs	{ <i>ṭṛtīyā</i> , <i>ṣaṣṭhī</i> (<i>karṭṛ</i> [<i>kṛtya-pratyayānta</i>]) }
pc	check <i>kṛtya-pratyayānta</i> if true then check <i>karṭṛ</i> assign <i>ṭṛtīyā</i> or <i>ṣaṣṭhī</i>

Kātyāyana adds one *vārtika* in which *ṭṛtīyā* and *ṣaṣṭhī vibhakti* are used in *karṭṛ kāraka* as follows-

rle #	<i>vā</i> of A 2.3.66
rule	<i>śeṣe vibhāṣā</i>
con	if ns used with word ending in the suffix <i>aka</i> and a ordained under the section <i>striyām ktin</i> (Aṣṭ.- 3.3.94) are excluded
res	<i>karṭṛ</i> → <i>ṭṛtīyā</i> , <i>ṣaṣṭhī</i>
fs	{ <i>ṭṛtīyā</i> , <i>ṣaṣṭhī</i> (<i>karṭṛ</i> [<i>aka</i> , <i>a</i> <i>pratyayānta</i> <i>rahita</i> <i>strīlingavācī kṛdanta</i>]) }
pc	check <i>kṛtya-pratyayānta</i> if true then check <i>karṭṛ</i> assign <i>ṭṛtīyā</i> or <i>ṣaṣṭhī</i>

Pāṇini assigns *ṣaṣṭhī vibhakti* to *karṭṛ* and *karman* both in two *sūtras* as follows-

rle #	A 2.3.67
rule	<i>ktasya ca vartamāne</i>
con	if ns used in the sense of <i>karṭṛ</i> or <i>karman</i> when a word ending in the suffix <i>cta</i> signifying <i>vartamāna</i>
res	<i>karṭṛ</i> , <i>karman</i> → <i>ṣaṣṭhī</i>
fs	{ <i>ṣaṣṭhī</i> (<i>karṭṛ</i> , <i>karman</i> [<i>vartamānakālīka cta</i> <i>pratyayānta</i>]) }
pc	check <i>kṛtya-pratyayānta</i> if true then check <i>karṭṛ</i> assign <i>ṣaṣṭhī</i>

rle #	A 2.3.65
rule	<i>kṛṭkarmanoh kṛti</i>
con	if ns in the sense of <i>karṭṛ</i> or <i>karman</i> used construction with a word ending in a suffix <i>kṛt</i>
res	<i>karṭṛ</i> , <i>karman</i> → <i>ṣaṣṭhī</i>
fs	{ <i>ṣaṣṭhī</i> (<i>karṭṛ</i> , <i>karman</i> [<i>kṛt</i> <i>pratyayānta</i>]) }
pc	check <i>kṛt</i> <i>pratyayānta</i> if true then check <i>karṭṛ</i> or <i>karman</i> assign <i>ṣaṣṭhī</i>

Kātyāyana adds one *vārtika* in which *ṣaṣṭhī vibhakti* used in *karṭṛ kāraka* as follows-

rle #	<i>vā</i> of A 2.3.66
rule	<i>strīpratyayayorakākārayornāyam niyamah</i>
con	if ns used with word ending in the suffix <i>aka</i> and a ordained under the section <i>striyām ktin</i> (Aṣṭ.- 3.3.94)
res	<i>karṭṛ</i> , <i>karman</i> → <i>ṣaṣṭhī</i>
fs	{ <i>ṣaṣṭhī</i> (<i>karṭṛ</i> , <i>karman</i> [<i>aka</i> , <i>a</i> <i>pratyayānta</i> <i>strīlingavācī kṛdanta</i>]) }
pc	check <i>aka</i> , <i>a</i> <i>pratyayānta</i> <i>strīlingavācī kṛdanta</i> if true then check <i>karṭṛ</i> or <i>karman</i> assign <i>ṣaṣṭhī</i>

Pāṇini negates the uses of *ṣaṣṭhī vibhakti* in *karṭṛ* or *karman kāraka* in specific conditions. Therefore, concerned *vibhaktis*

(*prathamā*, *dvitīyā*, *trītiyā*) are used in that condition. The formulation is as follows-

rle #	A 2.3.69
rule	<i>na lokāvayaniṣṭhākhalarthatrñām</i>
con	if ns used in the sense of <i>karṭṛ</i> or <i>karman</i> construction with <i>śatṛ</i> , <i>śānac</i> , <i>kānac</i> , <i>kvasu</i> , <i>kī</i> , <i>kin</i> , <i>u</i> , <i>uka</i> , <i>avyaya</i> , <i>kta</i> , <i>ktavatu</i> , <i>khalartha</i> and <i>trñ</i>
res	<i>ṣaṣṭhī niṣedha</i>
fs	{ <i>ṣaṣṭhī niṣedha</i> (<i>karṭṛ</i> , <i>karman</i> [<i>śatṛ</i> , <i>śānac</i> , <i>kānac</i> , <i>kvasu</i> , <i>kī</i> , <i>kin</i> , <i>u</i> , <i>uka</i> , <i>avyaya</i> , <i>kta</i> , <i>ktavatu</i> , <i>khalartha</i> or <i>trñ</i>]) }
pc	check above counted suffix ending if true then check <i>karṭṛ</i> or <i>karman</i> negates <i>ṣaṣṭhī</i>

Pāṇini assigns *trītiyā vibhakti* in *karṭṛ* and *karaṇa* both *kāraka* as follows-

rle #	A 2.3.18
rule	<i>karṭṛkaraṇayostrītiyā</i>
con	if <i>karṭṛ</i> (agent) or <i>karaṇa</i> (the most effective means) used and they are not expressed otherwise.
res	<i>karṭṛ</i> , <i>karaṇa</i> → <i>trītiyā</i>
fs	{ <i>trītiyā</i> ([<i>karṭṛ</i> , <i>karaṇa</i>]) }
pc	check <i>karṭṛ</i> , <i>karaṇa</i> assign <i>trītiyā</i>

B. FORMULATION AND MAPPING OF KARMAN KĀRAKA WITH VIBHAKTI(S)

Pāṇini uses all *vibhaktis* in the *karman kāraka* except *saptamī vibhakti* but this place was filled up by Kātyāyana. So after addition of Kātyāyana's *vārtika* on Aṣṭ.- 2.3.36, all *vibhaktis* are used in *karman kāraka*. [3] Pāṇini assign *dvitīyā vibhakti* in *karman kāraka* in two *sūtras* as follows-

rle #	A 2.3.2
rule	<i>karmanī dvitīyā</i>
con	if <i>karman</i> (object) is used and not expressed otherwise
res	<i>karman</i> → <i>dvitīyā</i>
fs	{ <i>dvitīyā</i> ([<i>karman</i>]) }
pc	check <i>karman</i> assign <i>dvitīyā</i>

Pāṇini negates the uses of *ṣaṣṭhī vibhakti* in *karman kāraka* in specific conditions. Therefore, concerned *vibhakti* (*dvitīyā*) is used in that condition. The formulation is as follows-

rle #	A 2.3.70
rule	<i>akenorbhaviṣyadādhamarṇyaṇi</i>
con	if words ending in the affixes <i>aka</i> or <i>in</i> and conveying the sense of <i>bhaviṣyat</i> or <i>bhaviṣyat</i> in addition to <i>ādhamarṇya</i> are used
res	<i>ṣaṣṭhī niṣedha</i>
fs	{ <i>ṣaṣṭhī niṣedha</i> (<i>karman</i> [<i>bhaviṣyatkālīka</i> <i>ak</i> <i>pratyayānta</i> , <i>bhaviṣyatkālīka</i> + <i>ādhamarṇya</i> in

	<i>pratyayānta</i>]) }
pc	check <i>karman</i> negates <i>dvitīyā</i>

Pāṇini assigns *dvitīyā* and *trītiyā vibhaktia* in *karman kāraka* as follows-

rle #	A 2.3.22
rule	<i>saṃjñō 'nyatarasyām karmaṇi</i>
con	if vb <i>jñā</i> use with pre-verb <i>saṃ</i>
res	<i>karman</i> → <i>dvitīyā</i> , <i>trītiyā</i>
fs	{ <i>dvitīyā</i> , <i>trītiyā</i> (<i>karman</i> [<i>pv</i> <i>saṃ</i> + <i>vb</i> <i>jñā</i>]) }
pc	check vb <i>jñā</i> with <i>pv</i> <i>saṃ</i> if true then check <i>karman</i> negates <i>dvitīyā</i> or <i>trītiyā</i>

Pāṇini assigns *caturthī vibhakti* in *karman kāraka* as follows-

rle #	A 2.3.14
rule	<i>kriyārthopapadasya ca karmaṇi sthāninaḥ</i>
con	if <i>kriyārthakriyā</i> is used with <i>aprayujyamāna tumun</i> <i>pratyayānta</i>
res	<i>karman</i> of <i>tumun</i> <i>pratyayānta</i> → <i>caturthī</i>
fs	<i>caturthī</i> { <i>karman</i> (<i>aprayujyamāna tumun</i> <i>pratyayānta</i> [<i>kriyārthakriyā</i>]) }
pc	check <i>kriyārthakriyā</i> if true then check <i>karman</i> of <i>tumun</i> <i>pratyayānta</i> assign <i>caturthī</i>

rle #	A 2.3.15
rule	<i>tumarthācca bhāvavacanāt</i>
con	if ns terminates in the affix that denotes action and is synonymous with <i>tumun</i>
res	<i>karman</i> → <i>caturthī</i>
fs	{ <i>caturthī</i> (<i>karman</i> [<i>tumartha</i> <i>bhāvavacana</i>]) }
pc	check <i>tumartha</i> if true then check <i>karman</i> assign <i>caturthī</i>

rle #	A 2.3.16
rule	<i>namaḥsvastisvāhāsvadhā'lamvaṣaḍyogācca</i>
con	if ns with <i>namas</i> , <i>svasti</i> , <i>svāhā</i> , <i>svadhā</i> , <i>alam</i> or <i>vaṣaṭ</i>
res	<i>karman</i> → <i>caturthī</i>
fs	{ <i>caturthī</i> (<i>karman</i> [<i>namas</i> , <i>svasti</i> , <i>svāhā</i> , <i>svadhā</i> , <i>alam</i> or <i>vaṣaṭ</i>]) }
pc	check words <i>namas</i> , <i>svasti</i> , <i>svāhā</i> , <i>svadhā</i> , <i>alam</i> or <i>vaṣaṭ</i> if true then check <i>karman</i> assign <i>caturthī</i>

Pāṇini assigns *dvitīyā* and *caturthī vibhakti* optionally in *karman kāraka* as follows-

rle #	A 2.3.12
rule	<i>gatyarthakarmaṇi dvitīyācaturthyau</i>

	<i>ceṣṭāyāmanadhvani</i>
con	if vb are having the sense of <i>gati</i> provided that the <i>gati</i> is <i>ceṣṭā</i> except the <i>karman</i> is not <i>adhvan</i>
res	<i>karman</i> → <i>dviṭīyā, caturthī</i>
fs	<i>dviṭīyā, caturthī</i> { <i>karman</i> (<i>gatyarthaka</i> vb [<i>ceṣṭā</i> + <i>adhvana</i>]) }
pc	check <i>gatyarthaka</i> vb with <i>ceṣṭā</i> + <i>adhvana</i> if true then check <i>karman</i> assign <i>dviṭīyā</i> or <i>caturthī</i>
rle #	A 2.3.17
rule	<i>manyakarmaṇyanādare vibhāṣā'prāṇīṣu</i>
con	if <i>karman</i> of bv <i>man</i> provided that it does not denote <i>prāṇin</i> and disrespect is expressed
res	<i>karman</i> → <i>dviṭīyā, caturthī</i>
fs	<i>dviṭīyā, caturthī</i> { <i>karman</i> (vb <i>man</i> [<i>anādara</i> + <i>aprāṇi</i>]) }
pc	check vb <i>man</i> with <i>ceṣṭā</i> + <i>adhvana</i> if true then check <i>karman</i> if true then check <i>anādara</i> + <i>aprāṇi</i> assign <i>dviṭīyā</i> or <i>caturthī</i>

Kātyāyana [4] modified the above rule and explained the word *aprāṇīṣu* as follows-

rle #	vā of A 2.3.17
rule	<i>naukākāṇnaśukaśrgālavarjeṣviti vācyam</i>
con	<i>aprāṇīṣu</i> is replaced by <i>nau, kāka, anna, śuka</i> and <i>śrgāla</i> words in above <i>sūtra</i>
res	<i>karman</i> → <i>dviṭīyā, caturthī</i>
fs	<i>dviṭīyā, caturthī</i> { <i>karman</i> (vb <i>man</i> [<i>anādara</i> + <i>aprāṇi</i> except <i>nau, kāka, anna, śuka</i> and <i>śrgāla</i>]) }
pc	check vb <i>man</i> with <i>ceṣṭā</i> + <i>adhvana</i> if true then check <i>karman</i> if true then check <i>anādara</i> + <i>aprāṇi</i> except <i>nau, kāka, anna, śuka</i> and <i>śrgāla</i> assign <i>dviṭīyā</i> or <i>caturthī</i>

Pāṇini assigns *pañcamī vibhakti* in *karman kāraka* in next *sūtra* as follows-

rle #	A 2.3.10
rule	<i>pañcamyapāṇparibhiḥ</i>
con	if <i>karmapravacanīya apa, ān</i> or <i>pari</i> are used
res	<i>karman</i> → <i>pañcamī</i>
fs	{ <i>pañcamī</i> (<i>karman</i> [<i>karmapravacanīya apa, ān</i> or <i>pari</i>]) }
pc	check <i>karmapravacanīya apa, ān</i> or <i>pari</i> if true then check <i>karman</i> assign <i>pañcamī</i>

Kātyāyana adds two *vārtikas* which are assigned *pañcamī vibhakti* in *karman* and *adhikaraṇa kāraka* optionally as follows-

rle #	vā of A 1.4.31
rule	<i>lyablope karmaṇyadhikaraṇe ca</i>
con	if <i>lyap</i> or <i>ktvā</i> ending vb are dropped

res	<i>karman, adhikaraṇa</i> → <i>pañcamī</i>
fs	{ <i>pañcamī</i> (<i>karman, adhikaraṇa</i> [<i>lyab, ktvā pratyayānta kriyā lopa</i>]) }
pc	check <i>lyab, ktvā pratyayānta kriyā lopa</i> if true then check <i>karman</i> or <i>adhikaraṇa</i> assign <i>pañcamī</i>
rle #	vā of A 1.4.31
rule	<i>gamyamānā'pi kriyā kārakavibhaktīnām nimittam</i>
con	If the sense of vb are though understood
res	<i>karman, adhikaraṇa</i> → <i>pañcamī</i>
fs	{ <i>pañcamī</i> (<i>karman, adhikaraṇa</i> [<i>lyabant kriyā gamyamāna</i>]) }
pc	check <i>gamyamāna kriyā</i> if true then check <i>karman</i> or <i>adhikaraṇa</i> assign <i>pañcamī</i>

Pāṇini assigns *ṣaṣṭhī vibhakti* in *karman kāraka* in next eight *sūtras* as follows-

rle #	A 2.3.52
rule	<i>adhīgarthadayeṣām karmaṇi</i>
con	if vb conveying the sense of <i>adhīk</i> (to remember), <i>day</i> and <i>īś</i> used
res	<i>karman</i> → <i>ṣaṣṭhī</i>
fs	{ <i>ṣaṣṭhī</i> (<i>karman</i> [<i>smaraṇārthaka adhīk</i> vb, <i>day, īś</i> vb]) }
pc	check <i>smaraṇārthaka adhīk</i> vb, <i>day, īś</i> vb if true then check <i>karman</i> assign <i>ṣaṣṭhī</i>
rle #	A 2.3.53
rule	<i>kṛñh pratiyatne</i>
con	if vb <i>ḍukṛñ</i> is used in the sense of <i>pratiyatna</i> (bringing about a different quality) and it is expressed as a reminder
res	<i>karman</i> → <i>ṣaṣṭhī</i>
fs	{ <i>ṣaṣṭhī</i> (<i>karman</i> [<i>pratiyatnārthaka ḍukṛñ</i> vb]) }
pc	check <i>pratiyatnārthaka ḍukṛñ</i> vb if true then check <i>karman</i> assign <i>ṣaṣṭhī</i>
rle #	A 2.3.54
rule	<i>rujārthānām bhāvavacanānāmajvareḥ</i>
con	if vb having the sense of <i>ruj</i> and they express <i>bhāvavacana</i> except vb <i>jvari</i>
res	<i>karman</i> → <i>ṣaṣṭhī</i>
fs	{ <i>ṣaṣṭhī</i> (<i>karman</i> [vb <i>rujārthānām ajvari</i>]) }
pc	check vb <i>rujārthānām ajvari</i> if true then check <i>karman</i> assign <i>ṣaṣṭhī</i>

Kātyāyana modified this rule by adding one more verb with verbal base *jvari* as follows-

rle #	vā of A 2.3.54
rule	<i>ajvarisantāpyoriti vācyam</i>

con if vb having the sense of *ruj* and they express a state/condition except the vb *jvari* and *samtāp*
 res *karman* → *ṣaṣṭhī*
 fs { *ṣaṣṭhī* (*karman* [vb *rujārthānām* except *jvari* and *samtāp*]) }
 pc check vb *rujārthānām* except *jvari* and *samtāp*
 if true then check *karman*
 assign *ṣaṣṭhī*

rle # A 2.3.55
 rule *āṣiṣī nāthaḥ*
 con if vb *nāthṛ* used in the sense of *āṣṭh* and *karman* itself s expressed as a remainder
 res *karman* → *ṣaṣṭhī*
 fs { *ṣaṣṭhī* (*karman* [vb *nāthṛ*]) }
 pc check vb *nāthṛ*
 if true then check *karman*
 assign *ṣaṣṭhī*

rle # A 2.3.56
 rule *jāsiniprahaṇanāṭakrāthapiṣām himsāyām*
 con if vb *jāsi* (*ñijanta*), *ni/pra/nipra/prani* + *han* (*ñijanta*), *nāṭ* (*ñijanta*), *krāth* (*ñijanta*) or *piṣ* are signifying *himsā* (inflicting harm) unless express otherwise
 res *karman* → *ṣaṣṭhī*
 fs { *ṣaṣṭhī* (*karman* [*himsārthaka jāsi* (*ñijanta*), *ni/pra/nipra/prani* + *han* (*ñijanta*), *nāṭ* (*ñijanta*), *krāth* (*ñijanta*) or *piṣ*]) }
 pc check above vb
 if true then check *karman*
 assign *ṣaṣṭhī*

rle # A 2.3.57
 rule *vyavahṛpaṇoḥ samarthayoḥ*
 con if vb *vyavahṛ* (to conduct) and *paṇ* (to bargain) are conveying the same meaning unless the *karman* is expressed otherwise
 res *karman* → *ṣaṣṭhī*
 fs { *ṣaṣṭhī* (*karman* [*samānārthaka* vb *vyavahṛ*, *paṇ*]) }
 pc check *samānārthaka* vb *vyavahṛ*, *paṇ*
 if true then check *karman*
 assign *ṣaṣṭhī*

rle # *vā* of A 2.3.65
 rule *guṇakarmani veṣyate*
 con if vb is teeminates with affix *kṛt*
 res *gauṇa karman* → *dviṭīyā*, *ṣaṣṭhī*
 fs { *dviṭīyā*, *ṣaṣṭhī* (*gauṇa karman* [*kṛt pratyayānta*]) }
 pc check *kṛt pratyayānta*
 if true then check *gauṇa karman*
 assign *dviṭīyā* or *ṣaṣṭhī*

rle # *vā* of A 2.3.69
 rule *dviṣaḥ śaturvā*
 con A *dviṭīyā* and *ṣaṣṭhī vibhakti* is optionally used in the *karman* of the verbal base *dviṣ* when it terminates with affix *śatr*.
 res *karman* → *dviṭīyā*, *ṣaṣṭhī*
 fs { *dviṭīyā*, *ṣaṣṭhī* (*karman* [vb *dviṣ* + affix *śatr*]) }
 pc check *gatyarthaka* vb with *ceṣṭā* + *adhvana*
 if true then check *karman*
 assign *dviṭīyā* or *caturthī*

Kātyāyana makes one *vārtika* to assign *saptamī vibhakti* in *karman kāraka* as follows-

rle # *vā* of A 2.3.36
 rule *ktasyenviṣayasya karmanyupasamkhyānam*
 con if *cta* affix-ending word is terminates with *in* affix also.
 res *karman* → *saptamī*
 fs { *saptamī* (*karman* [*cta-pratyayānta* + *in pratyaya*]) }
 pc check *cta-pratyayānta* + *in pratyaya*
 if true then check *karman*
 assign *saptamī*

C. FORMULATION AND MAPPING OF KARAṆA KĀRAKA WITH VIBHAKTI(S)

Pāṇini uses *ṛtīyā*, *pañcaṭī* and *ṣaṣṭhī vibhaktis* in the *karaṇa kāraka*. Pāṇini assigns *ṛtīyā* and *pañcamī vibhaktis* in *karaṇa kāraka* as follows-

rle # A 2.3.33
 rule *karāṇe ca stokaḥ pakṛcchakatipayasyāsatvavacanasya*
 con if *stoka*, *alpa*, *ḥcch* or *katipaya* are do not denote *sattva* and *karāṇa* is not expressed otherwise
 res *karāṇa* → *ṛtīyā*, *pañcamī*
 fs { *ṛtīyā*, *pañcamī* { *karāṇa* (*stoka*, *alpa*, *ḥcch*, *katipaya* [*asattva*]) }
 pc check *stoka*, *alpa*, *ḥcch*, *katipaya*
 if true then check *asattva*
 if true then check *karāṇa*
 assign *ṛtīyā* or *pañcamī*

Pāṇini assigns *ṣaṣṭhī vibhakti* in *karāṇa kāraka* as follows-

rle # A 2.3.51
 rule *jñō 'vidarthasya karāṇe*
 con if the vb *jñā* are used in the sense of *avida*
 res *karāṇa* → *ṣaṣṭhī*
 fs { *ṣaṣṭhī* (*karāṇa* [vb *jñā*]) }
 pc check vb *jñā*
 if true then check *karāṇa*
 assign *ṣaṣṭhī*

D. FORMULATION AND MAPPING OF SAMPRADĀNA KĀRAKA WITH VIBHAKTI(S)

Pāṇini uses *caturthī vibhakti* in the *sampradāna kāraka*. Kātyāyana adds one *vārtika* to assign *ṭṛtīyā vibhakti* also in *sampradāna kāraka*. Pāṇini assigns *caturthī vibhakti* in *sampradāna kāraka* as follows-

rule # A 2.3.13
rule *caturthī sampradāne*
con if *sampradāna* is used and it is not expressed otherwise.
res *sampradāna* → *caturthī*
fs { *caturthī* ([*sampradāna*]) }
pc check *sampradāna*
assign *caturthī*

Kātyāyana adds one *vārtika* to assign *ṭṛtīyā vibhakti* in *sampradāna kāraka* as follows-

rule # vā of A 2.3.23
rule *āśiṣṭavyavahāre dāṇaḥ prayoge caturthyarthe ṭṛtīyā*
con if vb *dāṇ* (to give) used with pre-verb *sam* and it denotes *āśiṣṭavyavahār* (illicit affair)
res *sampradāna* → *ṭṛtīyā*
fs *ṭṛtīyā* { *sampradāna* (vb *dāṇ* [*āśiṣṭavyavahār*]) }
pc check vb *dāṇ* with *āśiṣṭavyavahār*
if true then check *sampradāna*
assign *ṭṛtīyā*

E. FORMULATION AND MAPPING OF *APĀDĀNA KĀRAKA* WITH *VIBHAKTI(S)*

Pāṇini assigns *pañcamī vibhakti* in the *apādāna kāraka* in one *sūtra*. The formulation of this *sūtra* are as follows-

rule # A 2.3.28
rule *apādāne pañcamī*
con if ns is used in the sense of *apādāna* and it is not expressed otherwise
res *apādāna* → *pañcamī*
fs { *pañcamī* ([*apādāna*]) }
pc check *apadana*
assign *pañcamī*

F. FORMULATION AND MAPPING OF *ADHIKARAṆA KĀRAKA* WITH *VIBHAKTI(S)*

Pāṇini assigns *ṣaṣṭhī* and *saptamī vibhakti* in *adhikaraṇa kāraka*. The formulation of these *sūtras* are as follows-

rule # A 2.3.36
rule *saptamyadhikaraṇe ca*
con if ns is used in the sense of *adhikaraṇa* (locus) when it is not expressed otherwise additionally it occurs after *dūra* (far), *antika* (near) or their synonyms
res *adhikaraṇa* → *saptamī*
fs { *saptamī* ([*adhikaraṇa*]) }
pc check *adhikaraṇa*
assign *saptamī*

rule # A 2.3.64
rule *kṛtvo'rthaprayoge kāle'dhikaraṇe*
con if ns denotes *kāla* (time) and a word ending in a suffix having the meaning of *kṛtvasuc* (so many times) is actually used
res *kālavācī adhikaraṇa* → *ṣaṣṭhī*
fs { *ṣaṣṭhī* (*kālavācī adhikaraṇa* [*kṛtvasuc*-ending ns]) }
pc check *kṛtvasuc*-ending ns
if true then check *kālavācī adhikaraṇa*
assign *ṣaṣṭhī*

III. OPTIONAL *KĀRAKA* AND *VIBHAKTI*

Pāṇini assigns a special rule in the form of an *adhikāra* (section heading, governing). According to this rule, if concerned *kāraka* is expressed by any *tiṇ*, *kṛt*, *taddhita*, *samāsa* and sometimes *nipāta* then only *prathamā vibhakti* is used otherwise concerned *vibhaktis* are used. The formulation of this rule is as follows-

rule # A 2.3.1
rule *anabhihite*
con if concern *kāraka* is *anukta* (not stated) or *anirdiṣṭ* (not specified) by any *tiṇ*, *kṛt*, *taddhita*, *samāsa* and some times *nipāta* also.
res all *vibhaktis*
fs { *dvitīyā*, *ṭṛtīyā*, *caturthī*, *pañcamī*, *ṣaṣṭhī*, *saptamī* ((ii) *anabhihita kāraka* [*tiṇ*, *kṛt*, *taddhita*, *samāsa*, *nipāta*]) }
fs { *prathamā* (*abhihita kāraka* [*tiṇ*, *kṛt*, *taddhita*, (ii) *samāsa*, *nipāta*]) }
pc check *anabhihita*
assign all *vibhaktis* which is provided

The mapping between *kāraka* and *vibhakti* can be shown in the following table [5] as-

TABLE: 1

<i>Kāraka</i>	<i>Sūtra</i>	Explanation	<i>Vibhakti(s)</i>
<i>kartṛ</i>	A 1.4.54	One who is independent (the most important source) in any action and executes the action	A 2.3.01 → <i>prathamā</i>
			A 2.3.18 → <i>ṭṛtīyā</i>
			A 2.3.65 → <i>ṣaṣṭhī</i>
<i>karman</i>	A 1.4.49	which is most desired of agent through his action	A 3.4.69 → <i>prathamā</i>
			A 2.3.02 → <i>dvitīyā</i>
			A 2.3.22 → <i>ṭṛtīyā</i>
			A 2.3.12 → <i>caturthī</i>

			A 2.3.10 → <i>pañcamī</i>
			A 2.3.66 → <i>ṣaṣṭhī</i>
			A 2.3.36 vā → <i>saptamī</i>
<i>karāṇa</i>	A 1.4.42	that which is most instrumental in accomplishment of any action	A 1.4.43 → <i>dviṭīyā</i> A 2.3.18 → <i>trīṭīyā</i> A 1.4.44 → <i>caturthī</i> A 2.3.33 → <i>pañcamī</i> A 2.3.51 → <i>ṣaṣṭhī</i>
<i>sampradāna</i>	A 1.4.32	whosoever the agent approaches for the object of the act of giving/benefit	A 2.3.23 vā → <i>trīṭīyā</i> A 2.3.13 → <i>caturthī</i>
<i>apādāna</i>	A 1.4.24	that from which/where separation/departure is meant	A 2.3.32 → <i>trīṭīyā</i> A 2.3.28 → <i>pañcamī</i>
<i>adhikarāṇa</i>	A 1.4.45	that which is the locus/ substratum of the action	A 2.3.44 → <i>trīṭīyā</i> A 1.4.31 vā → <i>pañcamī</i> A 2.3.64 → <i>ṣaṣṭhī</i> A 2.3.36 → <i>saptamī</i>

IV. *VIBHAKTI SŪTRAS* RELATED TO VEDIC TEXTS

Pāṇini makes seven *kāraka/vibhakti* rules which are implemented only for the Vedic texts. These rules are mentioned in the third part of the second chapter of *Aṣṭādhyāyī*. In the Vedic text, sometime different *vibhaktis* are used in place of actual *vibhaktis*. Since the present research is focusing only on the *laukika* texts, therefore these rules are not covered in the scope of present work. These rules are shown in the following table as-

TABLE: 2

Sr. No.	<i>sūtra</i>	<i>Sūtra</i> No.
1	<i>trīṭīyā ca hośchandasi</i>	A 2.3.03
2	<i>sāmantritām</i>	A 2.3.48
3	<i>ekavacanām sambuddhi</i>	A 2.3.49
4	<i>dviṭīyā brāmhane</i>	A 2.3.60
5	<i>preṣyabruvorhaviṣo devatāsampradāne</i>	A 2.3.61
6	<i>yajēśca karāṇe</i>	A 2.3.63
7	<i>caturthyarthe bahulam chandasi</i>	A 2.3.62

CONCLUSION

The present research paper describe the logical and step-by step implementation for computation of Pāṇini's *kāraka* and *vibhakti* mapping rules stated in *Aṣṭādhyāyī* and illustrated in *Kāśikā*, *Mahābhāṣya* and *Vākyapadīya*. Seven rules are described separately because these *kāraka/vibhakti* rules are written only for the Vedic texts. A partial implementation of the *Kāraka* Analyzer for Sanskrit (KAS) has been done using the rule based approach of *kāraka*, *vibhakti* and its mapping. But further enhancement is required specially for making rule specific several other lexical resources. The KAS uses Java Server Pages (JSP) in the web format (Apache Tomcat) for the analysis of *kāraka* of given *laukika* Sanskrit sentence or a text.

REFERENCES

- [1] Rama Nath Sharma, 'The Aṣṭādhyāyī of Pāṇini', Munshiram Manoharlal Publishers Pvt. Ltd., Delhi, 2003.
- [2] Charu Deva Shastri, 'Pāṇini: Re-interpreted' Motilal Banarasiidass, Delhi, 1991.
- [3] Joshi, Sivaram Dattatray & Roodbergen J. A. F., 1998, The Aṣṭādhyāyī of Pāṇini', Śahitya Akademi, New Delhi.
- [4] Mishra, Shrinarayana (ed.), 1996, 'Kāśikā with prakāś commentary', Chawkhambha Sanskrit Sansthan, Varanasi.
- [5] Mishra, Sudhir Kumar, 2008, 'Sanskrit *kāraka* Analyzer for Machine Translation', Ph.D. thesis awarded, SCSS, JNU, New Delhi.